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Huckleberry Gold: A Specialty Market Potato Cultivar with Purple-Skin, Yellow-Flesh, High Tuber Antioxidants, and Resistance to Potato Cyst Nematode (*H1*) and *Potato virus X* (*Nb* and *Rx1*)

Jonathan L. Whitworth · Richard G. Novy · Jeffrey C. Stark · Stephen L. Love · Michael K. Thornton · Brian A. Charlton · Solomon Yilma · N. Richard Knowles · Mark J. Pavek · Xiaohong Wang · Joseph J. Pavek

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Abstract Huckleberry Gold is a purple-skin, yellow-flesh fresh market cultivar with similar culinary qualities to the market standard Yukon Gold. It has lower specific gravity, sucrose and vitamin C content, but a significantly higher level of tuber antioxidants than Yukon Gold. Notable disease resistant characteristics are *Potato virus X* resistance based on the presence of molecular markers for the PVX resistance genes, *Nb* and *Rx1*. In addition it also has the *H1* gene present which confers resistance to the potato cyst nematode, *Globodera rostochiensis,* which has been confirmed by bioassay to pathotype Ro1. The size profile of Huckleberry Gold is smaller than Yukon Gold, allowing a better fit into specialty markets that are geared to smaller size for fresh use. Huckleberry Gold represents the first purple-skin, yellow-flesh cultivar to come from the Northwest (Tri-State) Potato Variety Development program.

Resumen Huckleberry Gold es una variedad de piel morada, pulpa amarilla para mercado fresco, con cualidades culinarias similares a las comunes de mercado de Yukon Gold. Tiene un contenido más bajo de gravedad específica, sacarosa y vitamina C, pero un nivel significativamente más alto de antioxidantes de tubérculo que Yukon Gold. Características notables de resistencia a enfermedades son la resistencia al virus X de la papa, con base en la presencia de marcadores moleculares para los genes de resistencia al PVX, Nb y Rx1. Además, también tiene el gen H1, que le confiere resistencia al nematodo de quiste de la papa, *Globodera rostochiensis*, que ha sido confirmado con un bioensayo al patotipo Ro1. El perfil del tamaño de Huckleberry Gold es más pequeño que el de Yukon Gold, permitiendo un mejor ajuste en los mercados de especialidad que están diseñados a tamaños más chicos para uso en fresco. Huckleberry Gold representa la primera variedad de piel morada, pulpa amarilla, proveniente del Programa Triestatal de Desarrollo de Variedades de Papa de la Región del Pacífico Noroccidental.

Keywords *Solanum tuberosum* · Variety · *Globodera rostochiensis* · PVX

J. L. Whitworth (✉) · R. G. Novy
U.S. Department of Agriculture (USDA)-Agricultural Research Service (ARS), Aberdeen Research & Extension (R & E) Center, 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

M. K. Thornton
Parma R & E Center, University of Idaho, Parma, ID 83660, USA

B. A. Charlton
Klamath Basin R & E Center, Oregon State University, Klamath Falls, OR 97601, USA

S. Yilma
Oregon State University, Corvallis, OR 97331, USA

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

X. Wang
USDA-ARS, Ithaca, NY 14850, USA

J. J. Pavek
USDA-ARS, Aberdeen R & E Center, Aberdeen, ID 83210, USA

Introduction

Huckleberry Gold is a unique potato cultivar with medium purple skin and yellow flesh. The name was chosen in part because of its purple skin color reminiscent of the berry color on Huckleberry plants (genus *Vaccinium*) endemic to the Pacific Northwest. It was designated as breeding line A99326-1PY and originated from hybridization, conducted in 1999 by personnel of the USDA-Agricultural Research Service at Aberdeen, Idaho between Agria and COA94019-5R. Agria is a yellow-flesh, white to yellow-skin cultivar originally from Germany and COA94019-5R is a red-skin, white-flesh breeding clone from the Colorado State University potato breeding program. Huckleberry Gold is very resistant to *Potato virus X* (PVX) and the potato cyst nematode *Globodera rostochiensis*. Notable cultivars in the background of Huckleberry Gold include Clivia, with reported high PVX resistance (Hils and Pieterse 2005; ECPD 2013) and Agria which is listed as having high to very high resistance to *G. rostochiensis* races 1 and 4 (ECPD 2013) (Fig. 1).

For the purpose of this paper, Yukon Gold was chosen as a comparison cultivar because of its popularity in the U.S. as a specialty cultivar and its listing as a market class standard for yellow-flesh table-stock in the "Objective Description of Variety" form that is the basis for developing descriptions of new potato varieties (USDA Form OMB NO 0581–0055). Yukon Gold (Johnston and Rowberry 1981) is a widely accepted fresh market and processing cultivar with yellow flesh similar to Huckleberry Gold. Other yellow-flesh cultivars have been released, but of these, Yukon Gold is the most widely grown. In comparison against all cultivar types, Yukon Gold is listed as 16th in commercial acreage planted; from a list of the 38 most widely grown cultivars in the U.S. (NASS 2013). The next closest yellow-flesh cultivar listed is Satina at 33rd. Purple Majesty, a cultivar from the Colorado potato breeding program having purple skin and flesh (D. Holm, personal communication) also is used in this paper for culinary comparisons with Huckleberry Gold and Yukon Gold.

Interest in specialty cultivars has increased over the years. Different skin/flesh color combinations are of interest to the consumer, with some preferences noted for purple-skin, yellow-flesh over red-skin, yellow-flesh (Jemison et al. 2008). A study has shown the nutritional benefits (via higher antioxidant activity from carotenoids) from colored flesh and skin potatoes (Haynes et al. 2010) while others note the higher carotenoid levels available in yellow-flesh potatoes compared to white-flesh (Nesterenko and Sink 2003). Differences can exist in similar colored flesh cultivars such as in Peter Wilcox, a recently released purple-skin yellow-flesh cultivar with higher carotenoid levels in Yukon Gold (Haynes et al. 2010).

Huckleberry Gold was first selected in the field in 2003, was then evaluated as a 12-hill selection in 2004, and was subsequently evaluated in replicated breeding trials from 2005 through 2008, with advancement to the Western Regional Specialty Trials in 2009 and 2010. In those trials it was evaluated in Idaho, Oregon, Washington, California and

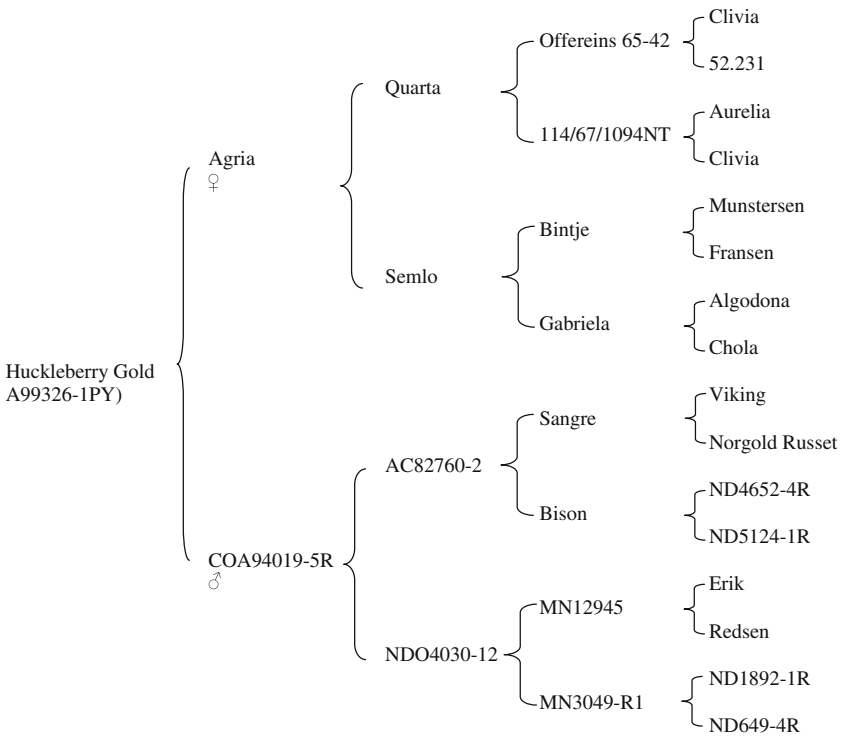

Fig. 1 Four generations of Huckleberry Gold

Texas. Huckleberry Gold was officially released from the Pacific Northwest (Tri-State) Potato Variety Development Program Committee in 2011.

Varietal Description

Plants

Huckleberry Gold has an erect growth habit with an intermediate vine type where stems and leaves are readily visible (Fig. 2a). It matures mid-season at about 115 days after planting and is very similar to Yukon Gold in this respect. The stem anthocyanin coloration is strong and much more apparent than Yukon Gold which is listed as weak. Stem wings are medium and the same as Yukon Gold. Leaf color is dark green with trichomes that are short and have a medium density. The compound leaf silhouette is open and the tip of a primary lateral leaflet is acuminate, the base is obtuse, and the size of the leaflet is medium (Fig. 2b). The base of the terminal leaflet is obtuse and the whole leaflet has medium leaf margin waviness. On the compound leaf, the average number of primary leaflet pairs is 4 with a range of 2–5 leaflet pairs per leaf.

Flowers

The shape of the Huckleberry Gold corolla is pentagonal and the color is blue violet-white at a 3:1 ratio. The corolla has

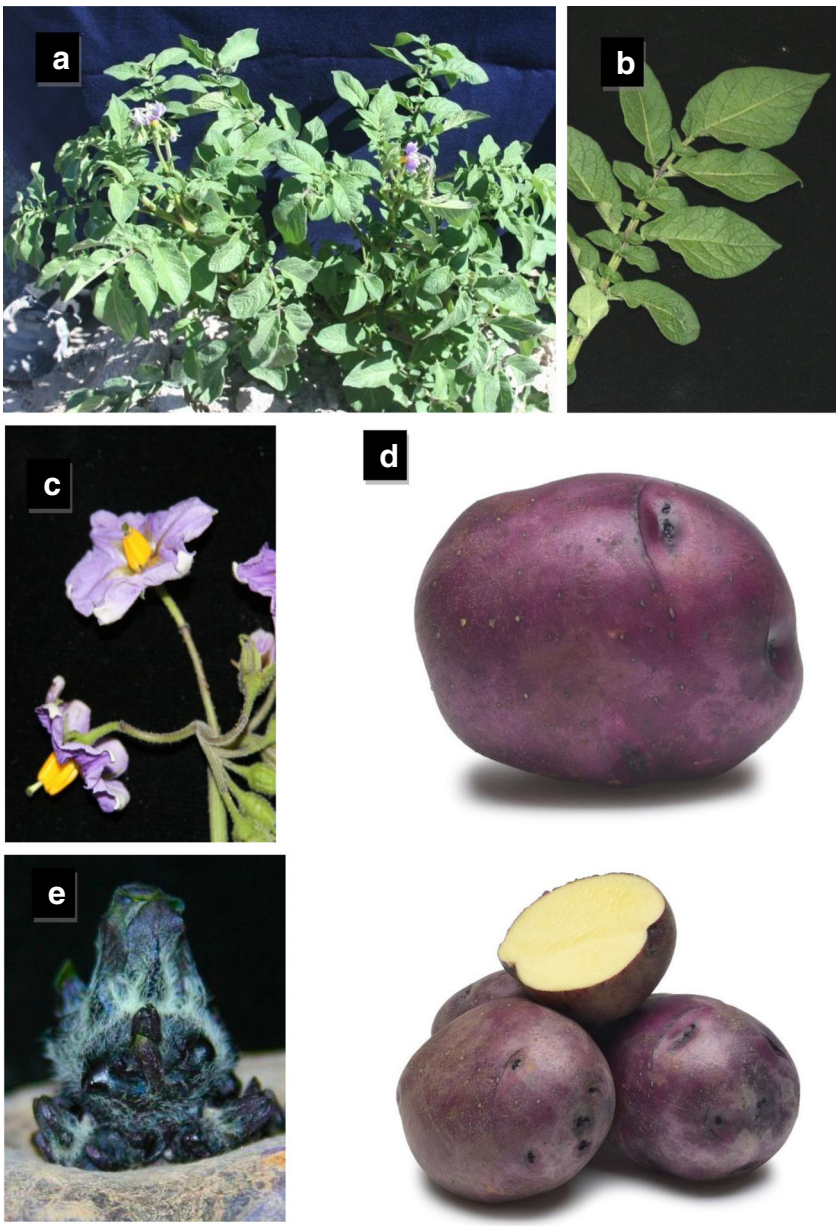

Fig. 2 Photographs of Huckleberry Gold showing **a** whole plant, **b** compound leaf, **c** flower, **d** external and internal tuber appearance, **e** light sprout (**d** photo, courtesy of Potato Variety Management Institute)

color values of 85A on the inner surface and 85B on the outer surface (Royal Horticulture Society Color Chart-RHSCC) (Fig. 2c). The average number of inflorescences per plant is 4.9 (range 3–8) with 12.4 florets (range 6–19) per inflorescence. Anthocyanin coloration in the calyx is medium. For comparison, Yukon Gold has a red violet-white (3:1) corolla and calyx coloration is weak. Anthers form a pear-shaped cone and have a yellow-orange color of 15A in RHSCC. Pollen production is medium and the same as Yukon Gold (3 on a 1–5 scale with 1 being none and 5 abundant). Male fertility of Huckleberry Gold is limited, with a low number of seed obtained in hybridizations; use as a female parent is preferable in hybridizations to obtain a larger number of true potato seed. The stigma shape is capitate with a yellow-green color of 146A in RHSCC. Berry production is absent under field conditions.

Tubers

Skin texture is smooth and color is purple (187A RHSCC) with no secondary skin color present. Tuber shape is oval and medium thick compared to Yukon Gold which is slightly flattened (Fig. 2d). Tubers have an average length of 71.4 mm and an average width of 69.4 mm making them shorter than Yukon Gold. Length to width ratios of Huckleberry Gold and Yukon Gold are 1.03 vs. 1.18, respectively. Tuber size is also smaller with Huckleberry Gold at 170 g and Yukon Gold at 214 g average weight. Tuber eye number averages 8.9 with an intermediate eye depth and slightly prominent eyebrows. Distribution of eyes is predominately apical. The tuber flesh color is yellow (10B RHSCC) and there is no secondary flesh color. The average number of tubers at 5.9 per plant is comparable to Yukon Gold at 5.5.

Huckleberry Gold indirect light sprouts have a very strong blue-violet coloration at the base of the sprout and have a strong red-violet coloration at the tip (Fig. 2e). Sprout shape is spherical and the sprout tip is intermediate, neither closed or open and the tip has medium pubescence. Root initial frequency is also intermediate.

Agronomic Performance

Huckleberry Gold had total yields that were comparable to Yukon Gold when averaged over six locations of the Western Regional Potato Variety Trials. The percent marketable yield was higher for Huckleberry Gold compared to Yukon Gold when averaged across all locations and Huckleberry Gold was higher than Yukon Gold in all locations except Texas. Specific gravity for Huckleberry Gold was lower than Yukon Gold averaged over five sites (Table 1). In a breakout of the size at harvest, Huckleberry Gold had fewer oversize (>284 g) tubers than Yukon Gold at all locations except for Texas (Fig. 3). At Texas, the overall size profile included more small to regular sized tubers (<285 g) than any other location. On the larger end of the size profile (>170 g), the other four locations had a range of larger tubers from 59 to 74 % of the total yield, while Texas was at 39 %. At all five locations listed in Table 1, a little over 3 weeks difference existed in the average number of growing days (range; 102–125 days). However, growing degree days (base 10 °C) averaged 2,290 in Texas compared to the range of 1,363–1,648 at the other locations. The Texas location also had the lowest total yield for Huckleberry Gold and Yukon Gold. The effect of growing region temperatures on the yield and size profile for this cultivar may need more study.

Table 1 Yields and specific gravity of Huckleberry Gold and Yukon Gold in regional potato variety trials

Location	Idaho[a]		Oregon[b]	Washington[c]	California[b]	Texas[b]	Overall
	Aberdeen	Parma	Klamath Falls	Othello	Tulelake	Springlake	
Total yield (mt/ha)							
Huckleberry Gold	42.8	47.6	62.3	39.3	59.9	34.3	47.7
Yukon Gold	40.5	51.6	56.7	57.0	49.7	29.7	47.5
Marketable yield (%)[d]							
Huckleberry Gold	70.1	90.3	65.4	55.3	64.2	83.3	71.4
Yukon Gold	66.5	77.6	49.3	35.0	62.4	89.5	63.4
Specific gravity							
Huckleberry Gold	1.075	–	1.075	1.069	1.081	1.071	1.074
Yukon Gold	1.086	–	1.085	1.076	1.093	1.071	1.082

[a] Aberdeen, ID data from 2008, 2009, 2010; Parma, ID data from 2009

[b] Oregon, California, Texas data from 2009 and 2010

[c] Othello, WA data from 2009

[d] Marketable yield calculated as from <284 g

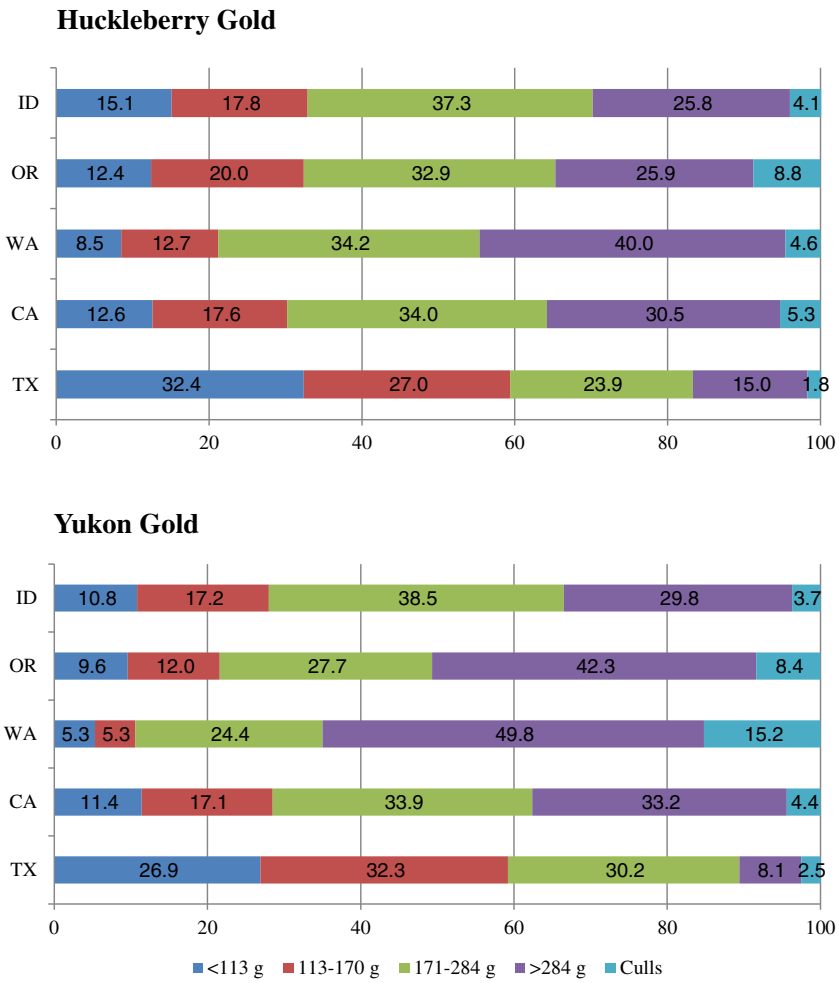

Fig. 3 Comparative size profile of Huckleberry Gold and Yukon Gold as a percent of total yield. Locations are; ID-Aberdeen, OR-Klamath Falls, WA-Othello, CA-Tulelake, TX-Springlake

Dormancy and Tuber Appearance

In trials at Aberdeen, Idaho, tubers were rated at harvest for incidence of external defects on a scale from 1 (severe defect) to 5 (no defect). Huckleberry Gold and Yukon Gold showed a low incidence of external defects, with growth cracks and second growth (i.e. knobbiness) both rated as 5.0 for Huckleberry Gold and 4.9 for Yukon Gold (data not shown). For internal defects, ten of the largest tubers per replication (n=4) were cut open and rated for incidence of hollow heart, brown center, internal necrosis, and vascular discoloration. Huckleberry Gold exhibited a much lower incidence of hollow heart (0.8 %) compared to Yukon Gold (7.5 %), brown center was low for both (0.8 % H. Gold and 1.7 % Y. Gold) and no internal necrosis or vascular discoloration was noted in either cultivar.

In a trial at Parma, Idaho, harvested tubers were put into storage at 10 °C and 85–90 % RH on August 19, 2008. The number of days to appearance of first sprouts (>5 mm) for Huckleberry Gold and Yukon Gold was approximately 130 days, which was later than both Yukon Gem (110 days) and IdaRose (80 days), two recently released specialty cultivars. In an evaluation of skin color in the same trial, Huckleberry Gold had a darker skin color at harvest (4.0 on a 1–5 scale with 5=dark) than it did after 84 days in storage when it was scored 3.0. Overall appearance was rated at 3.0 (1=poor; 5=good) at harvest and 1.0 after 84 days in storage. The characteristic that resulted in a lower appearance rating after storage was a fading of the skin color resulting in a dull gray sheen (not caused by silver scurf), a characteristic often noted in purple skin cultivars that progresses in storage.

Biochemical and Nutritional Characteristics

An analysis of the tuber biochemical composition showed that Huckleberry Gold had significantly higher antioxidants (Fig. 4), similar protein, lower vitamin C and sucrose levels when compared to Yukon Gold. Total glycoalkaloid levels for Huckleberry Gold were 3.1 mg/100 g tuber fresh weight, far below the critical threshold of 20 mg/100 g (Table 2). Since many specialty cultivars are consumed with the skin on, samples were processed with the skin on and tubers were sectioned into quarters so as to be representative of the whole

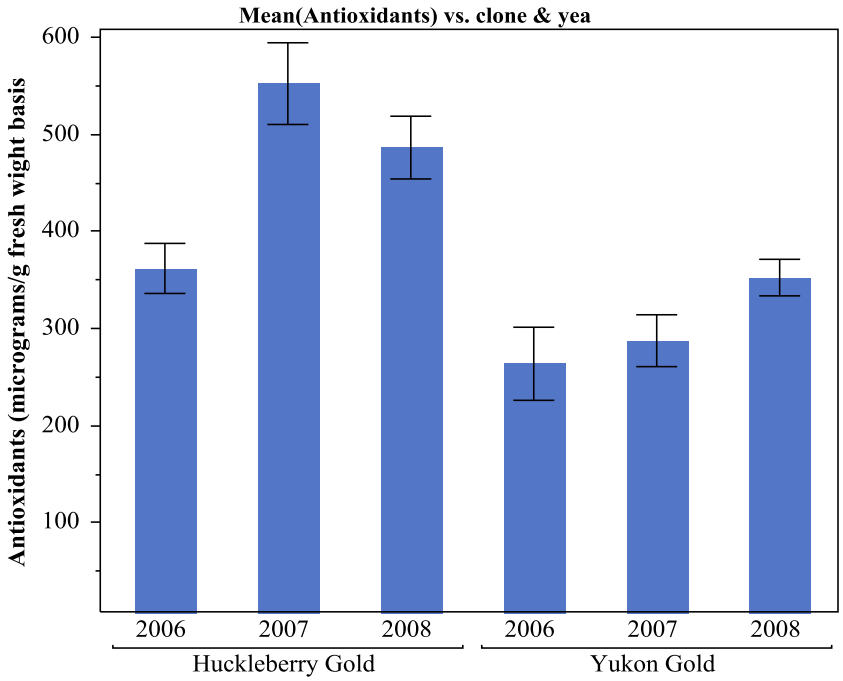

Fig. 4 Antioxidant activity, measured as μg Trolox equivalents/g fresh weight with associated standard error bars

tuber. Over 3 years, Huckleberry Gold's antioxidant measurements were 55 % higher (467 vs. 301 μg/g fresh weight) than Yukon Gold which has similar colored flesh. In a study of potatoes with different flesh color, total phenolics in potatoes with yellow or white flesh were significantly lower than with red or purple flesh (Stushnoff et al. 2008). In that same study, the antioxidant activity, was similar for white and yellow-flesh potatoes, but was much higher for red and purple-flesh potatoes. A study of breeding lines with different combinations of colored skin/flesh (yellow/yellow and purple/yellow lines) had no significant difference, regardless of skin color, in antioxidant activity and total phenolics (Reddivari et al. 2007). While cultivars may be expected to have higher antioxidant activity due to purple skin, the skin only accounts for 7 to 10 % of the total tuber weight. These comparisons show that Huckleberry Gold has significantly higher antioxidants compared to Yukon Gold.

Table 2 Biochemical composition for Huckleberry Gold tubers compared with those for Yukon Gold. Data was taken from five trials grown from 2006–2010 at Aberdeen, Idaho

Component	Huckleberry Gold	Yukon Gold
Glycoalkaloids (mg/100 g FWB)[a]	3.06	2.78
Reducing sugars (%FWB)[b]	0.06	0.04
Sucrose (% FWB)[b]	0.18	0.24
Protein (% DWB)[b]	5.88	5.44
Vitamin C (mg/100 g FWB)[c]	22.58	33.40

FWB fresh weight basis, *DWB* dry weight basis

[a] 2005–2010

[b] 2009–2010

[c] 2007–2010

Processing Evaluations

Culinary components of cultivars Huckleberry Gold, Yukon Gold, and Purple Majesty (purple skin/purple flesh) were evaluated at Washington State University in Pullman using a taste panel in accordance with methods developed with industry input for the Northwest Potato Variety Development program (Pavek and Knowles 2004–2012). Each year, consumer panelists (ca 10–12 panelists) were convened to rate the texture, flavor, after-cooking-darkening, skin characteristics, and the degree of 'doneness' for tuber centers in baked and microwave samples. Except for skin characteristics, these same attributes were evaluated in boiled samples with the addition of a rating given for the degree of sloughing (Table 3).

Each category was rated on a 1–5 scale with 5 equaling the best and then the five categories were combined. Four tuber samples consisting of 113–170 g tubers of each cultivar were evaluated. Scores from the consumer panelists for a particular trait (e.g. flavor) were subjected to ANOVA (randomized block design) and means for each attribute separated by LSD ($P<0.05$). The average scores for each attribute (flavor, texture, etc.) were summed to give a total culinary quality rating for each cultivar for each cooking protocol (25 points possible). A total overall culinary score was then derived by adding the scores for each cooking protocol (75 maximum points equally weighted for each of the three cooking

Table 3 Culinary qualities of Huckleberry Gold, Yukon Gold and Purple Majesty tubers

Cultivar	2009				2010			
	Boiled[a]	Baked	Microwaved	Overall	Boiled	Baked	Microwaved	Overall
Huckleberry Gold	18.4	19.5	18.3	56.2	17.3	17.8	18.0	53.1
Yukon Gold	18.3	20.0	17.9	56.2	17.5	20.5	21.0	59.0
Purple Majesty	19.2	19.5	19.2	57.9	15.8	18.3	19.5	53.6
LSD (0.05)	ns	ns	ns		ns	ns	2.9	

Tubers were produced in the Western Regional Red/Specialty variety trials, which were conducted at the Washington State University Research Center, Othello, WA in 2009 and in a commercial field near Mount Vernon, WA in 2010. Culinary evaluations were conducted at Washington State University, Pullman, WA

[a] Each column based on the sum of multiple categories that include; texture, flavor, after cooking darkening, tuber center, sloughing (boiled samples) or skin characteristics (baked and microwaved samples) were rated on a 1–5 scale (five best) and values summed to give overall score; a perfect score within a cooking protocol=25 and an overall score=75

protocols). The data acquired through these evaluations thus reflected the consensus opinions of the consumer panelists of the relative culinary qualities for each cultivar. Except for the microwave samples of Huckleberry Gold tubers which scored lower than Yukon Gold in 2010, culinary qualities of the three cultivars were equivalent in 2009 and 2010.

In Washington and Idaho, Huckleberry Gold samples were also processed as French fries (Table 4). The color of processed French fry sections was quantified with a photovolt meter that measures light reflectance or the USDA fry color chart. A photovolt reading of 19 or lower was considered unacceptably dark (>USDA 2). Huckleberry Gold produced acceptably light and uniformly colored (stem to bud difference) fries in 2009 and 2010 (29.5 and 46.1 photovolt readings, respectively). In Idaho, fry sections processed from tubers stored for 3 months at 4.4 and 7.2 °C were acceptably light regardless of storage temperature (Table 4).

Disease Response

Responses to diseases were obtained from a minimum of 2 years of evaluations (Table 5). Late blight trials were conducted in Oregon, Michigan, Minnesota, North Dakota, and Pennsylvania. Virus trials were conducted in Kimberly, Idaho, while bacterial and fungal resistance trials were conducted in Aberdeen, Idaho.

Bacterial

Common scab evaluations at Aberdeen were conducted utilizing naturally occurring inocula in a field with a history of scab. At harvest tubers were rated for incidence and lesion type. Huckleberry Gold displayed greater resistance to common scab than did Yukon Gold (Table 5). Huckleberry Gold had a serious scab incidence score of 17.1 % and Yukon Gold had a score of 42.5 %. Tubers were considered to have serious scab when the lesion type was a 3 or higher on a 0–5 scale. A

Table 4 Post-harvests fry processing ratings of Huckleberry Gold and Yukon Gold

Washington[a]						Idaho[a]		
Year	Clone	Photovolt Reading[b]			Difference[c] Stem vs. Bud	Year	overall fry color[d] (USDA Color)	
		Stem	Bud	Avg.			After 3 months in storage at:	
2009	Huckleberry Gold	27.3	31.8	29.5	4.9	2005	4.4 °C	1.7
	Yukon Gold	27.8	39.7	33.7	11.9		7.2 °C	1.0
2010	Huckleberry Gold	46.6	45.6	46.1	2.8			
	Yukon Gold	48.9	51.8	50.3	2.9			

[a] Washington- evaluated at harvest from tubers grown in Othello, Washington in 2009 and near Mount Vernon, Washington in 2010. Idaho—evaluated from tubers grown in Aberdeen, Idaho

[b] 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

[c] A difference of ≥9 photovolt units between bud and stem end constitutes non-uniform fry color

[d] USDA color (0=light and 4=dark)

Table 5 Disease reactions of Huckleberry Gold tubers compared with those of Yukon Gold

Disease	Huckleberry Gold	Yukon Gold
Common scab (*Streptomyces*)[a]	MR	S
Verticillium wilt (*Verticillium*)	MS	S
Foliar early blight (*Alternaria*)	MS	S
Tuber early blight (*Alternaria*)	S	MR
Dry rot (*Fusarium*)	MR	MS
Soft rot (*Pectobacterium*)	S	S
PVY	MS	S
PVX	VR[b]	S
PLRV foliar infection	MS	MS
PLRV net necrosis	MS	S
Late blight (*Phytophthora*)		
Foliar	S	S
Tuber	MS	S
Potato cyst nematode (*Globodera rostochiensis*)	VR	–

VS very susceptible, *S* susceptible, *MS* moderately susceptible, *MR* moderately resistant, *R* resistant, *VR* very resistant

[a] serious scab; based on % of tubers with significant surface lesions covering 10 % of surface or presence of any pitted scab

[b] readings of 0 % in three years of replicated trials

rating of three is described as having significant lesions covering at least 10 % of the surface or the presence of any pitted scab.

Soft rot evaluations were also done at Aberdeen with washed tubers collected from replicated field trials. Inoculations were done with *Pectobacterium atrosepticum* from a culture of a field collected isolate. Tubers were placed in a medium abrasive-lined cement mixer and tumbled for 30s to provide a uniformly wounded surface. Samples were then dipped briefly in a diluted *P. atrosepticum* solution (6×10^4 cells/ml) and then allowed to drain before being placed back into storage. One week post-inoculation, tubers were rehydrated by placing in water for 5 min. and then were placed in a warm mist chamber at 18 °C for 1 week. Under these conditions both cultivars were rated as susceptible to *Pectobacterium* soft rot.

Fungal

Verticillium wilt and early blight trials were conducted at Aberdeen, Idaho utilizing naturally occurring inocula. In order to enhance the natural disease pressure, the replicated plots for early blight were designed so that every third row in the plots were planted to Western Russet, a cv. that is susceptible to early blight. In addition, the plots were not sprayed with a fungicide to control early blight. For verticillium wilt and early blight, visual foliar ratings were recorded. Early blight tuber evaluations were done by collecting approximately 4.5 kg of tubers and keeping them in storage at 10 °C for approximately 4 months after which they were evaluated for lesions Dry rot evaluations were also done at Aberdeeen using tubers collected from replicated field plots. Cultures of field collected isolates of *Fusaium sambucinum* and *F. solani* var. *coeruleum* were used to infect washed tubers. The tubers were inoculated 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 were kept in 10 °C storage. Approximately 4 months post inoculation, tubers were visually scored for dry rot. Observations indicate that Huckleberry Gold is slightly less susceptible to verticillium wilt and foliar early blight, and is more susceptible to early blight tubers lesions when compared to Yukon Gold (Table 5). Huckleberry Gold is more resistant to dry rot compared to Yukon Gold.

Oomycetes

In national late blight trials Huckleberry Gold received a susceptible foliar rating at five sites in 2010 (MI, MN, ND, OR, PA) and four sites in 2011 (MI, MN, OR, PA), and ranked in the highest 1/3 of all readings for area under disease progress curve (AUDPC). Tuber evaluations showed that Huckleberry Gold had about half as much tuber rot from late blight as did Yukon Gold and therefore received a higher resistance rating (Table 5)

Virus

Virus evaluations were done at Kimberly, Idaho in replicated field plots. In Kimberly, PVX and PVY were mechanically inoculated using Idaho field isolates and for PVY, a mixture of PVY^O, PVY^{NTN}, and $PVY^{N:O}$ strains were used. In addition, every third row was planted as a "spreader row" of Russet Burbank that included plants with seed borne PVY and *Potato leafroll virus* (PLRV) as described by Corsini et al. (1994). After harvest, sprouted daughter tubers were planted and grown to 15 to 25 cm plants, which were then ELISA tested for PVX, PVY, and PLRV. Huckleberry Gold was field immune to PVX, showing no ELISA positives in daughter tubers collected from inoculated mother plants in two years of testing (2009–2010). Huckleberry Gold was moderately susceptible to PVY and PLRV and to PLRV net necrosis (Tables 5 and 6).

High resistance to PVX not uncommon, existing in about 20 % of the cultivars/line listed in the European Cultivated Potato Database (ECPD 2013). Incorporating high PVX resistance into widely grown cultivars would allow seed growers to reduce the cost of PVX testing currently required in seed certification programs. Another benefit from PVX resistance would be the elimination of much more severe

Table 6 Virus incidence[a] from 2009 and 2010 at Kimberly, Idaho

Cultivar	PVX (%)[b]	PVY (%)	PLRV (%)
Huckleberry Gold	0.0 a	43.3 a	44.0 a
Yukon Gold	96.3 b	67.0 a	31.8 a

[a] Virus responses are based on seed borne infections as determined by ELISA, following field infection of replicated plots with PLRV from aphid vectored sources of inter-planted virus infected potato, mechanical and aphid inoculated PVY, and mechanical inoculation with PVX

[b] t-test comparison. Columns with different letters are significantly different at $p \leq 0.01$

"rugose" symptoms that occur when PVX is found in combination with PVY, compared to milder symptoms present in PVX or PVY only infections (Nie and Singh 2013).

Huckleberry Gold and Yukon Gold were inoculated in controlled greenhouse studies with two strains of PVY (PVY^{O}, $PVY^{N:O}$). Each strain was inoculated and evaluated separately in different sets of Huckleberry Gold and Yukon Gold plants. Results show that with PVY^{O}, foliar symptoms were typical to severe and the typical symptoms had developed when the plants were first ELISA tested at 23 days post inoculation. One week later, the plants had developed severe symptoms, which included veinal necrosis and leaf drop. On plants inoculated with $PVY^{N:O}$, foliar symptoms were mild on plants that tested ELISA positive for PVY.

Molecular analysis of Huckleberry Gold for the presence of markers closely linked with PVX resistance genes *Nb* and *Rx1* showed that both were present (Fig. 4). Marker 221R was used for detection of the Rx1 linkage (Kanyuka et al. 1999) and is associated with extreme resistance to PVX (Bendahmane et al. 1997). Marker GM339 was used for linkage to the Nb gene (Marano et al. 2002) and is associated with a hypersensitive response to PVX infection (Nyalugwe et al. 2012) (Fig. 5). For the marker test, genomic DNA was extracted from 30 to 50 mg of young leaf tissue using DNeasy (QIAGEN, inc., Valencia, CA) kits according to manufacturer's instructions. PCR was performed in a total volume of 20 μl containing final concentration of 1× PCR buffer, 1.5 mM $MgCl_2$, 2 % mixed solution of sucrose in cresol red (2 % (w/v) of sucrose, 0.1 mM of cresol red), 0.1 mMdNTPs, 0.5 μM of each primer, 0.03U Fermentas (Thermo Fisher Scientific, Waltham, MA) Dream *Taq* DNA polymerase and total 40 ng of genomic DNA. PCR conditions and primers used for the *Rx1* and *Nb* genes are listed in Table 7. PCR products were visualized using agarose gels. These marker results corroborate the virus evaluations done in Kimberly, Idaho over 2 years with 0 % PVX in Huckleberry Gold (Table 6).

Nematode

Globodera rostochiensis, known as the golden nematode (GN) is of quarantine significance internationally and has been found in 75 countries including Canada (most recently in 2006) (Yu et al. 2010) and in the U.S. (Cannon 1941). Efforts to incorporate GN resistance into potato have resulted in a number of cultivars such as Missaukee (Douches et al. 2010), NemaRus (Goth et al. 1989), AC Sunbury (Murphy et al. 2002), St. Johns (Reeves et al. 1996) (none of these had any U.S. seed acreage produced in 2013) and Monticello (Porter et al. 2004), Andover and Eva (Plaisted et al. 1998, 2001), Amey (Haynes et al. 2001), Elba (Thurston et al. 1985) (from which 1 to 171 seed acres of these cultivars were produced in the U.S. in 2013) (http://www.mnseedpotato.org/usacres.pdf). None of the cultivars currently in production have yellow flesh, making Huckleberry Gold unique in this regard.

Huckleberry Gold is very resistant to the potato cyst nematode-*G. rostochiensis* (pathotype Ro1) as determined in bioassays using standard controls. Chippewa was used as a susceptible control cultivar and Reba as a resistant control. The resistance/susceptibility of Reba was established by Plaisted et al. (1999) and Chippewa was established in the Golden Nematode (GN) Laboratory located on the Cornell University campus, Ithaca, New York (David Thurston, pers. comm.). Huckleberry Gold and the controls were planted in 7.6 cm clay pots using sterile soil:sand in a 1:1 ratio. Two tests were run: Experiment 1) Huckleberry Gold, Chippewa, and Reba were inoculated with enough cysts before planting to give a level of 6,000 viable eggs per pot; Experiment 2), Huckleberry Gold and Chippewa were inoculated by adding five mls of inoculums containing 10,000 viable eggs per pot after plants had emerged. In both experiments, pots were submerged in moist sand set in metal trays in a greenhouse and plants were grown at 20–25 °C with a 16 hr light/8 hr dark cycle. There were six replications per cultivar with each plant serving as a replication. Samples were examined under magnification and cysts were visually counted on the root-ball of each plant (Exp. 1) and by using a USDA cyst extractor (Brodie 1996) (Exp. 2) to recover the total cysts from the roots

Table 7 Bioassay results from controlled pot experiments using *Globodera rostochiensis* (Ro1 pathotype) cysts and eggs for Huckleberry Gold against susceptible and resistant control cultivars

Average number cysts on root-ball			
Exp. 1 (cyst inoc.)	Huckleberry Gold	Chippewa	Reba
	0.3	>24.8[a]	1.0
Average number of cysts from soil analysis from pots			
Exp. 2 (egg inoc.)	Huckleberry Gold	Chippewa	$p \leq 0.1$
	2.8	455	**[b]

n=6 replications

[a] number of cysts/root-ball exceeded counting cutoff point of 30 on four of the replications

[b] ** = significantly different in *t*-test comparisona

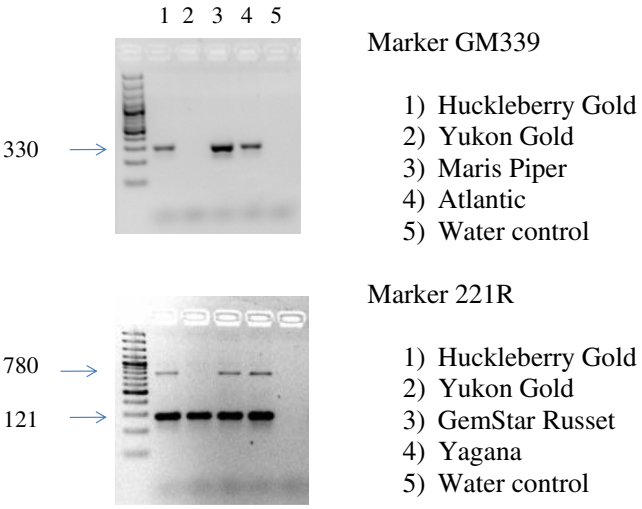

Fig. 5 Molecular markers for presence of the *Nb* gene using the GM339 marker and for the *Rx1* gene using marker 221R conferring resistance to *Potato virus X*. Yukon Gold is the negative control

and soil of each pot. Results with more than five recovered cysts per plant were considered susceptible.

Results show that after 9–10 weeks in experiment 1 using cysts as inoculums, Huckleberry Gold and Reba were both highly resistant with an average number of cysts ≤1 on the plant root-balls, while Chippewa was susceptible with more than 24 times as many cysts (Table 7). In experiment 2, Huckleberry Gold was again very resistant and Chippewa was susceptible. Experiment 2 was more definitive as it was done on the total soil from the pot and included the plant roots. Yukon Gold was previously tested in the GN lab and found to be susceptible at an average rate of 12.3 cysts (n=3) when plants were inoculated with cysts and the resulting root-balls were examined under a dissecting microscope (X.Wang, unpublished data).

To screen for the presence of molecular markers for nematode resistance, extractions were done as outlined under the previous "Virus" section of this paper. Extracted samples of Huckleberry Gold and Atlantic (used as resistant control) were loaded into an agarose gel along with other cultivar samples including Yukon Gold. Primers and PCR conditions for the TG689 marker, specific for the H1 gene was used (Bakker et al. 2004). Results showed that Huckleberry Gold and Atlantic had two PCR products at the expected sizes of 141 and 290 bp for the TG689 marker (Fig 6). Atlantic has been noted to have resistance to the golden nematode (Brodie 2003; ECPD 2013). The remaining cultivars did not produce the expected resistant band in the gel.

Management

A limited number of studies on the management of Huckleberry Gold have been conducted in southern Idaho. Results of these studies provide growers with a starting point for developing appropriate management guidelines for their locale.

Seed Management

Optimal seed size for Huckleberry Gold is about 70–85 g. Seed should be planted at near optimal temperatures (10–13 °C) to minimize the potential for soft rot decay. Huckleberry Gold has a tendency to produce some large tubers unless appropriate planting arrangement and spacing is used. In trials conducted at Aberdeen, Idaho, optimal seed piece spacing for 0.9 m wide rows was 18–20 cm. However, it appears that this cultivar could benefit from using narrower row and seed piece spacing such as that obtained with high density bed-planting to improve size uniformity and reduce the proportion of large tubers. Planting depth should be 12 to 15 cm, with an additional 3 to 5 cm of soil covering applied at final hilling to minimize tuber greening.

Fertilizer Management

To produce an optimal tuber size distribution, total seasonal nitrogen applications for Huckleberry Gold should be kept fairly low. Results from nitrogen response trials at Aberdeen show that near maximum yield of tubers less than 284 g were

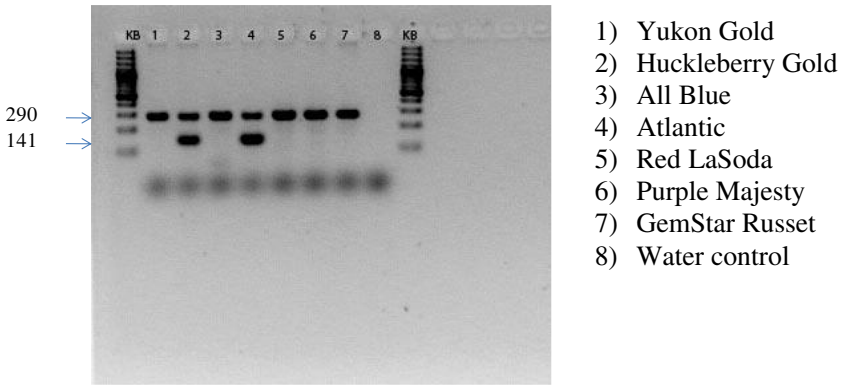

Fig. 6 Molecular marker (TG689) results for H1 gene conferring resistance to *Globodera rostochiensis*

obtained with about 70–80 kg N ha^{-1} of fertilizer N. At this rate, petiole nitrate concentrations were about 16,000 to 20,000 mg kg^{-1} at tuber initiation, 10,000 to 15,000 mg kg^{-1} during mid-bulking and 5,000 to 10,000 mg kg^{-1} during late bulking. About 2/3 of the seasonal N supply should be applied prior to planting with the remainder top dressed by row closure. Phosphorus and potassium requirements have not yet been established for Huckleberry Gold.

Herbicides

Huckleberry Gold has exhibited good resistance to metribuzin when applied at labeled rates. It has an erect, medium-sized vine that matures relatively early in the growing season and competes reasonably well with weeds after row closure during early to mid-tuber bulking.

Irrigation Management

Huckleberry Gold has good resistance to water stress-related tuber defects such as growth cracks and second growth shatter bruise. Available soil moisture (ASM) should be maintained within the range of 65–80 % for optimal yield and quality. Plant water uptake decreases appreciably in late August, so irrigation application rates need to be reduced according to soil moisture measurements to avoid developing excessively wet soil conditions that promote disease and enlarged lenticels.

Harvest Management

Soil moisture should be reduced to about 60–65 % ASM during tuber maturation and vine kill. Vines should be killed 2–3 weeks before harvest to allow for proper skin maturation and chemical maturity.

Seed Availability

In 2013, seed of Huckleberry Gold was available from potato seed growers in Idaho, Minnesota, Montana, and Washington. Small amounts of seed for research purposes can be obtained by contacting Jonathan Whitworth or Richard Novy, USDA-ARS, Aberdeen, Idaho. Pathogen-free tissue culture plantlets of Huckleberry Gold are also maintained by Lorie Ewing, Manager of the Potato Tissue Culture Lab, University of Idaho, Moscow, Idaho.

The University of Idaho, acting on behalf of the Northwest (Tri-State) Potato Variety Development Program has applied for Plant Variety Protection for Huckleberry Gold. Licensing and marketing of Huckleberry Gold will be conducted by the Potato Variety Management Institute (PVMI.org).

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