Effect of Whole Seed Tuber Size and Pre-plant Storage Conditions on Yield and Tuber Size Distribution of Russet Burbank

Walter J. Arsenault* and Bert R. Christie

Agriculture and Agri-Food Canada, Crops and Livestock Research Centre, 440 University Avenue, Charlottetown, PE, Canada, C1A 4N6
*Corresponding author: Tel: 902-566-6834; Fax: 902-566-6821; Email: arsenaultw@agr.gc.ca

ABSTRACT

Field experiments were conducted in 1995, 1996, and 1997 at Agriculture and Agri-Food Canada's Harrington Research Farm to assess the effect of whole seed tuber size and pre-plant seed storage conditions on processing yield (>51 mm dia.) of potato (*Solanum tuberosum* L. cv Russet Burbank). Following commercial storage, seed tubers were stored at 4.4 C then subjected to one of three pre-plant treatments: (1) planted directly from storage, (2) held at 10 C for 3 wk before planting, or (3) green-sprouted for 3 wk before planting. Five sizes of whole seed were used (28, 42, 56, 70, and 84 g) with a variable size cut seed treatment added for comparison. Plots were harvested 138, 134, and 131 days after planting in 1995, 1996, and 1997, respectively. Cut seed produced a higher yield of tubers >51 mm diameter in comparison to all whole tuber seed sizes, with the exception of the 28 and 56 g sizes. In terms of total yield, the 28- and 42-g whole seed tubers yielded significantly less than all other seed sizes examined. Warming or green-sprouting seed tubers prior to planting did not increase tuber yield. The larger whole seed tuber sizes tended to result in greater numbers of stems and tubers per plant. To maximize marketable yield of Russet Burbank planted from whole seed tubers, it is recommended that the seed be between 28 and 42 g in size.

RESUMEN

Durante los años 1995, 1996 y 1997 se realizaron experimentos de campo en papa (*Solanum tuberosum* L. cv Russet Burbank) en la Granja Experimental "Agriculture and Agri-food Canada's Harrington" con el objeto de evaluar el efecto del tamaño de tubérculo-semilla entero y condiciones de almacenamiento antes de la siembra, sobre el rendimiento de papa para procesamiento (>51 mm de diámetro). Después de almacenados comercialmente, los tubérculos- semilla se almacenaron a 4 C y luego fueron sometidos a tres tratamientos de presiembra (1) siembra inmediata después del almacén, (2) mantenidos por tres semanas a 10 C antes de la siembra, o (3) brotados por tres semanas antes de la siembra. Se trabajó con cinco tamaños de semilla entera (28, 42, 56, 70, y 84g), conjuntamente con semilla cortada de varios tamaños para comparación. Las parcelas fueron cosechadas a los 138, 134, y 131 días después de la siembra en 1995, 1996, 1997 respectivamente. La semilla cortada produjo un mayor rendimiento de tubérculos > de 51mm de diámetro en comparación con todos los tamaños de semilla entera, con excepción de los de 28 y 51g. En términos de rendimiento total, los tubérculos enteros de 28 y 42g rindieron significativamente menos que los de otros tamaños examinados. El reacondicionamiento de tubérculos brotados antes de la siembra no incrementó el rendimiento. Los tubérculos enteros de mayor tamaño mostraron tendencia a producir mayor número de tallos y tubérculos por planta. Para incrementar el rendimiento comercial de Russet Burbank sembrado de tubérculos- semilla entera, se recomienda una semilla de tamaño entre los 28 y 42g.

Accepted for publication 25 May 2004.
ADDITIONAL KEY WORDS: tuber storage temperature, processing yield, *Solanum tuberosum*, stem density, tubers per plant, total yield

INTRODUCTION

The Russet Burbank potato cultivar (*Solanum tuberosum* L.) is grown for processing and table markets in most areas of North America. Russet Burbank requires a long growing season for optimum production because it is indeterminate with a large tuber set (Rowe 1993). In comparison to many other potato-growing areas in North America, the climate on Prince Edward Island (PEI), Canada, is generally cool with a short growing season. These climactic conditions, when combined with inadequate rainfall, can result in substantial yields of small-sized tubers.

Although climate can influence yield and tuber size distribution of Russet Burbank, other factors, such as stem number per plant, can affect yield. Work by Iritani et al. (1983) has shown that more stems per plant can decrease yield of U.S. No. 1 size tubers and increase the yield of small tubers. Earlier work by Iritani et al. (1972) with Russet Burbank has shown that large cut seedpieces can result in a significant increase in the number of stems per plant. With whole seed tubers, Wurr and Morris (1979) determined a linear relationship between the number of stems per tuber and seed tuber weight using the Desiree and Maris Piper cultivars.

Physiological age and size of seed tubers can also strongly influence yield parameters of many potato cultivars. Experiments conducted by Wurr (1974), using the Maris Piper and Pentland Crown cultivars, revealed that larger cut seedpieces (100 g) can result in an increase in total yield. This was later supported by Rykbost and Locke (1999), who examined a variety of cultivars and found that larger cut seedpieces (64 g) optimized yield of fresh-market potatoes. However, some reports suggest that the total yield of many cultivars is not substantially affected by seed tuber weight (Allen et al. 1992). Iritani (1968) and Struik and Wiersema (1999) suggest that the physiological age of seed tubers is influenced by many factors including photoperiod, temperature, soil moisture, nitrogen, maturity at vinekill, and storage temperature; both propose that storing seed tubers at high temperatures may lead to increased physiological age of the tubers with a resultant increase of stem numbers. However, Toosey (1964) found that cold-storage-delayed sprouting can result in an increase in the number of stems produced by seed tubers, although year-to-year variability can occur.

During the late 1990s, potato virus levels increased in North America, thought to be a result of larger populations of virus-transmitting aphids (Novy et al. 2002). As a result, growers of seed tubers on PEI opted to apply vine desiccants earlier than normal, before the arrival of virus-transmitting aphids, in order to assure production of disease-free seed. However, early vine desiccation of late-maturing cultivars, such as Russet Burbank, can reduce yields of seed tubers of the size that require cutting, thus increasing yields of seed suitable for whole seed planting. The objective of the current work was to determine the impact of size of whole seed tubers and the effects of pre-plant seed tuber storage conditions on the production of Russet Burbank for processing.

MATERIALS AND METHODS

Experiments were conducted in 1995, 1996, and 1997 at Agriculture and Agri-Food Canada's Research Farm, Harrington, PEI, Canada (63°10'W, 46°21'N). Soil at the research farm is a fine sandy loam (Orthic Humo-Ferric Podzol) containing 60.4% sand, 29.0% silt, and 10.6% clay; pH and organic matter range from 5.7% to 6.0% and 2.2% to 3.1%, respectively (MacDougall et al. 1988). Commercially grown Elite 3 (cv Russet Burbank) seed tubers were purchased annually in late winter or early spring from the same commercial grower, then stored at 4.4 C until needed. Pre-plant seed treatments were (1) seed planted directly from 4.4 C (±2 C) storage, (2) seed warmed to 10 C (±2 C) for 3 wk before planting, and (3) seed green-sprouted 3 wk before planting. Seed tubers were green-sprouted in trays stacked on shelves in a greenhouse kept at a temperature range of 15-27 C . Treatments included whole seed tubers 28, 42, 56, 72, and 84 g (±2 g) in weight, with a variable-size cut seedpiece treatment added for comparison; cut seedpiece sizes ranged from 45 to 72 g and were cut from 113- to 226-g whole tubers. To minimize sprout damage, a planter modified to allow for hand placement of seed in a cup-type planting system was used.

All field plots were involved in a 3-year rotation of barley, annual ryegrass, and potatoes. Each plot consisted of a single row 7.5 x 0.9 m (Rykbost et al. 1999; Zvomuya et al. 2002) with an in-row seedpiece spacing of 38 cm. Plots were machine-planted on 25 May, 3 June, and 24 May in 1995, 1996, and 1997, respectively. Fertilizer (N:P:K 15-15-15) was band-applied at planting at a rate of 1,306 kg ha^{-1}. Above ground per plant stem number was recorded on 27 June, 5 July, and 3 July in 1995, 1996, and 1997, respectively. Pesticides were applied as needed according to current protocol (Atlantic Canada Potato Guide

1993). All plots were harvested 2 to 3 wk after application of the vine desiccant (Diquat® at 0.28 kg a.i. ha^{-1}) and occurred at 138, 134, and 131 days after planting in 1995, 1996, and 1997, respectively. All tubers were graded according to local processing contracts. Total yield, yield of tubers >51 mm in diameter, and yield of tubers >280 g were recorded for all treatment combinations. May to September weather data from 1994 to 1997 were collected near the study location (Table 1). Soil moisture was not supplemented with irrigation.

The experiment followed a randomized two-way factorial complete block design with four replications. The factors of interest were pre-plant storage condition (three levels) and seed size (six levels). Following verification of the ANOVA assumptions of normality and constant variance, data were analyzed using the ANOVA procedure with specific mean differences identified using the Duncan's Multiple Range test. All statistical procedures were performed using the Genstat (Version 5, Rel. 4.1) statistical analysis program (Genstat 5 Committee 1987), with effects considered significant when $P \leq 0.05$.

TABLE 1—*Average monthly maximum temperatures and total rainfall amounts in Harrington, PEI, for May to September, 1994-1997.*

	Maximum temperature (C)				Total rainfall (mm)			
	1994	1995	1996	1997	1994	1995	1996	1997
May	12.7	12.2	12.3	12.5	127	70	108	109
June	21.0	20.3	20.5	18.0	130	96	90	97
July	24.7	24.3	21.8	23.4	36	59	154	50
August	22.9	22.4	23.3	21.1	46	59	9	64
September	17.5	17.6	17.4	17.9	88	63	155	83
Total	98.8	96.8	95.3	92.9	427	347	516	403

TABLE 2—*Statistical summary of effects of year, pre-plant storage conditions and size of whole seed on the number of stems and tubers per plant and yield components for Russet Burbank.*

		# Tubers/plant		Yield (t ha^{-1})		Yield[3]
Factor	#Stems/plant	51 mm[2]	Total	51 mm	Total	% of total 280 g
Year	**	*	**	NS	*	**
PPSC[1]	**	NS	NS	NS	NS	*
Year x PPSC	*	NS	*	*	NS	*
Seed	**	**	**	*	**	**
Year x Seed	**	NS	**	NS	NS	**
PPSC x Seed	NS	NS	NS	NS	NS	*
Year x PPSC x Seed	*	NS	NS	NS	NS	NS

[1]Pre-plant seed storage condition = seed planted from 4.4 C storage, seed from 4.4 C storage warmed to 10 C 3 wk before planting, or seed from 4.4 C storage green-sprouted 3 wk before planting.
[2]Size of tubers >51 mm in diameter.
[3]Percent of total yield of tubers >280 g; NS = not significant; * = significant at $P \leq 0.05$; ** = significant at $P \leq 0.01$

RESULTS AND DISCUSSION

Results show significant treatment effects on many parameters of the Russet Burbank cultivar (Table 2). Each year the number of stems per plant decreased as the size of whole seed decreased (Table 3). These results are similar to those reported by Allen et al. (1992) and Wurr and Morris (1979) using a number of different cultivars. Planting directly from 4.4 C storage resulted in significantly fewer stems per plant than for green-sprouted seed. Warming seed to 10 C for 3 wk resulted in an intermediate number of stems per plant. The least number of stems were obtained

TABLE 3—*Effects of pre-plant storage conditions and size of whole seed on the number of stems per plant for Russet Burbank.*

	PPSC[1]			Seed Size (g)						
Year	4.4 C	10 C	GS	28	42	56	70	84	Cut seed[2]	Mean
1995	2.5e[3]	2.9cd	3.1c	2.0m	2.3lm	2.7ijk	3.0ghi	3.4ef	3.5ef	2.8
1996	2.5de	2.7de	2.9cd	2.2m	2.6jk	2.8hijk	3.1fg	2.9ghij	2.5kl	2.7
1997	3.5b	4.6a	4.7a	3.1fg	3.7de	4.5c	4.9b	5.5a	4.0d	4.3
Mean	2.8	3.4	3.6	2.4	2.9	3.3	3.7	3.9	3.3	

[1]Pre-plant seed storage condition = seed planted from 4.4 C storage, seed from 4.4 C storage warmed to 10 C 3 wk before planting, or seed from 4.4 C storage green-sprouted 3 wk before planting.
[2]Seedpieces were 45 to 72 g, cut from whole tubers 113 to 226 g.
[3]Means for year x per-plant storage conditions and for year x size of whole seed (plus cut seed) interactions followed by the same letter are not significantly different ($P \leq 0.05$).

by planting 28-g whole seed directly from 4.4 C storage, with the maximum number obtained by planting 84-g whole seed either warmed to 10 C or green-sprouted prior to planting (data not shown).

Because seed storage can affect physiological age of seed (Struik and Wiersema 1999), it is reasonable to assume that variability in the physiological age of seed occurred as a result of the storage conditions and the period of time seed was held in commercial storage before it was purchased each year. Results show that storage conditions for a short period before planting can also affect the number of stems per plant. Low rainfall in 1996 (Table 1) likely contributed to the higher number of stems per plant for seed tubers planted in 1997. It has been reported that soil moisture stress during seed production can influence the number of stems per plant by increasing the physiological age of seed (Struik and Wiersema 1999).

The size of whole seed had a significant effect on the number of tubers per plant >51 mm in diameter (Table 4). The 28-g whole seed produced significantly fewer tubers >51 mm than all other seed sizes, albeit there was variability between years. Our results are similar to those of Iritani et al. (1972) who reported a linear relationship between seed size and large tuber yield of Russet Burbank. Pre-plant storage treatments had no effect on the number of tubers per plant >51 mm in diameter (Table 2), but did affect the total number of tubers per plant in 1995 and 1996 (Table 5). In addition, yield of tubers

TABLE 4—*Size of whole seed and year effects on the average number of tubers per plant >51 mm in diameter size for Russet Burbank.*

	Size of whole seed (g)						Year		
	28	42	56	70	84	Cut seed[1]	1995	1996	1997
Number of tubers per plant >51 mm in diameter	6.1d[2]	6.6c	7.0ab	7.2a	7.2a	6.8bc	7.1a	6.4b	6.9a

[1]Cut seedpieces ranged from 45 to 72 g, cut from whole tubers 113 to 226 g.
[2]Means per variable followed by the same letter are not significantly different ($P \leq 0.05$).

TABLE 5—*Effects of pre-plant storage conditions and size of whole seed on the total number of tubers per plant and average tubers per stem for Russet Burbank.*

	PPSC[1]			Size of seed (g)						
Year	4.4 C	10 C	GS	28	42	56	70	84	Cut seed[2]	Mean
1995	10.8c[3]	11.6bc	12.3b	8.8h	10.2g	11.7de	12.6cd	13.4c	12.8cd	11.6
1996	11.2bc	10.9c	11.6bc	8.8h	10.4fg	11.3ef	12.5cd	12.7cd	11.7de	11.2
1997	14.6a	13.7a	14.0a	11.2efg	13.0c	14.9b	16.2a	16.5a	12.8c	14.1
Mean Tubers/Plant	12.2	12.1	12.6	9.6	11.2	12.6	13.8	14.2	12.4	

[1]Pre-plant seed storage condition = seed planted from 4.4 C storage; seed from 4.4 C storage warmed to 10 C 3 wk before planting, or seed from 4.4 C storage green-sprouted (GS) 3 wk before planting.
[2]Cut seed were 45 to 72 g, cut from whole tubers 113 to 226 g.
[3]Means for year x pre-plant storage condition and for year x size of whole seed (plus cut seed) interactions followed by the same letter are not significantly different ($P \leq 0.05$).

TABLE 6—*Effects of pre-plant storage conditions and whole seed size on yield (t ha^{-1}) of tubers >51 mm diameter for Russet Burbank.*

	PPSC[1]			Size of seed (g)					
Year	4.4 C	10 C	GS	28	42	56	70	84	Cut seed[2]
1995	32.7ab[2]	31.2abc	29.5c						
1996	32.6ab	33.4a	33.0ab						
1997	31.0abc	30.0c	30.8bc						
Mean	32.1	31.5	31.1	31.5ab	30.7b	32.1ab	31.4b	30.7b	33.1a

[1]Pre-plant seed storage condition = seed planted from 4.4 C storage; seed from 4.4 C storage warmed to 10 C 3 wk before planting; or seed from 4.4 C storage green-sprouted 3 wk before planting.
[2]Means for year x pre-plant storage condition as well size of whole seed (plus cut seed) followed by the same letter are not significantly different ($P \leq 0.05$).
[3]Cut seed ranged from 45 to 72 g, cut from whole tubers 113 to 226 g.

>51 mm in diameter was affected by seed size and by an interaction of year x pre-plant seed treatment (Tables 2 and 6).

The total yield of tubers was significantly different between years and from different seed sizes, but pre-plant treatments had no effect on total yield (Table 2). The greatest number of tubers per plant were produced from 84-g whole seed, although not significantly more than from the 70-g whole seed (Table 5). Overall the maximum number of tubers was obtained from 84-g whole seed, green-sprouted before planting (Table 5). In 1995 only, green-sprouting resulted in a significantly lower yield of >51 mm tubers than the same size tubers planted directly from 4.4 C storage, but there was no difference between the 3 year means of pre-plant storage conditions (Table 6). Cut seed produced the highest yield of tubers >51 mm in diameter, but not significantly more than from 28-g and 56-g whole seed (Table 6). Whole seed, 56, 70, and 84 g, as well as cut seed, produced the highest total yields; lowest yield was obtained from 28-g whole seed (Table 7). The percentage of large tubers (>280 g) was affected by all treatments (Table 2). In general, as the size of whole seed decreased, the percentage of large tubers tended to increase, but to maximize the percentage of tubers >280 g, the best results were obtained from the 28 g whole seed, either planted directly or warmed for 3 wk at 10 C prior to planting (Table 8).

For local processing markets, growers on PEI want to maximize the yield of tubers >51 mm in diameter. There is also a bonus for tubers >280 g. In this study, the size of whole seed had no significant effect on the yield of tubers >51 mm (Table 6). Cut seed resulted in total yields significantly higher than all whole seed sizes except 28 and 42 g. For percentage of tubers >280 g, the maximum was obtained from 28-g whole seed. Whole seed of 28 produced the least number of stems and fewest tubers per plant (Tables 3 and 5).

CONCLUSIONS

The maximum number of tubers per plant can be obtained by using 84-g whole seed, green-sprouted before planting. In 2 out of 3 years, there was no yield benefit of green-sprouting tubers prior to planting. Using 28-g whole seed, either planted directly or warmed 3 wk prior to planting, maximizes the percentage of tubers >280 g. Using 28-g whole

TABLE 7—*Effects of year and size of whole seed on total yield of Russet Burbank.*

	Year			Size of seed (g)					
	1995	1996	1997	28	42	56	70	84	Cut seed[2]
Total yield (t ha^{-1})	40.5b[1]	42.4ab	45.9a	38.9c	40.6b	43.8a	45a	45.0a	44.4a

[1]Means for year and size of whole seed (plus cut seed) followed by the same letter are not significantly different ($P \leq 0.05$).
[2]Cut seedpieces ranged from 45 to 72 g, cut from whole tubers 113 to 226 g.

TABLE 8—*Effects of pre-plant storage conditions and size of whole seed on percent yield of tubers >280 g for Russet Burbank.*

	PPSC[1]			Size of seed (g)						
Year	4.4 C	10 C	GS	28	42	56	70	84	Cut seed[2]	Mean
1995	9.9c[3]	8.8c	5.9d	16.3bc	10.1ef	6.5fg	5.6g	3.6g	7.1fg	8.2
1996	17.2b	21.6a	16.6b	26.6a	15.2bcd	18.4b	11.6de	15.9bc	23.0a	18.5
1997	7.8cd	8.0cd	7.1cd	14.7bcd	6.9fg	4.3g	3.8g	3.0g	13.0cde	7.6
Mean	11.6	12.8	9.9	19.2	10.7	9.7	7	7.5	14.4	
PPSC x Size of Seed Interaction Effects										
PPSC										
4.4 C				22.7a	10.2cd	9.7cde	5.7f	5.5f	15.9b	
10 C				20.1a	12.5bc	10.5cd	8.0def	10.7cd	14.9b	
GS				14.8b	9.5cde	9.0c-f	7.3def	6.2ef	12.3bc	

[1]Pre-plant seed storage condition = seed planted from 4.4 C storage; seed from 4.4 C storage warmed to 10 C 3 wk before planting; or seed from 4.4 C storage green-sprouted 3 wk before planting.
[2]Cut seedpieces ranged from 45 to 72 g, cut from whole tubers 113 to 226 g.
[3]Means for year x pre-plant storage condition, year x size of whole seed (plus cut seed), and pre-plant storage condition x size of whole seed interactions followed by the same letter are not significantly different ($P \leq 0.05$).

seed reduces the number of stems and tubers per plant, in comparison to cut seed, while 28- and 56-g-sized whole seed produced tuber yields similar to that obtained with cut seed. Using larger whole seed (42-84 g) may require alternative management practices in terms of in-row spacing to provide yields (total and >280 g) similar to cut seed. Green-sprouting or warming to 10 C did not provide any consistent advantage compared to planting directly from storage; as such, the recommendation is to plant seed directly from 4.4 C storage. However, the seed used in this study may have been warmed prior to being purchased and this may have influenced our results. In addition, it should be noted that the yield variability found in the current work may have been reduced by abbreviating the in-row seed spacing for the smaller whole seed. This is because the current experiments utilized only one in-row spacing, and Schotsko et al. (1984) reported that the economic optimum size for cut seed is dependent on in-row seed spacing. Further study of the in-row spacing interaction with whole seed size is needed.

ACKNOWLEDGMENTS

The authors would like to thank A. Malone for technical assistance and T. L. Gallant for manuscript compilation and editing.

LITERATURE CITED

Allen, EJ, PJ O'Brien, and D Firman. 1992. An evaluation of small seed for ware-potato production. J Agric Sci 118:185-193.

Atlantic Canada Potato Guide. 1993. Atlantic Provinces Agricultural Services Coordinating Committee, Publ.1300/93:Agdex 257-13.

Genstat 5 Committee. 1987. Genstat 5 reference manual. Oxford University Press, New York.

Iritani WM. 1968. Factors affecting physiological aging (degeneration) of potato tubers used as seed. Amer Potato J 45:111-116.

Iritani WM, R Thornton, L Weller, and G O'Leary. 1972. Relationships of seed size, spacing, stem numbers to yield of Russet Burbank potatoes. Amer Potato J 49:463-469.

Iritani WM, LD Weller, and NR Knowles. 1983. Relationships between stem number, tuber set and yield of Russet Burbank potatoes. Amer Potato J 60:423-431.

MacDougall JI, C Veer, and F Wilson. 1988. Soils of Prince Edward Island: Prince Edward Island Soil Survey Agr Can LRRC Contrib No 84-54.

Novy RG, A Nasruddin, DW Ragsdale, and EB Radcliffe. 2002. Genetic resistances to potato leafroll virus, potato virus Y, and green peach aphid in progeny of *Solanum etuberosum*. Amer J Potato Res 79:9-18.

Rowe RC. 1993. Potato Health Management. APS Press, Amer Phytopathol Soc, Saint Paul, MN.

Rykbost KA, and KA Locke. 1999. Effect of seedpiece size on performance of three potato varieties in the Klamath Basin of Oregon. Amer J Potato Res 76:75-82.

Schotzko R,WM Iritani, and RE Thornton. 1984. The economics of Russet Burbank seed size and spacing. Amer Potato J 61:57-66.

Struik PC, and SG Wiersema. 1999. Seed Potato Technology, Chapters: 4, 5. Wageningen Press, Wageningen, The Netherlands.

Toosey RD. 1964. The pre-sprouting of seed potatoes: factors affecting sprout growth and subsequent yield. Parts I and II. Field Crop Abstr 17:161-168, 239-224.

Wurr DCE. 1974. Some effects of seed size and spacing on the yield and grading of two maincrop potato varieties. II. Bulking rate. J Agric Sci Camb 82:47-52.

Wurr, DCE and GEL Morris. 1979. Relationships between the number of stems produced by a potato seed tuber and its weight. J Agric Sci 93:403-409.

Zvomuya F, CJ Rosen, and J Creighton Miller Jr. 2002. Response of Russet Norkotah clonal selections to nitrogen fertilization. Amer J Potato Res 79:231-239.