EFFECT OF TRANSPLANT CONTAINER VOLUME AND GROWING SEASON LENGTH ON FIELD PERFORMANCE OF MICROPROPAGATED POTATOES[1]

Michael K. Thornton[2] and Kenneth W. Knutson[3]

Abstract

Micropropagation is a tissue culture technique adapted for the rapid multiplication of disease-free seed stocks. Procedures for propagating potatoes in the laboratory and acclimating plantlets in the greenhouse are available, but information on cultural practices for maximizing tuber yield of plantlets when transplanted to the field is lacking. Centennial Russet and Russet Burbank plantlets were transferred from culture jars to three sizes of transplant containers for establishment under greenhouse conditions before transplanting to the field. Length of field growing season was varied by using two transplant dates and two vine kill dates. Survival of field transplanted plantlets was above 95 percent in both 1983 and 1984. Cultural practices significantly affected the tuber yield of plantlets of both cultivars. Total yield and yield of tubers larger than 35 mm in diameter increased with increasing transplant container volume. Transplant container volume had no effect on the yield of tubers less than 35 mm in diameter. Highest total yields and tuber production per plantlet for both Centennial Russet and Russet Burbank were obtained from the longest growing season (early transplant date with late vine kill). Yield of Russet Burbank plantlets increased more in response to a longer growing season than did Centennial Russet.

Resumen

La micropropagación es una técnica de cultivo de tejidos adaptada para la multiplicación rápida de existencias de semillas libres de enfermedades. Actualmente se dispone de procedimientos para propagar papas en el laboratorio y para aclimatación de las plántulas en el invernadero, pero no existe información sobre prácticas culturales para maximizar el rendimiento en tubérculos de las plántulas, cuando éstas son transplantadas al campo.

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[2]Assistant Professor, Department of Horticulture, Colorado State University, San Luis Valley Research Center, Center, Colorado 81125.

[3]Associate Professor, Department of Horticulture, Colorado State University, Fort Collins, Colorado 80523.

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Plántulas de los cultivares Centennial Russet y Russet Burbank fueron transferidas de potes de cultivo, a tres tamaños de recipientes de transplante, para su establecimiento bajo condiciones de invernadero antes de ser transplantadas al campo. Se varió la longitud de la estación de cultivo en el campo, utilizando dos fechas de transplante y dos fechas para la defoliación o eliminación del follaje. La supervivencia de las plántulas transplantadas al campo, tanto en 1983 como en 1984, fue mayor de 95 por ciento. Las prácticas culturales afectaron significativamente el rendimiento en tubérculos de las plántulas de ambos cultivares.

El rendimiento total, y el rendimiento en tubérculos más grandes de 35 mm de diámetro, se incrementó con el mayor volumen del recipiente de transplante. El volumen del recipiente de transplante, no tuvo efecto sobre el rendimiento de tubérculos de menos de 35 mm de diámetro. Los rendimientos totales más altos, así como la producción de tubérculos por plántula, tanto para Centennial Russet como para Russet Burbank, se obtuvieron en la estación más larga de cultivo (fecha temprana de transplante y defoliación tardía). El rendimiento de las plántulas de Russet Burbank, en respuesta a una estación de cultivo más larga, se incrementó más que el rendimiento observado para el cultivar Centennial Russet.

Introduction

Micropropagation is a tissue culture technique which involves *in vitro* propagation of plants in the laboratory. Procedures for initiating cultures and propagating potatoes by tissue culture are available (2, 4, 6, 8, 10, 13). Methods for rooting and acclimating tissue culture grown plantlets in the greenhouse prior to transplanting in the field have also been described (1, 3, 5). No reports were found in the literature on cultural practices which influence field performance of micropropagated potatoes. These experiments were initiated to study the effects of several factors on plantlet growth and tuber yield.

A direct relationship between the rooting volume of transplant containers and yield of tomato plants has been reported (14). Larger rooting volumes resulted in increased water and nutrient uptake, and less transplant shock. Optimization of transplant container volume should reduce greenhouse space requirements, while maximizing yield of transplanted potato plantlets. Both greenhouse space requirements and yield of field grown plantlets will influence the economics of producing disease-free potato seed.

Wattimena, *et al.* (12) reported that micropropagated potato plantlets produced more tubers than did seedpiece derived plants. Increased tuber production by plantlets was attributed to physiological differences which resulted in a longer period of tuber initiation, with less resorption of formed tubers in micropropagated plants. If micropropagated potato plantlets initiate tubers for a longer period during the season, then both tuber number and size should be affected by the length of the growing season.

The objective of this study was to determine the effect of transplant container volume and length of growing season on tuber production and yield of micropropagated Centennial Russet and Russet Burbank plantlets.

Materials and Methods

1983

Tissue cultures were initiated using sterile sprout cuttings containing a single node (3 to 5 mm) from virus-free tubers of Centennial Russet and Russet Burbank. Plantlets were grown in glass culture jars on Murashige and Skoog mineral salts medium (7) containing 3% sucrose and 0.8% agar, under a 16 hour photoperiod (2000 lux) at 20 to 25C. Plantlets were subcultured by nodal cuttings every 2 to 3 weeks. Twelve to 14 days after the last subculture, the plantlets were placed into plastic transplant trays (American Clay Works, Denver, CO) containing a 1:1 by volume peat moss and vermiculite soil mix. Volumes of individual cells in the transplant trays were 35.1, 50.0 and 67.0 cu.cm. Immediately before placing plantlets into the trays, the soil mix was saturated with Peters 20-20-20 (W.R. Grace & Co., Fogelsville, PA) fertilizer solution (473 ppm nitrogen). Approximately 2 g of Osmocote 14-14-14 (Sierra Chemical Co., Milpitas, CA) controlled release fertilizer was placed on the surface of the soil mix around each plantlet. The plantlets were placed in the greenhouse under a mist system which applied water for 30 seconds each 15 minutes the first day and 30 seconds each 30 minutes thereafter. The plantlets were shaded with white nylon shading cloth (50% shade) for approximately one week. Subsequently, the plantlets were acclimated to field conditions by placing them outside the greenhouse for 1 hour the first day, then increasing exposure up to 8 hours per day over a 2 week period. The plantlets were in the transplant trays for a total of 4 weeks prior to transplanting to the field.

Before transplanting, nitrogen (134 kg/ha) and phosphorus (73 kg/ha) were banded at a depth of 13 to 18 cm in the center of each row. Methamidophos was applied at 0.8 kg ai/ha on August 1 to control insects; the plots were hand weeded, and diquat was applied at a rate of 0.3 kg ai/ha to desiccate vines on August 15 or August 29.

The plantlets were transplanted by hand into a field with Norte gravelly sandy loam soil at the San Luis Valley Research Center. Plantlets were placed at a depth of 7 to 10 cm to ensure that the roots were completely covered with soil. Approximately 120 ml of Peters 20-20-20 fertilizer were applied to the soil around each plantlet. Plantlets were irrigated by solid set sprinkler after transplanting. Data were taken on plantlet survival on July 27.

The experiment was designed as a randomized complete block factorial with four replications. The factorial consisted of 3 container volumes, 2 cultivars and 2 vine kill dates. Duplicate plots were established on June 23

and July 6. Twenty-five plantlets were transplanted in each plot, with 30 cm in-row spacing between plantlets and 86 cm between rows.

The plots were harvested by hand on September 15, and the tubers separated into two size categories (<35 mm or >35 mm diameter). The data were analyzed by analysis of variance and means separated by a single degree of freedom F-test and regression analysis.

1984

Virus-free Centennial Russet and Russet Burbank plantlets were propagated as described above. Plantlets were placed into expanded polystyrene transplant trays (Speedling, Inc., Sun City, FL). Volumes of individual cells in the transplant trays were 16.4, 30.7 and 41.8 cu.cm. The soil mix, greenhouse conditions and acclimation procedures were the same as in 1983. The plantlets were transplanted with a mechanical transplanter (Mechanical Transplanter Co., Holland, MI) to a field with a Norte gravelly sandy loam soil at the San Luis Valley Research Center. Duplicate plots were established on June 14 and June 28. The transplanter placed the plantlets at a depth of 7 to 10 cm and applied soluble fertilizer to each plantlet as described above. The plantlets were irrigated by solid set sprinkler after transplanting. Data were taken on plantlet survival on July 10.

Before transplanting, nitrogen (63 kg/ha), phosphorus (34 kg/ha), and potassium (20 kg/ha) were banded at a depth of 13 to 18 cm in the center of each row. Alachlor was applied at 2.2 kg ai/ha on June 12 for weed control; disulfoton at a rate of 1.1 kg ai/ha in 3 applications beginning July 21 to control insects; and dinoseb at a rate of 1.4 kg ai/ha to desiccate vines on August 15 or August 29. The experimental design was essentially the same as in 1983.

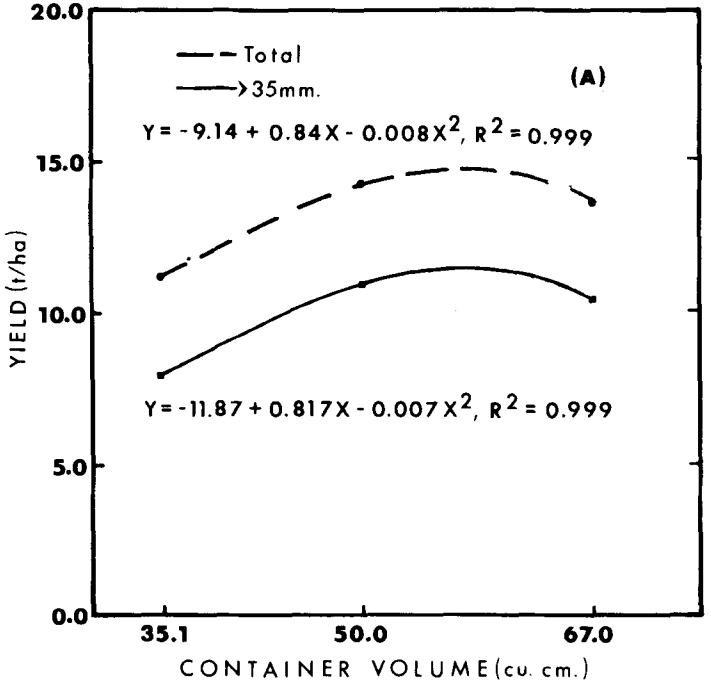
Results

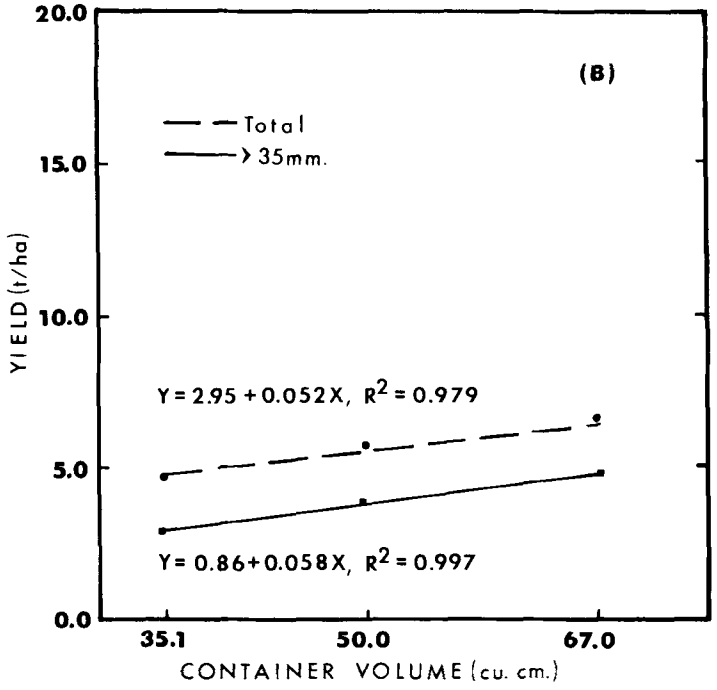
1983

More than 98% of the plantlets transplanted on either date survived.

Container volume significantly affected the yield of large size (>35 mm diam.) tubers and total tuber yield of plantlets transplanted on either date (Figure 1). Total yield and yield of large size tubers increased about 3 t/ha between the small (35.1 cu.cm.) and medium (50.0 cu.cm.) containers, but decreased slightly when the largest (67.0 cu.cm.) container was used on the June 23 transplanting date (Figure 1A). Total yield and yield of large size tubers increased by 2 t/ha as container volume increased from 35.1 to 67.0 cu.cm. for plantlets transplanted on July 6 (Figure 1B). Container volume did not significantly affect the yield of small size (<35 mm diam.) tubers produced by plantlets transplanted on either date (data not shown).

Delaying vine kill from August 15 to August 29 increased the yield of large size tubers and total yield by about 6 t/ha for plantlets transplanted on June 23 (Table 1). The yield of small size tubers, large size tubers, and total


20.0
15.0
10.0
5.0
0.0
YIELD (t/ha)
Total
>35mm.
(A)
Y = -9.14 + 0.84X - 0.008X2, R2 = 0.999
Y = -11.87 + 0.817X - 0.007X2, R2 = 0.999
35.1
50.0
67.0
CONTAINER VOLUME (cu. cm.)


20.0
15.0
10.0
5.0
0.0
YIELD (t/ha)
(B)
Total
>35mm.
Y = 2.95 + 0.052X, R2 = 0.979
Y = 0.86 + 0.058X, R2 = 0.997
35.1
50.0
67.0
CONTAINER VOLUME (cu. cm.)

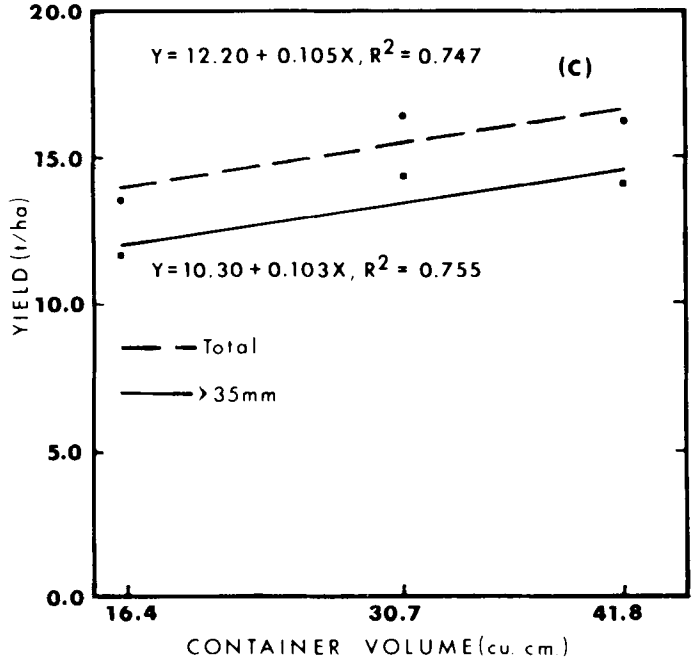


FIG. 1. Effect of transplant container volume on tuber yield of potato plantlets transplanted on (A) June 23, 1983, (B) July 6, 1983, or (C) June 14, 1984. Values are means of 4 replications averaged over 2 cultivars and 2 vine kill dates.

yield increased by 0.3, 4.6, and 4.9 t/ha, respectively, when vine kill was delayed from August 15 to August 29 for plantlets transplanted on July 6.

Centennial Russet produced significantly higher yields of large size tubers and higher total yields than Russet Burbank plantlets transplanted on both dates (Table 1). Russet Burbank produced the highest yield of small size tubers regardless of transplant date. The highest yields of all tuber sizes for both cultivars were obtained from plantlets transplanted on June 23 (Table 1). Total yields of Centennial Russet and Russet Burbank plantlets transplanted on June 23 were 7.0 and 7.7 t/ha higher, respectively, than those transplanted on July 6.

1984

More than 95% of the plantlets transplanted on each date survived.

Container volume significantly affected the yield of plantlets transplanted on June 14 (Figure 1C). The yield of large size tubers and total yield increased by 2.4 t/ha as container volume increased from 16.4 to 41.8 cu.cm. Container volume did not significantly affect the yield of large size tubers or total yield of plantlets transplanted on June 28, or the yield of small size tubers of plantlets transplanted on either date (data not shown).

TABLE 1. — *Effect of cultivar and vine kill date on tuber yield of micropropagated potato plantlets in 1983 and 1984.*

Transplant Date	Main Effect	Tubers <35 mm Diam.	Tubers >35 mm Diam.	Tubers Total
		t/ha		
1983				
June 23	Cultivar			
	Centennial Russet[1]	2.76*[3]	10.36*	13.12NS
	Russet Burbank	3.79	9.16	12.95
	Vine Kill Date			
	August 15[2]	3.39NS[4]	6.65*	10.04*
	August 29	3.16	12.87	16.03
July 6	Cultivar			
	Centennial Russet[1]	1.53*	4.58*	6.11*
	Russet Burbank	2.15	3.10	5.25
	Vine Kill Date			
	August 15[2]	1.67*	1.55*	3.22*
	August 29	2.01	6.13	8.14
1984				
June 14	Cultivar			
	Centennial Russet[1]	1.68*[3]	7.82*	9.50*
	Russet Burbank	2.26	18.94	21.20
	Vine Kill Date			
	August 15[2]	1.94NS[4]	10.24*	12.18*
	August 29	2.00	16.51	18.51
June 28	Cultivar			
	Centennial Russet[1]	1.04*	2.98*	4.02*
	Russet Burbank	1.40	6.61	8.01
	Vine Kill Date			
	August 15[2]	1.11NS	2.57*	3.68*
	August 29	1.33	7.02	8.35

[1]Mean of 4 replications averaged over 2 vine kill dates and 3 container volumes.
[2]Mean of 4 replications averaged over 2 cultivars and 3 container volumes.
[3]Differences between cultivar or vine kill date means are significant at 0.05 level using single degree of freedom F-test.
[4]Differences between means are not significant.

Delaying vine kill from August 15 to August 29 increased yield of large size tubers and total yield of plantlets transplanted on June 14 by about 6 t/ha (Table 1). Yield of large size tubers and total yield were increased by 4.4 and 4.7 t/ha, respectively, for plantlets transplanted on June 28 by delaying vine kill from August 15 to August 29. The yield of small size tubers was not significantly affected by vine kill date.

Russet Burbank plantlets transplanted on either date produced significantly higher yields of all tuber sizes than Centennial Russet (Table 1). The

highest yields of all tuber size classes for both cultivars were obtained from plantlets transplanted on June 14 (Table 1). Total yields of Centennial Russet and Russet Burbank plantlets transplanted on June 14 were 5.5 and 13.2 t/ha higher, respectively, than for plantlets transplanted on June 28.

Container volume significantly affected tuber production of plantlets transplanted on either date. The number of large size tubers and total number of tubers produced increased by 0.7 and 1.2 tubers per plantlet, respectively, for plantlets transplanted on June 14 as container volume increased from 16.4 to 41.8 cu.cm. (Figure 2A). Container volume did not significantly affect the number of small size tubers produced by plantlets transplanted on June 14 (data not shown). Total tuber number, and the number of small size tubers produced decreased by 0.9 and 1.1 tubers per plantlet, respectively, for plantlets transplanted on June 28 as container volume increased (Figure 2B). Container volume did not significantly affect the number of large size tubers produced by plantlets transplanted on June 28 (data not shown).

The number of large size tubers and total tubers produced by plantlets transplanted on both June 14 and June 28 increased by 1.2 to 2.1 tubers per plantlet with delayed vine kill (August 15 vs August 29) (Table 2). The number of small size tubers produced by plantlets transplanted on June 28 was also increased by 0.8 tubers per plantlet by delaying vine kill (Table 2).

Russet Burbank plantlets transplanted on June 14 produced between 0.8 and 3.5 more tubers per plantlet in all size categories than did Centennial Russet (Table 2). Russet Burbank plantlets transplanted on June 28 produced about 1.2 more large size tubers and total tubers per plantlet than did Centennial Russet. The June 14 transplanting date resulted in highest tuber production per plantlet for both cultivars (Table 2).

Discussion

Tuber yield of micropropagated potato plantlets was significantly affected by transplant container volume in 3 of 4 trials over a two year period (Figure 1). Increasing container volume provides a larger area for root development. The top growth of plantlets in this experiment did not appear to be affected by transplant container volume. A higher root to shoot ratio has been associated with an increase in water and nutrient uptake upon transplanting (14), which may reduce transplant shock and increase yield. Potato plantlets rooted in transplant containers with a rooting volume over 40 cu.cm. produced the highest yields under San Luis Valley conditions (Figure 1); but container volume did not consistently affect the number of tubers produced per plantlet (Figure 2). Although plantlets grown in small containers require less greenhouse space and are therefore less expensive to produce, the associated decrease in yield of basic seed stocks may nullify the economic benefits of lower cost of production.

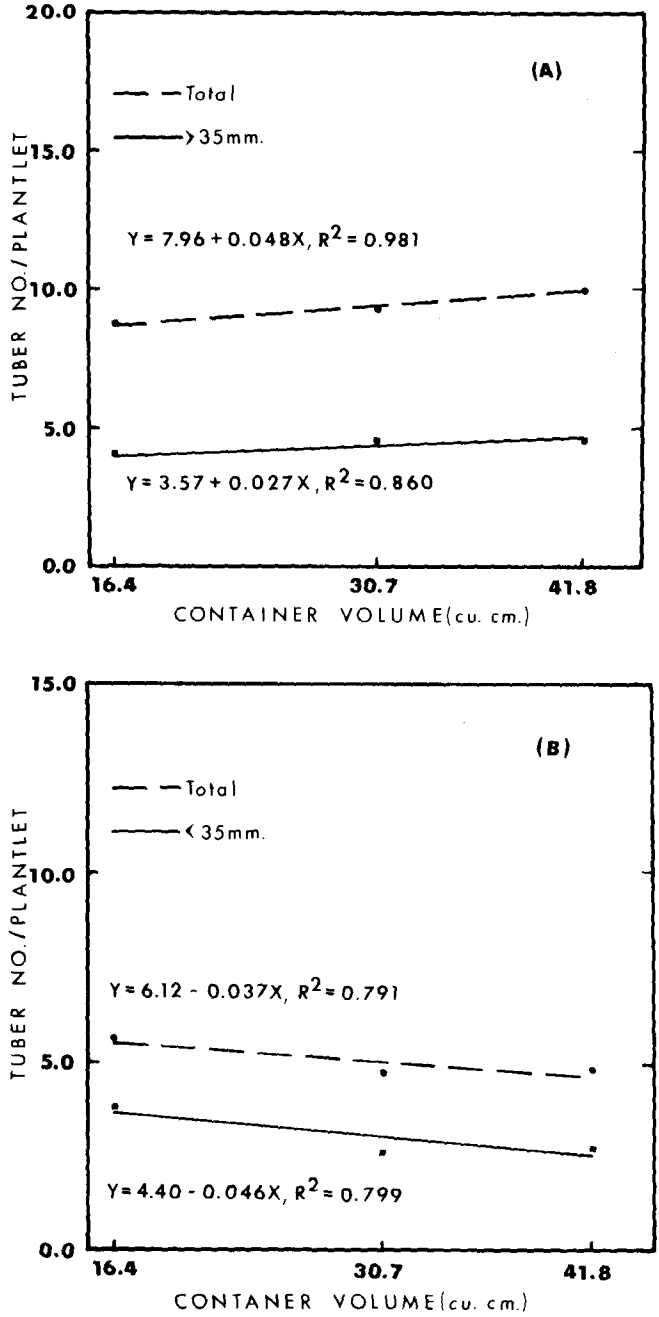


FIG. 2. Effect of transplant container volume on tuber production of potato plantlets transplanted on (A) June 14, 1984, or (B) June 28, 1984. Values are means of 4 replications averaged over 2 cultivars and 2 vine kill dates.

TABLE 2. — *Effect of cultivar and vine kill date on tuber production of micropropagated potato plantlets in 1984.*

Transplant Date	Main Effect	Tubers <35 mm Diam.	Tubers >35 mm Diam.	Tubers Total
		Tuber no./plantlet		
June 14	Cultivar			
	Centennial Russet[1]	4.6*[3]	3.1*	7.6*
	Russet Burbank	5.4	5.7	11.1
	Vine Kill Date			
	August 15[2]	4.9NS[4]	3.7*	8.6*
	August 29	5.1	5.0	10.1
June 28	Cultivar			
	Centennial Russet[1]	2.9NS	1.4*	4.4*
	Russet Burbank	3.1	2.6	5.7
	Vine Kill Date			
	August 15[2]	2.6*	1.4*	4.0*
	August 29	3.4	2.6	6.1

[1]Mean of 4 replications averaged over 2 vine kill dates and 3 container volumes.
[2]Mean of 4 replications averaged over 2 cultivars and 3 container volumes.
[3]Differences between cultivar or vine kill date means are significant at 0.05 level using single degree of freedom F-test.
[4]Differences between means are not significant.

Delaying vine kill by two weeks resulted in yield increases of 4 to 6 t/ha, regardless of transplanting date (Table 1). This increase in yield was associated with both significant increases in production of large size tubers (>35 mm diam.) and total tuber number per plantlet (Table 2). Total tuber production increased by about 2 tubers per plantlet between the early and late vine kill dates (Table 2). These results confirm previous reports (12) that micropropagated plantlets initiate new tubers for a long period during the growing season.

Plantlets of both cultivars produced the highest yields during the longest growing season (early transplanting date and late vine kill). However, plantlets of the two cultivars responded differently to changes in length of growing season. Russet Burbank produced a larger yield increase in response to a two week earlier transplanting than did Centennial Russet (Table 1). Russet Burbank also produced a larger yield increase in response to delayed vine kill than did Centennial Russet (data not shown). Russet Burbank requires 10 to 14 days longer than Centennial Russet to produce maximum yield when grown from seed tubers in the San Luis Valley (Thornton, unpublished). Apparently, plantlets respond similarly to some cultural practices as plants grown from seed tubers.

The purpose of growing micropropagated potatoes is to provide disease-free basic seed (9). The incidence of virus disease spread in certified seed potatoes has been associated with both heat unit accumulation (11) and time of vine desiccation (15). Therefore, determination of vine kill date for these seed stocks will have to take into account both yield and disease spread factors.

These results indicate that cultural practices such as container volume and growing season length can affect tuber yield of tissue culture plantlets grown for basic seed production. The yield of field grown plantlets will affect the cost of producing basic seed. As micropropagation technology becomes more a part of certified seed production, it is clear that optimum cultural practices for micropropagated potatoes will need to be developed.

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