VARIATIONS IN STOLON LENGTH AND IN INCIDENCE OF TUBER ROOTS AMONG EIGHT POTATO CULTIVARS[1]

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Abstract

The stolon length and percentage of tubers with tuber roots were compared for eight cultivars of *Solanum tuberosum* L. over two growing seasons. Although stolon lengths varied considerably within cultivars, there were significant differences in the average stolon lengths among cultivars. The cultivars Norchip and Monona had the shortest stolons whereas Norland had the longest average stolons. The length of the stolon did not appear to be related to color type or time of tuber maturity. Since there was no significant difference in stolon length between years, stolon length appears to be a consistent genetic trait. There was no significant correlation between the stolon length and tuber size. The incidence of tuber roots also showed variation among cultivars, although there was significant variability between times of sampling. Recent studies have demonstrated that to maximize calcium uptake by tubers, the calcium must be placed around the tubers and stolons. Since stolon length determines the location of the tubers in the hill, the stolon length of different cultivars may need to be considered for fertilizer application, cultivation or hilling procedures. Thus, to get maximum benefit from supplemental calcium for Norchip and Monona, application would need to be made close to the main stem. However, in the other cultivars, the majority of the hill would have to be enriched in calcium to effectively supply calcium to the various tubers in the hill.

Compendio

La longitud de los estolones y el porcentaje de tubérculos con raíces en los tubérculos fueron comparados para ocho cultivares de *Solanum tuberosum* L. durante dos temporadas de cultivo. Aunque la longitud de los estolones varió considerablemente entre los cultivares, hubo diferencias significativas en el promedio de las longitudes de los estolones en los cultivares. Los cul-

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tivares Norchip y Monona tuvieron los estolones más cortos mientras que Norland tuvo los estolones promedio más largos. La longitud del estolón no pareció estar relacionada al color o al momento de la maduración del tubérculo. Desde que no hubo diferencia significativa en la longitud de los estolones entre los años de cultivo, la longitud de los estolones parece ser un atributo genético consistente. No hubo una correlación significativa entre la longitud de los estolones y el tamaño del tubérculo. La incidencia de raíces en los tubérculos mostró también variaciones entre los cultivares, aunque existió una variabilidad significativa entre las muestras tomadas a diferentes tiempos. Estudios recientes han demostrado que para maximizar la toma de calcio por los tubérculos, el calcio debe colocarse alrededor de los tubérculos y estolones. Desde que la longitud de los estolones determina la ubicación de los tubérculos en la mata, dicha longitud puede ser considerada en la aplicación de fertilizantes para diferentes cultivares, en las labores de cultivo y en el aporque. Así, para obtener máximos beneficios por la aplicación suplementaria de calcio para Norchip y Monona, la aplicación debera efectuarse cerca del tallo principal. Sin embargo, en los otros cultivares la mayoría de las matas deberán ser enriquecidas con calcio para suministrar efectivamente este elemento a los diversos tubérculos en ellas formados.

Introduction

The initiation and subsequent growth of stolons and tubers in *Solanum tuberosum* L. has been studied extensively. Environmental factors which affect stolon initiation (14, 17, 18, 22), stolon length (2, 8, 16) and stolon number (18) have been examined. Several researchers have also examined the relationship between the position of the stolon on the main stem and the growth of stolon or tuber (3, 4, 8, 19, 23). There are occasionally conflicting results reported in these studies, which can, in part, be attributed to differences in cultivars used by different researchers. Wurr (23) reported that the patterns of tuber formation and the extent of tuber growth varied widely among the three cultivars (Pentland Crown, Desiree, and Maris Piper) tested.

To maximize calcium uptake by potato tubers, Kratzke and Palta (12) and Simmons *et al.* (20) reported that the calcium must be placed directly around the tubers and stolons. Potato stolons have small adventitious roots growing at the nodes (11). Some tubers of the cultivar Russet Burbank have been shown to have tiny roots growing directly out of the tubers (11, 21). These functional roots are capable of supplying water and perhaps some inorganic nutrients to the tuber (11). Uptake of calcium through these stolon and tuber roots may be one explanation for the necessity of calcium application close to the tubers and stolons. In order to place calcium properly around the tuber, it is important to determine the pattern of tuber development in the hill for individual cultivars.

Tuber growth or bulking is thought to be primarily due to the transport of carbohydrates and water into the tuber via the phloem (1, 9). There is some evidence that stolon characteristics may influence this aspect of tuber growth. Engels and Marschner (7) have found a small, but significant positive correlation between stolon length and tuber volume in small three-week-old tubers. These investigators also found significant positive correlations between stolon volume and tuber volume, and between stolon diameter and tuber volume. These positive correlations were thought to be due to increased carbohydrate sink strength provided by the stolon. Kunkel *et al.* (15) have shown that the amount of nutrients removed from a field was well correlated to the tuber yield. It is possible that tubers with longer stolons, and therefore more stolon roots, may be larger since they have more access to water and nutrients.

The purpose of this study was to investigate the variations in stolon length and observe the incidence of tuber roots in eight potato cultivars grown in Wisconsin. A secondary objective was to investigate any possible relationship between the stolon length and tuber weight.

Materials and Methods

Eight cultivars of *Solanum tuberosum* L. were grown at the University of Wisconsin Hancock Experiment Station in 1985 and 1986. The soil at this location is a sandy loam with a pH of 5.9. The eight cultivars were selected with a range of tuber types (white, red and russet), and time of maturity (early, mid, late). The cultivars chosen were Butte (late, russet), Monona (early, white), Norchip (mid, white), Norland (early, red), Red Pontiac (late, red), Redsen (mid, red), Russet Burbank (late, russet), and Superior (early, white). All the cultivars were grown using standard cultural procedures for the central sands of Wisconsin. The fertilizers applied were 400 $kg \cdot ha^{-1}$ of potassium sulfate as preplant broadcast, 600 $kg \cdot ha^{-1}$ of $6N\text{-}24P_2O_5\text{-}24K_2O$ at planting, and 300 $kg \cdot ha^{-1}$ of ammonium nitrate at emergence and hilling.

Sampling was done the last week of July in 1985 (approximately 14 weeks after planting) and the last weeks of June and July in 1986 (approximately 10 and 14 weeks after planting). The plants were removed from the soil taking great care to keep tubers, stolons and as many roots as possible intact. The stolon length and number of tubers with tuber roots were recorded for four plants from each cultivar in 1985.

The stolon length, number of nodes with roots on the stolon, number of tubers with tuber roots and the tuber weight were recorded for five plants from each cultivar at both sampling times in 1986.

Eight stolons were chosen randomly from each plant for analysis of variance for stolon length. Differences in stolon length between cultivars were determined using Fisher's Least Significance Difference. Since the

number of plants sampled in 1985 was different from the number sampled in 1986, the frequency distributions of stolon lengths were expressed on the basis of 100 stolons. To determine the influence of stolon length on tuber size, linear regression correlation coefficients (r) for stolon length vs. tuber weight were calculated for tubers of each cultivar. The percentage of tubers with tuber roots was calculated from all tubers sampled from each cultivar.

Results and Discussion

Stolon Length Variations Among Cultivars—The length of individual stolons varied considerably among cultivars (Fig. 1). Within cultivars however, the average and variation in stolon length were quite consistent over three separate samplings, obtained in two seasons as shown by frequency distributions of stolon lengths for the eight cultivars (Fig. 2). Norchip and Monona clearly had the shortest stolons and least variation in stolon length. All the other cultivars had stolons that ranged from very short (<3 cm) to very long (>26 cm). In spite of this wide variation, there were significant differences in the mean stolon length between cultivars (Table 1). Norchip and Monona had significantly shorter stolons, while Norland had the longest average stolons. The rest of the cultivars were intermediate. The length of stolon did not appear to be related to color type or time of tuber maturity.

Although environmental factors, such as day length and nitrogen level, play a role in determining stolon length (13, 16), there was no significant difference in stolon length at different times of sampling, nor was there a cultivar $\times$ time of sampling interaction. All potato cultivars within any one season in this study were subjected to similar environmental conditions since they were grown close to each other on the same location. This indicates that the stolon length is a consistent genetic trait. This does not imply that environment has no effect on stolon length, since the mean stolon length did vary somewhat between the two seasons of the study (Figure 2). However, the pattern of variations among cultivars was quite similar in the three samplings made in the present study (Figure 2). Thus, the data suggest that stolon length has a strong genetic component among the cultivars studied.

The fact that stolons sampled in June 1986 (10 weeks after planting) were not significantly longer than those sampled in July 1986 (14 weeks after planting), indicates that the stolons had completed elongation by 10 weeks. These results agree with the observations of Krijthe (10) who found that the majority of stolons had initiated tuberization, and therefore stopped elongating, 4 to 8 weeks after planting.

Stolon Length and Tuber Growth—The number of nodes with roots on a stolon was highly correlated with the stolon length in all eight cultivars (linear correlation coefficient $r = 0.74$ to 0.92, data not shown). However, stolon length, and therefore the number of roots on the stolon, did not seem to have any effect on the size of the tuber at 10-14 weeks after planting. Lin-

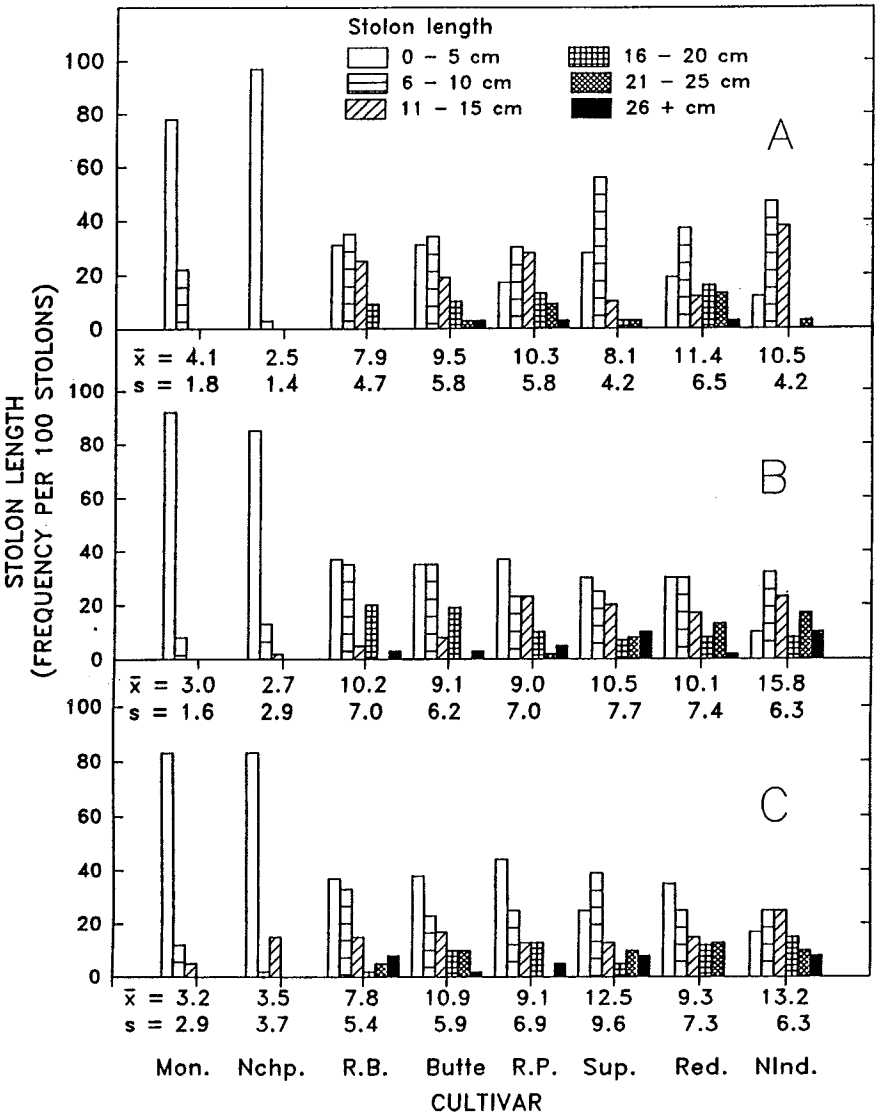

FIG. 1. Examples of cultivars sampled in June 1986. Norchip and Monona have significantly shorter stolons than the other cultivars.

ear regression coefficients calculated for stolon length vs. tuber weight ranged from 0.01 to 0.32 and were not significant (data not shown). This is not surprising since a whole array of factors including radiation, water, nutrients, haulm size, sink strength, enzymes and hormones influence tuber size and yield (5, 6, 17). Engels and Marschner (7) also examined stolon

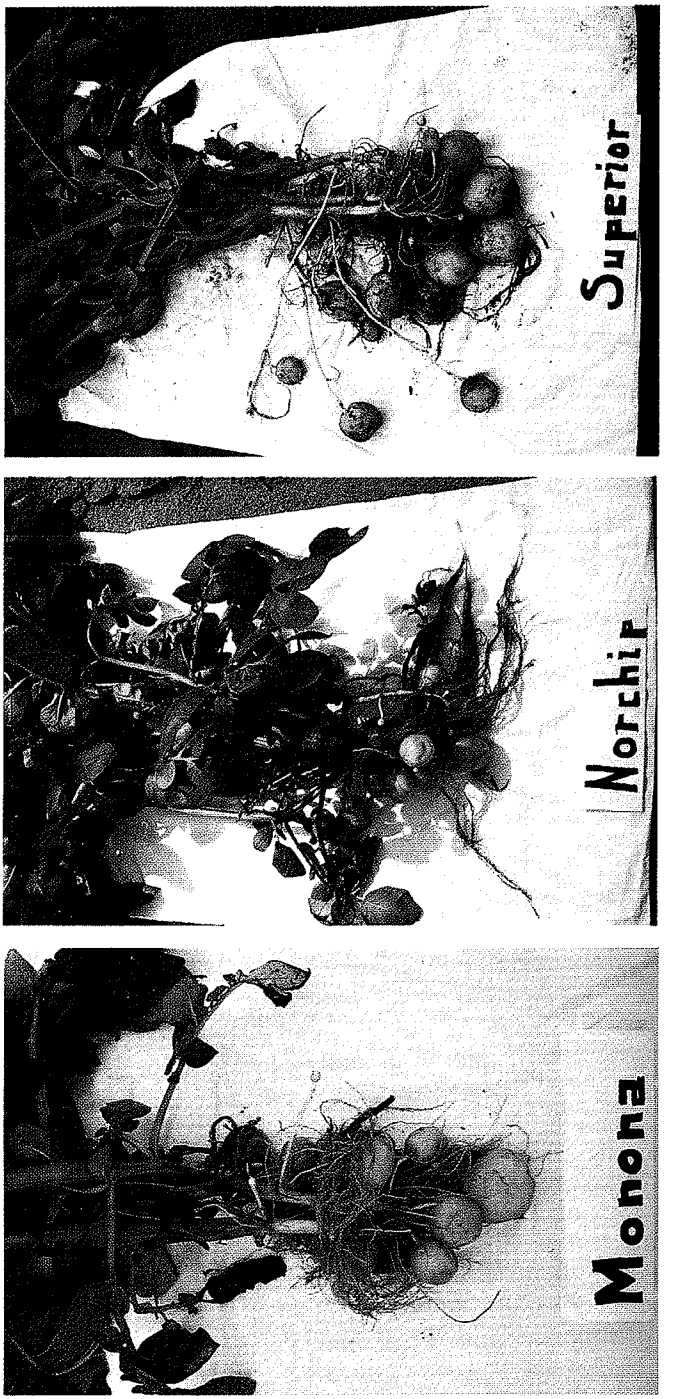
Superior
Norchip
Monona

FIG. 2. Distribution of stolon lengths for eight potato cultivars. Bars represent the number of stolons that have a given stolon length, expressed as % of total stolons. Mon. = Monona, Nchip. = Norchip, R.B. = Russet Burbank, Butte = Butte, R.P. = Red Pontiac, Sup. = Superior, Red. = Redsen, Nlnd. = Norland. A: sampled in July 1985; B: sampled in June 1986; C. sampled in July 1986.

TABLE 1.—*Mean stolon length and analysis of variance for eight potato cultivars sampled in July 1985, June 1986 and July 1986.*

Cultivar		Mean Stolon Length (cm)[1]
Monona		3.0 a[2]
Norchip		3.2 a
Russet Burbank		8.6 b
Butte		9.3 b
Red Pontiac		9.8 b
Superior		9.9 b
Redsen		10.3 bc
Norland		12.2 c
ANOVA	d.f.	F Values[3]
Cultivar (C)	7	23.52**
Time of Sampling (T)	2	.77 n.s.
C × T	14	.80 n.s.

[1]Means for main cultivar effects (mean of all three samplings).
[2]Values with the same letters are not significantly different at P=.05 using Fisher's LSD.
[3]n.s.=not significantly different, **=significantly different at P<.01

size as a possible influence on sink strength for photosynthate. They found the growth rate of three-week-old tubers in controlled environments was significantly correlated to the volume and the cross sectional area of the phloem. This indicated that the size of stolons may have influenced early sink strength and therefore subsequent tuber growth. They also observed a significant positive correlation (r = 0.32) between the tuber volume and stolon length. In the present study, observations were made at 10-14 weeks after planting, whereas Engels and Marshner (7) studied three-week-old tubers. Failure to find any significant correlation between stolon length and tuber size in the present study may be due to the more advanced age of the tubers and stolons at the time the measurements were made.

Tuber Root Variations Among Cultivars—The incidence of tuber roots varied considerably among cultivars (Table 2). Russet Burbank and Red Pontiac had the highest percentage of tubers with roots, while Norchip and Norland had the lowest percentages. Once again, tuber color did not appear to be related to the incidence of tuber roots. However, the late maturing cultivars tended to have higher incidences of tuber roots than the early cultivars. More cultivars would need to be studied to confirm this trend. Redsen and Butte had high variability in the incidence of tuber roots, depending on sampling time. There was variation between the two seasons in most cultivars, indicating that environmental factors may play a significant role in the incidence of tuber roots. In general, there were more roots on all cultivars in 1985. It should be noted that the tuber roots are very small and

TABLE 2.—*Percentage of potato tubers with tuber roots, for eight potato cultivars grown in 1985 and 1986.*

Cultivar	Percentage of tubers with at least one set of tuber roots at three sampling times		
	July 1985	June 1986	July 1986
Butte	23	29	2
Monona	20	14	17
Norchip	4	0	0
Norland	2	1	5
Red Pontiac	72	22[1]	42[1]
Redsen	47	4	12
Russet Burbank	47	34	37
Superior	12	18	11

[1]Serious scab infection in this cultivar in 1986.

fragile. Early rotting in the field or root breakage during removal from the soil may have also contributed to the observed variations.

Practical Implications in Tuber Nutrition and Fertilizer Placement—Since stolon length also determines location of the tubers in the hill, the stolon lengths of different cultivars may need to be taken into account for fertilizer application, cultivation or hilling procedures. This is especially significant for calcium nutrition of the tuber since calcium placed in close proximity to the tuber is able to increase the calcium content of the tuber (12, 20). Thus, to get maximum benefit from supplemental nutrients (calcium) for Norchip or Monona, application would need to be made close to the main stem. However, in the other cultivars, the majority of the hill would have to be enriched in calcium to effectively supply calcium to the various tubers in the hill.

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