

INFLUENCE OF LOW FERTILITY AND VINE KILLING ON SUGAR DEVELOPMENT IN APICAL AND BASAL PORTIONS OF RUSSET BURBANK POTATOES¹

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Abstract

Russet Burbank tubers from plants which died prematurely (low fertility plots) accumulated significantly greater amounts of reducing sugars in storage than tubers from plants which were adequately fertilized. Also, a significantly greater difference in relative amounts of reducing sugars between the apical and basal portions was obtained from tubers of the low fertilizer regime. The basal portion had a three times greater amount of sugars than the apical portion. This is of particular interest to processors of French fries who try to obtain uniformity of color in processed fries. The difference in total reducing sugar accumulation in storage between tubers of high and low fertilizer regimes was greater at the lower storage temperatures. Tubers allowed to mature in the ground (second harvest date) accumulated less sugars in storage than tubers dug shortly after vine kill.

Resumen

Tubérculos Russet Burbank de plantas que murieran prematuramente (parcelas de baja fertilidad) acumularon significativamente cantidades mayores de azúcares reductores en el almacenamiento que tubérculos de plantas con fertilización adecuada. También, una diferencia significativamente más grande en las cantidades relativas de azúcares reductores entre las porciones apical y basal fueron obtenidos de tubérculos bajo el régimen de fertilizantes bajo. La porción basal tuvo tres veces más azúcares que la porción apical. Esto es de interés particular para los procesadores de papas fritas quienes tratan de obtener uniformidad en el color de las papas fritas. La diferencia en la acumulación total de azúcares reductores en almacenamiento entre los tubérculos de alta y baja fertilización fue mayor a las temperaturas más bajas de almacenamiento. Los tubérculos que se dejaron madurar en el suelo acumularon menos azúcares en almacenamiento que los tubérculos cosechados a corto tiempo de matar el follaje.

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Introduction

With the advent of sprinkler irrigation in the Columbia Basin of Washington and nitrification (application of fertilizers through the sprinkler system), potato growers in Washington have been able to keep vines green much longer in the fall than in the past, thus requiring greater usage of chemical defoliant prior to harvest. With greater cost-price squeeze on growers, the tendency is to keep potatoes growing for higher yields with the result that more potatoes are being placed into storage in an immature state (more skinning). On the other hand, there are still many fields in which the vines have died prematurely, primarily because of miscalculation of fertilizer requirements, cost cutting on fertilizer needs, or because of disease problems such as verticillium wilt (*Verticillium albo-atrum*). The present recommendation in Washington is not to store potatoes from vines which have died prematurely. One of the reasons which has been documented, is that these potatoes are more susceptible to blackspot development during harvest (12). The present investigation was initiated to determine the storageability of overmature potatoes (from prematurely dead plants in terms of reducing sugar development during low temperature storage. With greater amounts of immature potatoes being placed into storage, information is needed on temperature management in relation to sugar development in immature potatoes, especially the relative amounts of sugars in the apical and basal portions.

The literature is replete with references on the influence of fertilizer rates on reducing sugar accumulation, especially the influence on chip color (1, 2, 3, 4, 6, 11, 13, 14, 16, 17, 18, 19, 20, 21). However, as pointed out by Kunkel (13), much of the data is inconclusive and sometimes conflicting. Many of the studies have pointed out the detrimental effects of large applications of nitrogen (14, 16, 17, 19). However, Kunkel (13) has shown that under Columbia Basin growing conditions, high fertilizer rates did not have a detrimental influence on chip color.

The studies in other areas have concentrated on the influence of higher than optimum rates of nitrogen. The present studies are concerned with low rates of nitrogen which in many cases result in premature death of the foliage.

Maturity is a confusing term which in most cases refers to a degree of skin set. However, physiological and biochemical changes within the tuber also undoubtedly take place. A number of factors influence skin set, such as: fertilizer rate, killing of foliage several weeks prior to harvest, temperature and moisture content of soil after vine kill, and also storage conditions.

The studies reported herein have attempted to determine the influence of low fertilizer rates and also the interaction of fertilizer rates and vine killing prior to harvest on sugar accumulation in the apical and basal portion of stored Russet Burbank potatoes.

Materials and Methods

Russet Burbank cultivar was used exclusively through the three growing and storage seasons of 1973 through 1976. Fertilizer treatments of 146.2 kg/ha (130 lbs of N/A) and 339.7 kg/ha (320 lbs of N/A) in a 16:16:16 fertilizer were used each year. With the lower fertilizer rates, the vines died by the middle of September in each of the years. With the higher fertilizer rates, the vines were killed during the third week of September. The first harvest date was several days later and the second harvest date approximately two weeks after vine kill. Planting dates, fertilizer level, vine killing date, and harvest dates are given in Table 1. The treatments were designed to obtain extremes in relative maturities of the tubers.

After harvest, the tubers were washed, graded, and U.S. No. 1 tubers were placed in 50 lb (22.7 kg) bags, suberized for one week at 55 to 60 F (12.8 to 15.5 C) and placed in controlled temperature storages of 42 F (5.6 C), 45 F (7.2 C), and 48 F (8.9 C). Monthly analysis of sucrose, reducing sugars, and percentage dry matter were made from December through May of each storage season. Methods of sampling and analysis of sugars were as described previously (9).

TABLE 1. — *Planting dates, fertilizer level, date of vine kill, and harvest date for each growing and storage season.*

Season	Planting Date	Fertilizer Rate (lbs N/A)	Vine Killing Date	Harvest Dates	
				First	Second
1973-74	4/19/73	130	Vines Dead	9/18/73	10/3/73
	"	300	9/17/73	"	"
1974-75	4/24/74	130	Vines Dead	9/18/74	10/9/74
	"	300	9/17/74	"	"
1975-76	4/19/75	130	Vines Dead	9/15/75	10/9/75
	"	300	9/22/75	"	"

Results

The three years' data were combined into a single analysis of variance. The results are shown in Tables 2 and 3. Tubers from the low fertilizer treatment had significantly higher reducing sugar accumulation over a seven-month storage period than tubers from the high fertilizer regime. Greater amounts of reducing sugars resulted in storage from tubers of the first harvest date as compared to harvest two weeks later. As would be expected, lower storage temperatures resulted in greater amounts of reducing sugars than higher storage temperatures and the basal portion had three times more sugar than the apical portion. A highly significant interaction of reducing sugar accumulation was obtained between fertility rate and harvest date. The tubers of the second harvest date of the low fertilizer regime

TABLE 2. — *Results of analysis of variance on the influence of fertility rate, harvest dates, and storage temperatures on reducing sugar accumulation of Russet Burbank potatoes over 7 months storage (Average 3 years' data).*

Fertility Rate**	% Reducing Sugar	Harvest Date**	% Reducing Sugar
Low (130 lbs)	2.2	First	1.97
High (320 lbs)	1.6	Second	1.84
Storage Temp.**	% Reducing Sugar	Tuber Portion**	% Reducing Sugar
42 F	3.3	Apical	0.9
45 F	1.5	Basal	2.9
48 F	0.9		
Fertility Rate × Harvest Date**			
	Fertility Rate	Harvest Date	
	130 lbs	First	Second
	300 lbs	2.3	2.1
		1.6	1.5

** Significantly different at 1% level.

TABLE 3. — *Results of analysis of variance on the influence of fertility rates, harvest dates and storage temperatures on the amount of sucrose in Russet Burbank potatoes stored 7 months (Average 3 years' data).*

Treatment	Percent Sucrose
Tuber Portion**	
Apical	0.9
Basal	0.7
Storage Temperature (N.S.)	
42 F	0.8
45 F	0.8
48 F	0.7
Harvest Date (N.S.)	
First	0.8
Second	0.7
Fertility Rate (N.S.)	
130 lbs	0.8
320 lbs	0.7

** Significantly different at 1% level.

accumulated less sugars than tubers of the first harvest date; whereas, no significant differences were obtained between harvest dates of tubers of the high fertilizer plots.

The interaction of fertility rate × tuber portion on reducing sugar accumulation was highly significant as is shown in Fig. 1. A significantly greater difference in sugars between the apical and basal portions was obtained from tubers of the low fertilizer treatment as compared to the high fertilizer treatment. A similar significant interaction was obtained between fertility rate and storage temperature (Fig. 2). The difference in reducing sugar accumulation between high and low fertility rates was much greater at 42 F storage temperature than at 48 F.

Sucrose content in the tubers (Table 3) was not significantly influenced by the treatments imposed under the conditions of this study. However,

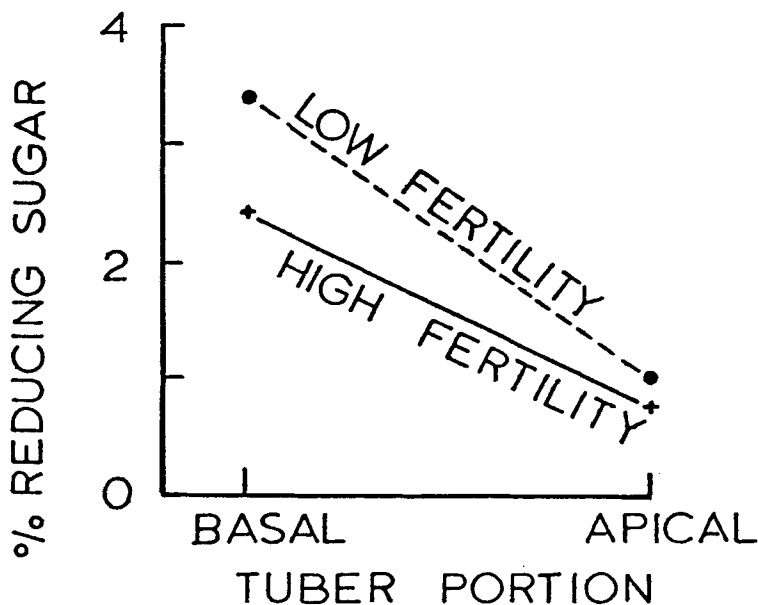


FIG. 1. Significant interaction effect of fertility level on reducing sugar accumulation in the apical and basal portions of Russet Burbank potatoes. Average of 3 storage temperatures and 3 years.

the apical portion had significantly higher sucrose content than the basal portion.

Discussion

Studies on the influence of fertility level on reducing sugar accumulation in potatoes have been concerned primarily with high or excessive fertility levels. The present studies have investigated the influence of lower than optimum fertilizer rates on sugar accumulation in stored Russet Burbank potatoes. The results indicate significantly higher reducing sugar accumulation in storage of tubers from the lower fertility level (Table 2). Why this is so is a matter of speculation at this time. Findlen (5) observed that the longer vines were killed before harvest the poorer the chip color. The authors (10) have previously pointed out that tubers exposed to high (70 F) (21.1 C) curing temperatures for two weeks and then lowered to 42 F accumulated more sugars than tubers held at a two-week curing temperature of 48 F. A similar type of response could occur in tubers from plants grown under a low fertility regime. Inadequate fertility with premature dying of plants could result in a stress condition in the tubers. The stressed tubers react in storage by producing greater amounts of reducing sugars (8).

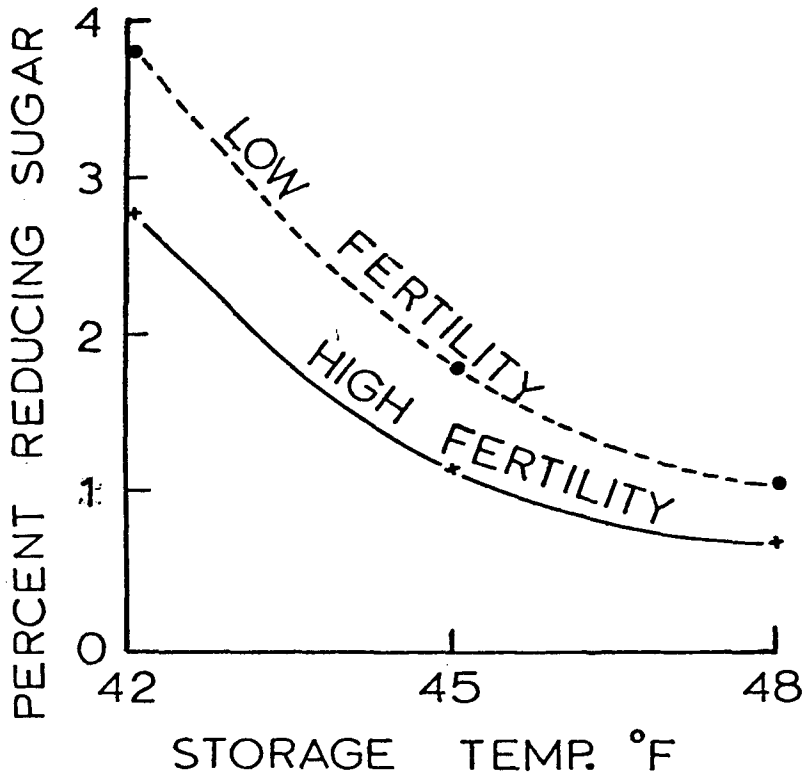


FIG. 2. Significant interaction effect of fertility level and reducing sugar accumulation at 3 storage temperatures. Average of apical and basal portion over 3 storage seasons.

Ohad, et al. (15) and also Isherwood (7) have suggested that stress conditions such as low temperatures cause damage to the amyloplast surrounding the starch granules allowing degradative enzymes to attack the starch, converting it to sugars. It is possible that premature death of a plant and exposure to high temperatures in the soil can also initiate membrane disintegration. Not only greater total sugars were observed, but also a greater differential in amount of sugars between the apical and basal portions was obtained from the low fertility potatoes (Fig. 1) This is of concern to processors of French fries who would like a low or even distribution of reducing sugars in the two ends. This type of a sugar-end potato is different from that due to moisture or high temperature stress previously described by the authors (8).

Other studies (9) have also indicated that relative maturity (early vs late harvest) or storage temperatures (42 F, 45 F, and 48 F) had no influence

in affecting the relative amounts of reducing sugars between the apical and basal portions. However, there were considerable differences among growing seasons. The present results would indicate that tubers from vines which died prematurely because of low fertility should not be stored for use in processing French fries because of high and differential sugar accumulation in the apical and basal portions.

The highly significant interaction of fertility rate \times harvest date is difficult to explain. One would expect greater differences in sugars between the first and second harvest dates of the high fertility plots than from tubers from the low fertility plots. Apparently, the tubers from the high fertility plots were more mature than had been anticipated, particularly at the time of the first harvest date. The similarity between the first and second harvests of the high fertility plots are reflected somewhat by sucrose content which on the average was similar in content on the first and second harvest dates (Table 3).

The highly significant interaction between fertility rate and storage temperature in reducing sugar accumulation during storage indicates that as storage temperatures were reduced, the differences in amount of reducing sugars increased between high and low fertility treatments.

These results suggest the importance of adequate fertility, not only to prevent susceptibility to blackspot bruise as suggested by Kunkel (12), but also to minimize total amount and differential reducing sugar accumulation in the apical and basal portions of Russet Burbank potatoes.

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