SOME POST-HARVEST PHYSIOLOGICAL STUDIES OF POTATOES AND RELATION OF SOME POTATO CULTIVARS TO INCIDENCE OF INTERNAL BROWN SPOT

by

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INTRODUCTION

The potato (Solanum tuberosum) belongs to the family Solanaceae. It is by far the most important of the vegetables in term of quantities produced and consumed.

Stored potatoes basically undergo three different phases or periods which influence their physiology (Toko and Johnston,1962). These periods can be classified as 1) the curing period which begins when potatoes are placed in storage for limited time when storage atmosphere is maintained at levels which are conductive to wound healing, 2) the resting and holding period which is the remainder of the time that potatoes are dormant, 3) the sprouting period is when dormancy has been broken and sprout growth progresses.

Potatoes from storage are the greater part of the potatoes used in the processing industry. Their suitability depends not only upon their quality at harvest but upon their response to storage conditions (Burton and Wilson,1978). These factors must be a compromise between the varying claims of avoiding low-temperature sweetening, rotting, water loss and sprout growth.

The purpose of potato storage is to maintain tubers in edible and salable condition and enable the grower to move the potatoes onto the market and processing plant in a more orderly manner. Good storage should prevent excessive loss of moisture, development of rots and excessive sprout growth. It should also prevent large accumulation of sugars and other constituents which result in dark-colored processed products (Talburt and Smith,1959). If the potato losses weight it will shrink; and when this loss reaches 10% of the original weight, the potato becomes wrinkled and spongy, difficult to peel, and virtually unsalable (Burton,1963).

When new cultivars are released, the post-harvest and storage characteristics often are still unknown. Some characteristics are weight loss and sprouting which influence the acceptability of a cultivar to producers and consumers. The degree of total loss that a cultivar undergoes should be one of the factors determined in considering its total processing potential (Samotus et al,1973).

Limited research has been done on some new cultivars (such as Crystal and Denali which were released in 1980 and 1978 respectively) to determine their storage characteristics in comparison with older cultivars. Most storage studies conducted on potatoes have been in the northern states, where the soil and air temperatures as well as day length are decreasing prior to harvest. This study was from potatoes grown under higher temperatures as the season progressed. Also the tubers were developing under long day conditions. Previous storage studies using these cultivars grown under hot climate's conditions have not been reported. For these reasons, the present study was conducted to meet the following objectives:

1. To evaluate four potato cultivars during storage for weight loss, sprouting, and specific gravity.
2. To study the effect of harvest date on weight loss, sprouting, and specific gravity.
3. To study the effect of different storage temperatures on weight loss, sprouting, and specific gravity.
4. To study the relationship between the calcium content in potato tubers and the incidence of internal brown spot.

LITERATURE REVIEW

Weight Loss

There are many factors which influence weight loss of the potato in storage: stage of maturity of potato at time of harvest, injury during harvesting and storing, storage temperature and humidity during a short time after harvest, temperature, humidity and amount of ventilation during storage, and length of storage (Talburt and Smith,1959).

Temperature is an important consideration in potato storage design. It can cause an increase in the respiration rate, tuber vapor pressure and enhance sprouting conditions later during the storage life of the potatoes (Butchbaker et al,1973). There are two temperature portions for storage period which influence weight loss of potato during storage. The first portion is for curing or suberization and the second is for holding period in storage. Smith (1933) reported that tubers stored 8 to 12 days at 17.2 to 20^{o}C lost considerably less weight in subsequent storage than those stored for the same length of time at a temperature of 3.9^{o}C to 6.7^{o}C. Similar results were found by Singh and Mathur (1938). They indicated that potatoes stored for 10-12 days at 18^{o}C lost considerably less weight during storage than those pre-stored at 7^{o}C previous to permanent storage. Schippers (1971a) found that final weight losses of potatoes during storage were not greatly influenced by the temperature under which the potatoes were kept for a limited period immediately after harvest if it was not lower than 7.5^{o}C.

Tubers stored continuously at 7.2°C lost significantly less weight than those stored at 5.6 or 8.9°C (Iritani et al, 1977). This attributed to lack of suberization and delayed maturation of tubers at 5.6°C resulting in increased weight loss and to higher respiration at 8.9°C in comparison to tubers held at 7.2°C storage. The same result was found by Sparks (1965) when he showed that storage at 7.2°C resulted in less weight loss than storage at 3.3 or 11.1°C. On the other hand, Murphy (1945) noticed that 2.2°C favored a minimum loss and 10°C was superior to 0°C. The higher weight loss at 0°C was probably due to the severe internal mahogany browning which affected most of the tubers at that temperature.

Harvesting date had no significant influence on weight loss in storage of tubers which were grown under a low fertilizer regime (vine died prematurely). However under a higher fertilizer regime, tubers harvested 21-45 days after vine kill lost significantly less weight than those harvested 2-13 days after vine kill (Iritani et al, 1977). Immature tubers lost more weight than mature tubers during the storage period of 1, 3, and 5 months (Smith, 1933). During 7 months of storage period, however, the physiological loss in weight was greater in the mature than in the immature lots. This increase in weight loss of the mature over the immature lots occured during the sixth and seventh months of storage. Smith observed that the mature tubers terminated their dormant period sooner than the immature tubers. on the other hand, Singh and Mathur (1938) reported that in the adolescent tubers the loss in weight during storage is high and decreases with increasing maturity of the tubers.

Another factor which has an influence on weight loss is relative humidity. Schippers (1971b) indicated that weight loss of potatoes was much more dependent on relative humidity than on temperature, working with temperatures of 5 to 10^{o}C and relative humidities of 80 to 100%. In further study Schippers (1971c) showed that weight losses of potatoes during storage were closely related to the product of average water vapor pressure deficit of the air between the tubers and the duration of storage in weeks. Shortly after harvest, water loss per cm^2 skin area per hour per mm Hg vapor pressure deficit was five to seven times as high as later in the storage period. Sparks (1973) concluded that maintaining at least 95% relative humidity in the ventilating air caused significantly less weight loss than ventilating with air of 85% relative humidity. In addition, intermittent ventilation allowed significantly less weight loss than continuous ventilation.

The weight of tubers will decrease as the sprout growth progresses primarily because both solids and water move from the tuber to serve as food for the new growth condition occuring in the sprouts (Toko and Johnston, 1962). That indicated loss in weight is accelerated in proportion to the rate of sprout growth. The rate of moisture evaporation from tubers is increased during sprout growth because the surface of the sprouts is much more permeable to water vapor than is the skin of the tuber.

Sprouting

When potatoes reach maturity they enter a dormant phase during which the buds or sprouts do not grow (Eddowes, 1978). The length of dormancy varies considerably and depends on factors such as cultivar, temperature, mechanical damage and tuber infections. Dormancy breaks more readily when potatoes are kept at temperatures above 5^{o}C. Bogucki and Nelson (1980) reported that dormancy was shortest in the warmest (20^{o}C) storage. Storage at 2^{o}C for six to nine weeks increased sprouting after dormancy ended compared with continuous 10 or 20°C storage.

Storage temperature is the most important environmental factor affecting sprouting behavior (Krijthe, 1962). High temperature storage produces physiologically old tubers with well developed sprouts while low temperature storage gives physiologically younger tubers with slight sprout development (Wurr, 1978). Sprout growth is very slow at temperature of 3.3 to 4.4°C even when potato tubers are out of their rest period (Sawyer, 1959). As the holding temperature is raised above 4.4°C, the rate of sprouting increases. Above 10°C the increase is more rapid than between 4.4 and 10°C. Also Heinze (1961) concluded that potatoes stored at 4.4°C will usually remain free of sprouts for 5 to 7 months after which sprout growth proceeds very slowly unless the tubers are transferred to higher temperatures.

Wurr (1975) found that a period of storage at 2-3°C followed by storage at higher temperature more suitable for sprouting, gave a more rapid and greater total sprout development than that produced by continuous storage in sprouting conditions. Seed tubers held at 1.7°C for 96 hours exhibited temporary sprout inhibition after transfer to 20°C (Herman and Schweers, 1965).

Smith (1933) showed that the mature tubers had longer sprouts and greater number of sprouts at the end of 7 months than those tubers harvested while immature. Starting from the day of harvest, the initiation of sprouting is hastened more and more with increase of the time during which the tubers are allowed to remain in the soil (Singh and Mathur, 1938). This indicated that the adolscent tubers begin to sprout 20-40 days later than the mature ones. Tubers of the cultivars Arran Banner and Alpha harvested immature sprouted earlier than tubers harvested mature (Huchinson, 1978a). This result was inconsistent to the result found by Toko and Johnston (1962) who showed that tubers which are mature at time of harvest sprout sooner than immature ones. In another study, Hutchinson (1978b) found that there was little difference in the beginning time of sprout growth with immature tubers sprouted at 15 or 20^{o}C, but with mature tubers there was an advantage in favor of the higher temperature.

The sprouting tendency varies particularly between cultivars but also between years and places of cultivation (Lindblom, 1970). Leach (1978) showed that 'Atlantic' was equal to 'Katahdin' and 'Kennebec' with regard to storability, except that at storage temperatures above 4.4^{o}C for six months, sprouting was excessive. Bornman and Hammes (1977) found that 'Vanderplank' had a very long dormant period (232 days at 3-4^{o}C) and showed little sprout growth at 180 days. 'Koos Smit' had a very short dormant period (92 days at 3-4^{o}C) and developed considerable sprout growth at the higher temperatures.

The relationship between specific gravity and sprouting was studied by Brown and Smith (1968) using 'Red Pontiac' potatoes that had been previously sprayed with Maleic Hydrazide. They showed that the tubers with a low specific gravity sprouted more than those with a higher specific gravity stored under the same conditions (10^{o}C). This may have been due to selective partial inhibition of sprouting in higher specific gravity tubers by Maleic Hydrazide. It may have been a response to specific gravity or some factor associated with specific gravity. Similar results were obtained by Silva and Andrew (1983), but they suggested that this relationship is not due to any selective partial inhibition of sprouting in higher specific gravity tubers by Maleic Hydrazide since no Maleic Hydrazide was used in their experiment.

Specific Gravity

Specific gravity is a common procedure in the potato industry to predict quality of potatoes for processing (Talburt and Smith, 1959). High specific gravity potatoes are preferred for potato chips, French fries and dehydration. On the other hand, potatoes of low specific gravity are preferred for canning because they slough or fall apart less during processing than potatoes of higher specific gravity (Smith, 1977). Tubers of high specific gravity (1.100) produced lighter colored chips than did the tubers of low specific gravity (Lyman and Mackey, 1961).

Specific gravity increased with maturity and significant differences were observed between harvest dates 3 weeks apart; the rate of increase in specific gravity was higher in medium-late than in early cultivars (Vakis, 1978). However Bokhari (1965) found that ten days harvest interval did not significantly influenced tuber specific gravity. In general lower specific gravity will result as date of harvest is delayed beyond the peak of physiological maturity (Murphy and Goven, 1959).

Specific gravity of potatoes increases with length of time in storage and indicates an increase in percentage of solids in the tubers (Terman et al, 1950). This is a result of greater loss of water by evaporation than loss of solids by respiration. Tubers that increased in specific gravity when stored, lost significantly more weight than those that decreased, fluctuated, or remained unchanged in specific gravity during storage (Joiner and Mackey, 1962). Although tuber specific gravity differ among cultivars, tuber specific gravity of all cultivars increased during storage (Kushman and Haynes, 1971).

Temperature and humidity of storage may have an effect on change in specific gravity of the tubers. Potatoes stored at 83-84% relative humidity increased in specific gravity at both 4.4 and 12.8°C storage (Heinze et al, 1952). At 90% relative humidity specific gravity of the tubers remained unchanged in storage up to six and one-half months at 4.4 and 10°C. Cunningham et al (1966) reported that at the end of one year of storage potatoes at 1.7°C showed little overall change in specific gravity, while those stored at 7.2°C tended to increase slightly. Tubers stored at 11.1°C gradually increased in specific gravity during six months of storage.

Internal Brown Spot

Internal Brown Spot is a physiological disorder which has been referred to as: internal browning, chocolate spot, internal necrosis, and internal rust spot (Ellison and Jacob,1952, Kamal and Marroush,1971). It has been found that Internal Brown Spot is considered to be a physiological disorder associated with drought or high temperature (Friedman,1955).

Internal Brown Spot is characterized by brown necrosis lesions of internal rust spots distributed through the tuber, associated with a low concentration of calcium in the affected tubers (Collier et al,1978). Withholding calcium from sand culture, when tubers were rapidly enlarging induced internal necrosis symptom (Kelley and Christiansen,1970). However, Henninger (1979) found that no treatment with calcium sources (0 to 1000 Ib/A) reduced the amount of tuber necrosis symptoms, but he didn't show the relationship between the calcium content in the tubers and the incidence of internal necrosis.

The growth of 'Red Lasoda' potatoes was monitored weekly to ascertain the relationship among location of planting, planting date, soil and air temperature, and fertilizer practices upon the onset and the incidence of internal tissue necrosis of the potato (Timm et al,1984). Supplemental soil and/or foliar application of plant nutrients and foliar applications of growth regulators have failed to correct the abnormality. They concluded that shifts in soil and air temperature are suspects that contribute to the marked change in plant growth accompanied by temporary insufficiency of calcium uptake by roots of plants to simultaneously support rapid foliar tissue growth and potato tuber initiation.

The incidence of Internal Brown Spot was markedly decreased with delay in planting (Shuja,1969 and Ahmadi et al,1960). The same result was found by Iritani et al (1984). They found that a significant decrease in the incidence of Internal Brown Spot occured as planting date was delayed from March to May 12. This indicated that early planting , generally results in large tubers which had a significantly higher incidence of Internal Brown Spot. Large size tubers may result not only from early tuber initiation but also from rapid growth.

The objectives of this study were to study the effect of cultivar, harvest date and storage temperature on weight loss, sprouting and specific gravity of potatoes during storage. Also to show the relationship between Ca content in potato tubers and the incidence of internal brown spot.

This study showed that Atlantic and Superior cultivars lost less weight during storage than did Denali and Crystal cultivars. Superior and Denali cultivars sprouted significantly more than Crystal and Atlantic. Potato cultivars were different in specific gravities at harvest time. Among cultivars, 'Atlantic' was the highest in specific gravity followed by Denali. Specific gravity of all cultivars increased during storage except Crystal which was unchanged in specific gravity during the length of the storage period.

Harvest date had a significant effect on weight loss during storage. Potato tubers harvested early showed lower percent of weight loss during storage than did those harvested later. Delay in harvest date resulted in significantly higher rate of sprouting during two months of storage. At harvest, there were no significant differences in specific gravity between tubers from the first and second harvest dates, but those from the third harvest date decreased in specific gravity. Tubers harvested early decreased in specific gravity during storage, while tubers from the second and third harvests increased in specific gravity during storage.

Low storage temperature (2-5^{o}C) resulted in a higher rate of weight loss than did higher storage temperatures during two and four months of storage. However, 15^{o}C storage temperature resulted in a higher rate of sprouting during storage, while low storage temperature caused inhibition of sprouting during the same length of storage. Tubers stored at 2-5 or 10^{o}C increased in specific gravity during storage, while tubers stored at 15^{o}C showed slight decrease in specific gravity after four months of storage.

It was concluded that Atlantic was the only cultivar which showed susceptibility to internal brown spot among potato cultivars tested. The result indicated that the correlation between low concentration of calcium in Atlantic potato tubers and the incidence of internal brown spot does not prove that low calcium content in the tubers is the major factor contributing to the incidence of internal brown spot. Probably there are other factors which act directly or indirectly to cause this physiological disorder. On the basis of these studies 'Atlantic' should not be grown here because of its susceptibility to internal brown spot.

MATERIALS AND METHODS

Experiment with four potato cultivars and three harvesting dates was conducted at Ashland Horticulture Farm, Manhattan, Kansas. Uniform seed pieces, approximately 50-60 gm in weight, of 'Superior', 'Atlantic', 'Denali', and 'Crystal' were planted on 6th of April, 1984. Seed pieces were planted 30.5 cm apart in rows 91 cm apart. Cultural practices for commercial potato production were followed. Nitrogen fertilizer (56 kg/ha) was applied on May 3. An additional 56 kg nitrogen per hectare was applied as a sidedressing on June 12.

Soil temperature was measured by thermometer at depth 10 and 15 cm during growing season (Fig. 1).

The treatments were harvested July 24, August 6 and August 17. The tubers were dug with a Champion Potato Digger. At harvest the treatments were stored in room temperature for a short period (6 days) to encourage suberization before being graded. They were then graded with a mechanical grader which eliminated tubers less than 5 cm in diameter.

This research consisted of harvest date, storage and internal brown spot studies.

Storage

After grading the potato tubers, three 5 kg samples from U.S. No. 1 tubers (5 cm in diameter or larger) from each cultivar X harvest date treatment were placed in boxes and stored in chambers at three storage temperatures (2-5, 10 and 15^{o}C) with relative humidities 94-98, 92-96, and 94-98% respectively. These samples were used for weight loss and sprouting

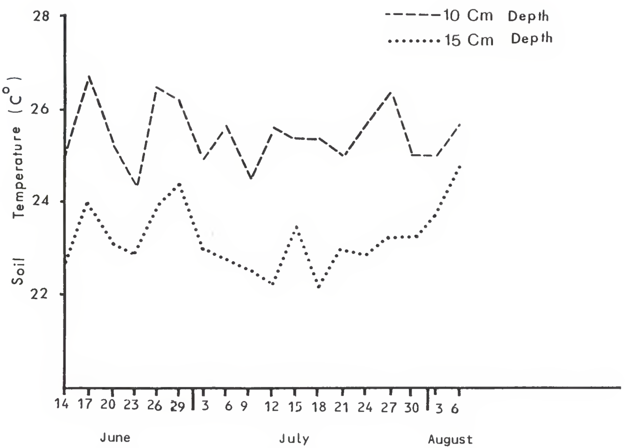

Fig.1. Mean soil temperatures at 10 and 15 cm depth, Summer, 1984.

determination. Also three 2.5 kg subsamples from U.S. No. 1 tubers from each treatment were placed in polyethylene bags and stored at same temperatures. These subsamples were used for specific gravity evaluation after harvest and during storage.

The specific gravity and the percentage of weight loss and sprouting (weight basis) of potato tubers were evaluated during storage after two and four months. The specific gravity was determined by weight in air and weight in water method. The equation used is:

$$\text{Specific Gravity} = \frac{\text{Weight of tubers in air}}{(\text{Weight in air}) - (\text{Weight in water})}$$

A split plot design with four replications was utilized in this study. Storage temperatures as whole plots and cultivar X harvest date treatments as subplots.

Internal Brown Spot

Potato cultivars from the first harvest date stored at 2-5^{o}C were evaluated for the incidence of internal brown spot. The incidence was determined directly after 4 months of storage in 4 replicates of each cultivar . The tubers were cut longitudinally and observed for browning. Any discoloration which could be identified as internal brown spot was counted and the percentage of the incidence was evaluated. The categories, no damage, slight, moderate, and severe were used to score the intensity of severity of internal brown spot development and to compute internal brown spot rating. Then the tubers of all these categories were sliced and dried in oven at temperature 65^{o}C for 3 days. The slices were ground in a Wiley Mill and sent to Agronomy

Department, Kansas State University, to determine calcium, potassium and magnesium contents in the tubers. These elements were determined by atomic absorption spectrophotometry after digesting 0.25 gm of each sample with nitric and percholic acids. Nutrient concentrations were determined after 4 months of storage since storage temperature had no significant influence on Ca, Mg or K contents of the tubers (Shekhar and Iritani, 1978).

RESULTS AND DISCUSSION

Storage Study

A. Weight Loss

Appendix Table I and II show the analysis of variance for weight loss during storage. There were significant differences among cultivars and harvest dates after two and four months of storage. There were no significant differences among the interaction treatments.

1. Effect of storage temperature on weight loss of potatoes

The mean weight loss (%) of potatoes stored at 2-5, 10 and 15^{o}C is given in Table 1. These data show that loss in weight occurred at a higher rate at 2-5^{o}C after two and four months of storage than at either 10 or 15^{o}C. There were no differences in mean weight loss of tubers stored at 10 and 15^{o}C. The greater weight loss at low storage temperature was in agreement with the results found by Iritani et al (1977) and Sparks (1965) who found that tubers stored at 7.2^{o}C lost significantly less weight than those stored at 5.6 or 3.3^{o}C. Iritani et al (1977) attributed that to lack of suberization and delayed maturation at low temperatures resulting in increased weight loss, however, Sparks (1965) attributed that to low concentration of respirable substrate at 7.2^{o}C which tended to reduce the amount of weight loss through respiration. Rastovski (1981) reported that at temperature below 3^{o}C respiration accelerates very rapidly in the potato tubers resulting in rapid weight loss. Also Workman and Towmey (1970) noted that intact tuber respiratory rates were higher at 0^{o}C than 5^{o}C. These observation were confirmed by our results.

Table 1. Means of weight loss (%) of potato tubers stored at three storage temperatures.

Storage Temperature (C^{o})	Weight loss (%)	
	2 months of storage	4 months of storage
2-5	6.24	9.17
10	4.49	8.35
15	4.47	8.39

2. <u>Effect of cultivar on weight loss during storage</u>

The data concerning the effect of cultivar on weight loss of potatoes during storage are presented in Table 2. Tubers of 'Atlantic' and 'Superior' lost significantly less weight after two and four months of storage than tubers of 'Denali' and 'Crystal' stored for the same length of time. There were no significant differences in weight loss between 'Denali' and 'Crystal' and between 'Superior' and 'Atlantic' after two and four months of storage.

In general Atlantic cultivar lost slightly less weight during storage because it has a russet skin and that lessen the loss of moisture from the tubers. Samotus et al (1973) indicated that susceptibility of potato tubers to total losses during storage is a feature of the cultivar and that different cultivars, under the same storage conditions, have a different inclination to lose weight.

3. <u>Effect of harvest date on weight loss during storage</u>

The relationship between harvest date and weight loss in storage is shown in Table 3. The results indicated that tubers from first harvest date lost less weight after two and four months of storage than did tubers from second and third harvest dates stored for the same length of time. Significantly greater weight loss occurred in the tubers from third harvest date after two months of storage, but after four months of storage the greater weight loss occurred in the tubers from second harvest date.

The results indicated that greater weight loss occurred when harvest date was delayed and that probably because tubers harvested late broke their dormancy and sprouted faster than those harvested earlier. This result was not consistent

Table 2. The effect of cultivar on weight loss (%) after two and four months of storage.

Cultivar	Weight loss (%)	
	2 months of storage	4 months of storage
Superior	4.74 b	8.21 b
Atlantic	4.67 b	7.96 b
Denali	5.69 a	9.26 a
Crystal	5.17 ab	9.11 a

Means within the same column having the same letter are not significantly different (LSD .05).

Table 3. The effect of harvest date on weight loss (%) after two and four months of storage.

Harvest Date	Weight loss (%)	
	2 months of storage	4 months of storage
1st	4.26 c	7.68 c
2nd	5.00 b	9.66 a
3rd	5.94 a	8.57 b

Means within the same column having the same letter are not significantly different (LSD .05).

with the result found by Smith (1933) who found that immature tubers lost more weight than mature tubers during the storage period of 1, 3 and 5 months. Toko and Johnston (1962) found that weight of tuber will decrease as the sprout growth progresses primarily because both solids and water move from the tuber to serve as food for the new growth condition occuring in the sprouts. This indicated loss in weight is accelerated in proporation to the rate of sprout growth.

B. Sprouting

Analysis of variance for potato sprouting during storage is presented in Appendix Table III and IV. There were highly significant differences among cultivars, harvest dates, and temperature X harvest date interactions after two and four months of storage. Also there were significant differences between temperature X cultivar, and temperature X cultivar X harvest date interactions after two months of storage, but there were no significant differences between them after four months of storage.

1. Effect of storage temperature on potato sprouting

The mean sprouting (%) of potatoes stored at three storage temperatures is given in Table 4. The data show that sprouting was absent in the tubers stored at low temperature (2-5^{o}C) after two and four months of storage. It is evident from the data that sprouting increased with increasing of storage temperature. The highest rate of sprouting after two and four months of storage was occurred in tubers stored at 15^{o}C.

The results indicated that sprouting was inhibited by low temperature storage and enhanced by higher temperature storage. These results were in agreement with those found by Heinze (1961) and Wurr (1978). Wurr (1978)

Table 4. Means of sprouting (%) of potato tubers stored at three storage temperatures.

Storage Temperature (C^{o})	Sprouting (%)	
	2 months of storage	4 months of storage
2-5	0.00	0.00
10	4.67	90.72
15	13.92	91.61

concluded that high temperature storage produces physiologically older tubers with well developed sprouts while low temperature storage gives physiologically younger tubers with slight sprout development.

2. Effect of cultivar on potato sprouting during storage

Data presented in Table 5 indicated the effect of cultivar on potato sprouting during two and four months of storage. It is seen from the table there were large differences between cultivars in the sprouting tendency during storage. Of the four cultivars studied, Atlantic and Crystal significantly showed the least sprouting during two months of storage with no significant differences between them. Superior significantly produced high rate of sprouting among cultivars after two months of storage followed by Denali. After four months of storage, there was little significant differences among cultivars. 'Superior' and 'Atlantic' showed slightly higher rate of sprouting than 'Denali' and 'Crystal'.

The variation in percentage of sprouting among cultivars is due to the length of dormancy which varies considerably and depends on cultivar (Eddowes, 1978). The result from Table 5 showed that Superior, which is an early maturing cultivar, broke its dormancy faster than other cultivars and produced the highest rate of sprouting. These observations agree with the reports of Wurr (1975) who noted that early cultivars usually break dormancy soon after harvest.

3. Effect of harvest date on potato sprouting during storage

Effects of harvest date on potato sprouting during storage are given in Table 6. After two months of storage, sprouting occurred at a significantly higher rate in the tubers from the third harvest date. Tubers from the earlier

Table 5. The effect of cultivar on sprouting (%) after two and four months of storage.

Cultivar	Sprouting (%)	
	2 months of storage	4 months of storage
Superior	15.69 a	61.15 ab
Atlantic	2.47 c	61.39 a
Denali	4.96 b	60.44 bc
Crystal	1.65 c	60.11 c

Means within the same column having the same letter are not significantly different (LSD .05).

Table 6. The effect of harvest date on sprouting (%) after two and four months of storage.

Harvest Date	Sprouting (%)	
	2 months of storage	4 months of storage
1st	0.20 c	61.22 a
2nd	2.64 b	60.14 b
3rd	15.75 a	60.97 a

Means within the same column having the same letter are not significantly different (LSD .05).

harvest date had the least rate of sprouting followed by tubers from second harvest date. After four months of storage, there were no significant differences in sprouting between tubers from first and third harvest dates. A slight decrease in rate of sprouting occurred in the tubers from second harvest date.

Increase in rate of sprouting in the tubers from the latest harvest date because the initiation of sprouting was hastened more with increase of the time during which the tubers are allowed to remain in the soil (Singh and Mathur, 1938). The relationship between harvest date and percentage of sprouting agree, in general, with the findings of Toko and Johnston (1962) who showed that tubers which are mature at time of harvest sprout sooner than immature ones.

4. Effect of storage temperature X cultivar interaction on potato sprouting after two months of storage

Sprouting (%) of potato tubers as influenced by the interaction between cultivar and storage temperature is shown in Table 7. There were no significant differences in sprouting among cultivars stored at low temperature (2-5^{o}C), but there were significant differences among cultivars stored at 10 or 15^{o}C. The data showed that 'Superior' had the highest rate of sprouting among cultivars stored at 10 or 15^{o}C, followed by 'Denali'. The lowest rate of sprouting observed in the tubers from 'Crystal' and 'Atlantic' stored at 10 or 15^{o}C with no significant differences between them. As we mentioned earlier, 'Superior' broke its dormancy faster than the other cultivars at either 10 or 15^{o}C, so it had higher rate of sprouting than the others.

Table 7. Effect of cultivar X storage temperature interaction on sprouting (%) after two months of storage.

Cultivar	Storage Temperature		
	2-5°C	10°C	15°C
Superior	0	13.67 a	33.42 a
Atlantic	0	1.04 bc	6.38 c
Denali	0	3.96 b	10.92 b
Crystal	0	0.00 c	4.96 c

Means within the same column having the same letter are not significantly different (LSD .05).

5. Effect of storage temperature X harvest date interaction on potato sprouting during storage

The data on effect of storage temperature X harvest date interaction on sprouting are given in Table 8. These data indicated that sprouting after two and four months of storage was absent in the tubers from all three harvest dates stored at low temperature (2-5°C) while at higher temperatures, sprouting was prevalent. Tubers from later harvest date stored at 10 or 15°C after two months of storage had greater rate of sprouting than those from first and second harvest dates stored at the same temperatures. Tubers from first and second harvest dates stored at 10°C showed no significant differences between them after two months of storage but at 15°C tubers from second harvest date produced significantly higher rate of sprouting than those from the first harvest date stored at the same temperature. After four months of storage, tubers from second harvest stored at 10°C had slightly lower rate of sprouting than those from first and third harvests. While at higher temperatures, tubers from second and third harvests had slightly the lowest rate of sprouting with no significant differences between them.

This study indicated that tubers harvested late and stored at either 10 or 15°C for two months produced significantly the highest rate of sprouting. These results confirmed previous works of Singh and Mathur (1938) and Toko and Johnston (1962).

6. Effect of storage temperature X cultivar X harvest date interaction on potato sprouting after two months of storage

The data presented in Table 9 shows that no visible sprouting occurred in the tubers from all interaction treatments stored at 2-5°C, but at higher

Table 8. The effect of storage temperature X harvest date interaction on sprouting (%) during storage.

Harvest Date	Storage Temperature					
	$2-5^{o}$ C		10^{o} C		15^{o} C	
	2 months of storage	4 months of storage	2 months of storage	4 months of storage	2 months of storage	4 months of storage
1st	0	0	0.22 b	90.78 b	0.38 c	92.88 a
2nd	0	0	0.59 b	89.52 c	7.31 b	90.89 b
3rd	0	0	13.19 a	91.84 ab	34.06 a	91.06 b

Means within the same column having the same letter are not significantly different (LSD .05).

Table 9. The effect of storage temperature X cultivar X harvest date interaction on sprouting (%) after two months of storage.

Harvest Date	Cultivar	Storage Temperature		
		2-5°C	10°C	15°C
1st	Superior	0	0.00 c	1.50 e
	Atlantic	0	0.88 c	0.00 e
	Denali	0	0.00 c	0.00 e
	Crystal	0	0.00 c	0.00 e
2nd	Superior	0	1.88 c	22.63 bc
	Atlantic	0	0.00 c	0.63 e
	Denali	0	0.50 c	4.75 e
	Crystal	0	0.00 c	1.25 e
3rd	Superior	0	39.13 a	76.13 a
	Atlantic	0	2.25 c	18.50 cd
	Denali	0	11.38 b	28.00 b
	Crystal	0	0.00 c	13.63 d

Means within the same column having the same letter are not significantly different (LSD .05).

temperatures there were significant differences among them. The results indicated that 'Superior' harvested late gave the highest rate of sprouting at 10 or 15°C. 'Denali' was second to show high rate of sprouting when harvested late and stored at the same temperatures. These variation in rate of sprouting depend on cultivar and maturity of the tubers at harvest.

C. Specific Gravity

A. Specific gravity of potatoes after harvest

Analysis of variance for potato specific gravity is given in Appendix Table V. There were highly significant differences among cultivars, harvest dates, and the cultivar X harvest date interaction.

1. Effect of cultivar on potato specific gravity

Table 10 shows the effect of potato cultivar on specific gravity after harvest. It is seen from the table that significant differences existed within cultivars with the order of high specific gravity among cultivars being Atlantic, Denali, then Crystal and Superior. These differences in specific gravities depend on cultivars and climatic conditions under which the potatoes are grown.

2. Effect of harvest date on potato specific gravity

The data concerning the effect of harvest date on specific gravity of potato tubers are presented in Table 11. Tubers from first and second harvest dates showed the highest specific gravity with no significant differences between them, while tubers harvested late showed the lowest specific gravity. This decrease in specific gravity with delay in harvest date was due to high temperature during the growing season. This result was incompatible with the

Table 10. The effect of cultivar on specific gravity of potato tubers.

Cultivar	Specific Gravity
Superior	1.072 c
Atlantic	1.092 a
Denali	1.086 b
Crystal	1.073 c

Means within the same column having the same letter are not significantly different (LSD .05).

Table 11. Specific gravity of potato tubers as influenced by harvest date.

Harvest Date	Specific Gravity
1st	1.082 a
2nd	1.082 a
3rd	1.079 b

Means within the same column having the same letter are not significantly different (LSD .o5).

result observed by Bokhari (1965) who found that ten days harvest intervals did not significantly influenced tuber specific gravity. In general lower specific gravity will result as date of harvest is delayed beyond the peak of physiological maturity (Murphy and Goven, 1959).

3. Effect of cultivar X harvest date interaction on potato specific gravity

Fig. 2 shows the effect of cultivar X harvest date interaction on specific gravity of potato tubers. The result indicated that among cultivars, Atlantic from all harvest dates produced the highest specific gravity followed by Denali. Harvest date had no significant effect on specific gravity in tubers of 'Atlantic', 'Denali', or 'Crystal', but it had a significant effect on specific gravity in 'Superior' tubers. Tubers of 'Superior' harvested earlier had higher specific gravity than those harvested late.

The decrease in specific gravity when 'Superior' tubers were harvested late was that 'Superior' is an early maturing cultivar and probably reached its physiological maturity at the early harvest date and produced high specific gravity. After that the cultivar decreased in specific gravity probably due to respiration and there were no significant differences between the second and third harvest dates.

B. Specific gravity of potatoes during storage

Analysis of variance for specific gravity of potato tubers during storage is presented in Appendix Table VI. Highly significant differences occurred among storage periods, temperature X storage period, cultivar X storage period, and harvest date X storage period interactions.

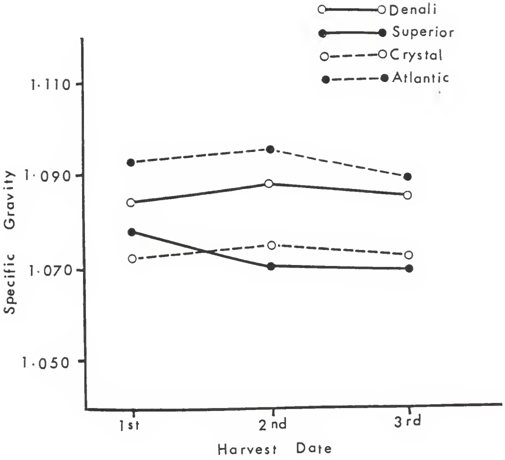

Fig.2. Effect of cultivar X harvest date interaction on specific gravity of potato tubers after harvest.

1. Effect of length of storage on potato specific gravity

The relationship between length of storage and specific gravity is shown in Table 12. The data showed that there was no significant change in specific gravity after two months of storage from that after harvest. However, there was a slight decrease in specific gravity after four months of storage.This decrease in specific gravity after four months of storage was probably due to high rate of sprouting which caused loss of solids through respiration.

2. Effect of storage temperature X length of storage on potato specific gravity

Table 13 shows significant differences in specific gravity between storage temperature X length of storage interactions. During storage, there was a significant increase in specific gravity at 2-5 or 10^{o}C with no significant differences between two and four months of storage at either temperature. At higher temperature (15^{o}C) there was no significant increase in specific gravity after two months of storage while after four months of storage there was slightly significant decrease in specific gravity, but not significantly different from that after harvest. This increase in specific gravity during storage at 2-5 or 10^{o}C was in agreement with that found by Terman et al (1950) who showed that specific gravity of potatoes increased with length of time in storage and indicates an increase in percentage of solids in the tubers. The slight decrease in specific gravity after four months of storage from that after two months of storage at 15^{o}C was probably due to high rate of sprouting which caused more loss of solids through respiration at this high temperature.

Table 12. Specific gravity of potato tubers as influenced by length of storage.

Length of Storage (month)	Specific Gravity
0	1.082 a
2	1.082 a
4	1.081 b

Means within the same column having the same letter are not significantly different (LSD .05).

Table 13. Specific gravity of potato tubers as influenced by storage temperature and length of storage.

Length of storage (month)	Storage Temperature		
	2-5^{o}C	10^{o}C	15^{o}C
0	1.081 b	1.081 b	1.081 ab
2	1.083 a	1.082 a	1.082 a
4	1.083 a	1.082 a	1.080 b

Means within the same column having the same letter are not significantly different (LSD .05).

3. Effect of cultivar X length of storage on potato specific gravity

Data in Table 14 show the specific gravity of potatoes as influenced by cultivar X length of storage interactions. It is seen from the table that 'Crystal' was the only cultivar that showed no change in specific gravity during storage, however, Superior and Atlantic cultivars showed significant increases in specific gravity during storage. On the other hand, 'Denali' increased in specific gravity after two months of storage, then significantly decreased after four months of storage, but in specific gravity was still significantly higher than from non-stored tubers.

These results indicated that specific gravity of all cultivars increased during storage except that of Crystal which remained unchanged. These results were consistent with fingings by Kushman and Haynes (1971). Joiner and Mackey (1962) indicated that tubers tended to vary in specific gravity from month to month.

4. Effect of harvest date X length of storage on potato specific gravity

The data in Table 15 showed that significant decrease in specific gravity during storage in tubers harvested early with no significant differences between two and four months of storage. However, tubers from the second or third harvest date showed increase in specific gravity during storage. This increase in specific gravity was due to greater loss of water by evaporation than loss of solids by respiration (Terman et al, 1950). The decline in specific gravity after two months of storage in the tubers from first harvest was consistent with the result observed by Murphy and Goven (1959) who reported that specific gravity of potato tubers declined in storage until the dormancy ended, then

Table 14. Specific gravity of potato tubers as influenced by cultivar and length of storage.

Length of Storage (month)	Cultivar			
	Superior	Atlantic	Denali	Crystal
0	1.072 b	1.092 b	1.086 c	1.073 a
2	1.074 a	1.094 a	1.089 a	1.073 a
4	1.074 a	1.093 a	1.087 b	1.073 a

Means within the same column having the same letter are not significantly different (LSD .05).

Table 15. Specific gravity of potato tubers as influenced by harvest date and length of storage.

Length of Storage (month)	Harvest Date		
	1st	2nd	3rd
0	1.082 a	1.082 c	1.079 b
2	1.079 b	1.085 a	1.083 a
4	1.078 b	1.083 b	1.084 a

Means within the same column having the same letter are not significantly different (LSD .05).

increased slightly at a rate closely related to the amount of physiological shrinkage. Our results were consistent with these observations since tubers from first harvest broke their dormancy later than those from second or third harvest (Table 6).

Internal Brown Spot

Evaluation of four potato cultivars for the incidence of internal brown spot is presented in Table 16. The data indicates that 'Denali', 'Crystal' and 'Superior' were entirely free of internal brown spot. 'Atlantic' was the most susceptible cultivar to incidence of this physiological disorder. Wolcot and Ellis (1959) indicated that during hot weather vigorous plants are more susceptible to internal browning than plants which are approaching maturity. In our study, even though 'Crystal' and 'Denali' plants were in approximately the same stage of development as 'Atlantic' plants, the 'Crystal' and 'Denali' plants seemed to be more resistant to internal brown spot during hot weather conditions.

Nutrient analysis (Table 17) showed that only significant differences in calcium and magnesium concentrations existed among potato cultivars. Of the four cultivars studied, Atlantic and Denali significantly had the least concentration of calcium with no significant differences between them. On the other hand, 'Atlantic' accumulated less concentration of magnesium than the other potato cultivars.

The relationship between calcium or magnesium content and the incidence of internal brown spot in 'Atlantic' tubers is given in Fig. 3. There were no significant differences in calcium or magnesium content among the tubers which

Table 16. The incidence of Internal Brown Spot in potato cultivars.

Cultivar	Internal Brown Spot (%)
Atlantic	81.7
Superior	0
Denali	0
Crystal	0

Table 17. Nutrient concentrations (%) in four potato cultivars.

Cultivar	Ca	Mg	K
Superior	0.063 a	0.111 a	2.36 a
Denali	0.049 bc	0.096 b	2.77 a
Crystal	0.058 ab	0.116 a	2.79 a
Atlantic	0.043 c	0.082 c	2.46 a

Means within the same column having the same letter are not significantly different (LSD .05).

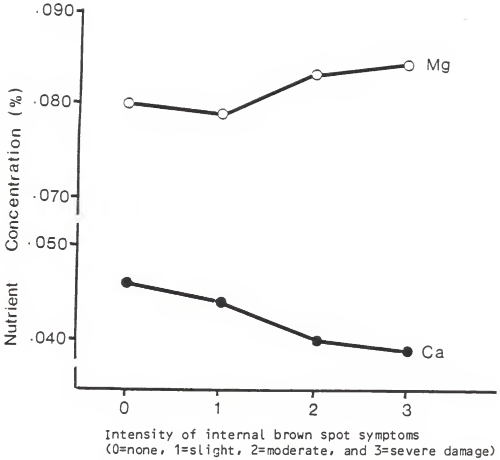

Fig. 3. The relationship between Ca and Mg contents in Atlantic potato tubers and the incidence of internal brown spot.

showed different intensities of internal brown spot symptoms, but the trend of calcium content in the tubers decreased with increase the intensity of damage. From the data presented here, together with previous references on the subject (Kelley and Christiansen, 1970 and Collier et al, 1978) it appears that a correlation between low concentration of calcium in the tubers and the incidence of internal brown spot occurs, but this correlation is not proved to indicate that low calcium content in the tubers is the major factor contributing to incidence of internal brown spot since there were no significant differences in calcium content among the tubers which showed different intensities of internal brown spot symptoms. However, a certain level of calcium in the tubers may be necessary to maintain membrane integrity and thereby enable the tubers to resist the disorder. Wolcot and Ellis (1959) stated that the primary mechanisms responsible for necrosis should be sought for in enzymatic or nutritional imbalances associated with shifts in metabolism of the plants. Fluctuations in moisture or temperature act indirectly by regulating the basic metabolism of the plant.

SUMMARY AND CONCLUSIONS

This study was designed to determine the effects of cultivar, harvest date and storage temperature on weight loss, sprouting and specific gravity during two and four months of storage. Also to show the relationship between calcium, magnesium and potassium content in potato cultivars and the incidence of internal brown spot.

1. Weight Loss

It was concluded that 2-5°C storage caused higher weight loss than did 10 or 15°C storage during two and four months of storage.

Potato cultivars were different in their susceptibilities to weight loss during storage. Atlantic and Superior cultivars lost less weight during storage than did Denali and Crystal cultivars stored under the same conditions.

Potato tubers harvested early showed a significantly lower percent of weight loss during storage than did those harvested later.

2. Sprouting

Low storage temperature (2-5°C) caused inhibition of sprouting during the length of the storage period, while high storage temperature (15°C) caused high rate of sprouting during storage.

Crystal and Atlantic cultivars significantly gave lower rate of sprouting during two months of storage than did Denali and Superior cultivars.

The rate of sprouting in potato tubers during two months of storage increased with delay in harvest date.

3. Specific Gravity

It was found that potato cultivars were different in specific gravities at harvest time. Atlantic cultivar was the highest in specific gravity followed by Denali cultivar.

There were no significant differences in specific gravity between tubers from first and second harvest dates, but those from third harvest date showed a decrease in specific gravity due to high temperature during growing season.

Harvest date had no significant effect on specific gravity in tubers of Atlantic, Denali or Crystal, but it had a significant effect on specific gravity in tubers of Superior cultivar.

It was indicated that specific gravity of all potato cultivars increased during storage except of Crystal which was unchanged in specific gravity during the length of the storage time.

Tubers harvested early showed decrease in specific gravity during storage, while tubers from the second and third harvests showed an increase in specific gravity during storage.

4. Internal Brown Spot

It was concluded that Atlantic was the only cultivar which showed susceptibility to internal brown spot among potato cultivars tested.

The results of this study indicated that the correlation between low concentration of calcium in Atlantic potato tubers and the incidence of internal brown spot does not prove that low calcium content in the tubers is the major factor contributing to the incidence of internal brown spot since there were no significant differences in calcium content among the tubers which showed different intensities of internal brown spot symptoms. Probably there are other factors which act directly or indirectly to cause this physiological disorder. On the basis of these studies 'Atlantic' should not be grown because of its susceptibility to internal brown spot.

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APPENDIX

Appendix Table I. Analysis of variance for weight loss (%) after two months of storage.

Source	DF	SS	F value
Temp	2	-	-
Cul	3	24.08	5.45**
HD	2	67.79	23.02**
Temp X Cul	6	5.73	0.65
Temp X HD	4	5.73	0.97
Temp X Cul X HD	12	22.08	1.25

** Indicates significant differences at the 5% level of probability.

Appendix Table II. Analysis of variance for weight loss (%) after four months of storage.

Source	DF	SS	F value
Temp	2	-	-
Cul	3	45.17	6.73**
HD	2	94.70	21.17**
Temp X Cul	6	27.76	2.07
Temp X HD	4	16.78	1.88
Temp X Cul X HD	12	41.29	1.54

** Indicates significant differences at the 5% level of probability.

Appendix Table III. Analysis of variance for sprouting (%) after two months of storage.

Source	DF	SS	F value
Temp	2	-	-
Cul	3	4545.35	64.90**
HD	2	6716.82	143.87**
Temp X Cul	6	3168.24	22.62**
Temp X HD	4	5152.36	55.18**
Temp X Cul X HD	12	2681.85	9.57**

** Indicates significant differences at the 5% level of probability.

Appendix Table IV. Analysis of variance for sprouting (%) after four months of storage.

Source	DF	SS	F value
Temp	2	-	-
Cul	3	38.51	4.46**
HD	2	30.89	5.37**
Temp X Cul	6	30.95	1.79
Temp X HD	4	51.21	4.45**
Temp X Cul X HD	12	47.54	1.38

** Indicates significant differences at the 5% level of probability.

Appendix Table V. Analysis of variance for specific gravity of potato tubers after harvest.

Source	DF	SS	F value
Cul	3	0.010339	156.29**
HD	2	0.000294	6.66**
Cul X HD	6	0.000553	4.18**

** Indicates significant differences at the 5% level of probability.

Appendix Table VI. Analysis of variance for specific gravity of potato tubers during storage.

Source	DF	SS	F value
Time	2	0.00019	12.85**
Temp X Time	4	0.00017	5.81**
Cul X Time	6	0.00011	2.59**
HD X Time	4	0.00118	40.23**
Temp X Cul X Time	12	0.00006	0.66
Temp X HD X Time	8	0.00007	1.20
Temp X Cul X HD X Time	24	0.00015	0.87

** Indicates significant differences at the 5% level of probability.

VITA

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SOME POST-HARVEST PHYSIOLOGICAL STUDIES OF POTATOES AND RELATION OF SOME POTATO CULTIVARS TO INCIDENCE OF INTERNAL BROWN SPOT

by

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AN ABSTRACT OF A MASTER'S THESIS

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1985

ABSTRACT

Four potato cultivars (Superior, Atlantic, Denali, and Crystal) were planted on 6th of April, 1984, at Ashland Horticulture Farm and harvested at three harvesting dates (July 24, August 6, and August 17). After harvesting and grading, U. S. No 1 tubers were placed in boxes and stored four months in chambers at three storage temperatures (2-5, 10, and 15^{o}C). The influence of cultivar, harvest date, and storage temperature on weight loss, sprouting, and specific gravity were determined after two and four months of storage.

This study showed that Atlantic and Superior cultivars lost less weight during storage than did Denali and Crystal cultivars. Superior and Denali cultivars sprouted significantly more than Crystal and Atlantic. Potato cultivars were different in specific gravities at harvest time. Among cultivars, 'Atlantic' was the highest in specific gravity followed by Denali. Specific gravity of all cultivars increased during storage except Crystal which was unchanged in specific gravity during the length of the storage period.

Harvest date had a significant effect on weight loss during storage. Potato tubers harvested early showed lower percent of weight loss during storage than did those harvested later. Delay in harvest date resulted in significantly higher rate of sprouting during two months of storage. At harvest, there were no significant differences in specific gravity between tubers from the first and second harvest dates, but those from the third harvest date decreased in specific gravity. Tubers harvested early decreased in specific gravity during storage, while tubers from the second and third harvests increased in specific gravity during storage.

Low storage temperature (2-5°C) resulted in a higher rate of weight loss than did higher storage temperatures during two and four months of storage. However, 15°C storage temperature resulted in a higher rate of sprouting during storage, while low storage temperature caused inhibition of sprouting during the same length of storage. Tubers stored at 2-5 or 10°C increased in specific gravity during storage, while tubers stored at 15°C showed slight decrease in specific gravity after four months of storage.

It was concluded that Atlantic was the only cultivar which showed susceptibility to internal brown spot among potato cultivars tested. The result indicated that the correlation between low concentration of calcium in Atlantic potato tubers and the incidence of internal brown spot does not prove that low calcium content in the tubers is the major factor contributing to the incidence of internal brown spot. Probably there are other factors which act directly or indirectly to cause this physiological disorder. On the basis of these studies 'Atlantic' should not be grown here because of its susceptibility to internal brown spot.