T H E S I S

CAUSES OF POST HARVEST DISCOLORATION OF POTATO CHIPS FROM SUMMER POTATOES

Submitted by

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WE HEREBY RECOMMEND THAT THE THESIS PREPARED UNDER OUR SUPERVISION BY MAX DEWAYNE CLEGG ENTITLED CAUSES OF POST HARVEST DISCOLORATION OF POTATO CHIPS FROM SUMMER POTATOES. BE ACCEPTED AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE.

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Permission to publish this report or any part of it must be obtained from the Dean of the Graduate School.

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Chapter I

INTRODUCTION

The production of early harvested summer potatoes is limited to the Gilcrest and Rockyford early potato producing areas of Colorado. Near Gilcrest soil types are sandy in texture, therefore, these soils warm up from two to three weeks earlier than surrounding heavy soils allowing early plantings. Using early maturing varieties a crop is ready for harvest in early July.

During the period from May until September the chip processor uses potatoes that have been newly harvested from this area or other areas. These potatoes have been erratic in performance, some lots producing light colored chips, others making a dark undesirable product. Since these months are a period of peak demand for potato chips, the problem becomes still more acute. Chip plants have been closed without a supply of potatoes from time to time during this period. Information on the causes of this after harvest darkening has been lacking.

Problem

What causes summer potatoes to chip dark in color within a few days following harvest?

Problem analysis.--This problem has been divided into the following parts:

1. The influence of storage temperatures.

2. The influence of severe injury to tubers.

3. The influence of the fertility level and application of nitrogen.

4. The influence of the harvest date.

Delimitations.—This investigation has been limited to (1) the early variety Irish Cobbler; (2) three storage compartments at the Colorado State University Horticulture farm maintained at 50°, 70° and 90°F; (3) a humidity of 85% or above; (4) potatoes harvested from two plots in the Gilcrest early potato producing area on six different dates.

Definition of terms.—Chip color - The degree of whiteness, "Rd" value, of potato chips as read with the Hunter-Gardner colorimeter. An "Rd" of 30.0 is the lower limit of acceptable color, as determined by periodic color measurements of five brands of commercial potato chips.

Reducing sugar - A sugar with a ketone or aldehyde group free to react.

Non-reducing sugar - A sugar with the reacting groups tied up with another sugar or compound. In potatoes, this is considered to be sucrose, for all pratical purposes.

Chapter II

REVIEW OF LITERATURE

Many factors must be considered in producing potatoes that will process into high quality, light colored chips. Practically everything the grower does in producing a crop of potatoes has some effect on the quality or yield of chips made from them (22).

Specific gravity

Specific gravity is a good index in selecting high quality chipping potatoes. Rogers et al. (19) stated that the weight of chips made from Russet Burbank, Warba, and Chippewa varieties increased with the percentage increase in dry matter of the slices. Kunkel et al. (15) separated the variety Russet Rural into two specific gravity groups with a brine solution. Potatoes from the high specific gravity group (mean value 1.0916) averaged 3.5% more salable chips than those from the low specific gravity group (mean value 1.0777).

Specific gravity varies with different varieties. Trials by Murphy et al. (18) showed that the specific gravity of twelve named varieties and sixteen seedling varieties ranged from 1.064 to 1.099. The specific gravity of each variety also differed at different locations. Heinze and Craft (10) observed that the specific gravity differed from year to year for lots of potatoes in the same general area.

Smith (27) reported that fertilizers affect specific gravity. High rates of nitrogen decreased the specific gravity, phosphorus caused an increase and potassium caused a decrease in specific gravity. Investigations by Murphy et al. (18) showed that rates of more than 150 lbs. of nitrogen applied to the variety Delus resulted in potatoes of a lower specific gravity than when rates of less than 150 lbs. of nitrogen were applied.

Irrigation during hot weather tended to keep the soil temperatures low and increased the specific gravity (26).

Chip color

Maintaining desirable chip color is probably the most important problem of the chipping industry. Many difficulties are encountered in controlling chip color, since the color is a result of the chemical composition of the potato tuber. Storage, variety, soil type, maturity, cultural practices and many other factors will affect the chemical balance of the tuber.

Reactants causing chip color.--Denny and Thornton (5) using model systems and varying the amount of reducing sugars, established a good color gradient. They attributed the dark color development to changes in the reducing sugars during heating. Later research established this discoloration to be a chemical reaction between reducing sugars and amino acids.

A review of the chemistry of the browning reaction by Hodge (12) showed that the reducing sugars and amines condense in an equal molar ratio. In aqueous solutions the sugars and amines undergo browning in proportion to the basic strength of the amines employed. Smith and Shallenberger (25) observed that the apparent order of reactivity of the amino acids changed significantly at different concentrations of amino acids. Also, the color of the pigment developed was qualitatively the same regardless of the amino acid used.

Smith (24, 26), using fifteen amino acids to determine their effects, found that glycine and lysine were the most active in color formation. Synthetic systems of known concentrations of reducing sugars plus amino acids were compared with actual potato chips having the same concentrations. The actual potato chips were darker in color, therefore, indicating that other substances were reacting to cause color development. To develop 70-80% of the total color intensity of potato chips, Shallenberger and Smith (20) found that total sugars, total nitrogen and ascorbic acid had to be used.

Color studies by Townsend and Hope (31) revealed that the initial presence of reducing sugars was not a requirement for the browning reaction provided sucrose was present and conditions favored hydrolysis. Shallenberger et al. (21) reported that both reducing sugars and sucrose will react and cause chip color, but sucrose will not react as readily as glucose. Correlations revealed that color is a function of both reducing sugars and sucrose. The "r" value of reducing sugars was 0.86 and of sucrose

0.39. The "r" value of a multiple correlation where the color was dependent on both reducing sugars and sucrose was 0.98.

Effect of storage.--Late-crop potatoes - Investigators have shown that sugars accumulate at low temperatures (4, 8, 13, 26, 30). Removal of cold storage potatoes to warm storage temperatures will cause a rapid disappearance of these sugars (8, 13, 23, 30).

According to Denny and Thornton (6) the date potatoes were put into storage had an effect on the amount of reducing sugars that accumulated. They found the critical low temperature for development of off-colored chips to be about 45°F - a safe temperature being 46.5°F.

Potato chips from potatoes stored at 32°F were lighter in color than chips from potatoes stored at 40°F. Prolonged storage of potatoes at 40°F produced increasingly darker chips, whereas prolonged storage of potatoes at 50° and 80°F produced increasingly lighter chips. In length of storage studies, potatoes stored at 40° and 50°F gave similar results but at 50°F reducing sugars were always lower. The reducing sugars increased rapidly the first two months with little change the next two, four, and six months. At 80°F there was little change in reducing sugars after one, two, and four months. Most potatoes with 0.2% or less reducing sugar (wet weight basis) content will produce acceptable chips. From 0.2% to 1.25% reducing sugar content there was a rapid increase in color. Once the content of reducing sugar reached 1.25% or above all chips are uniformly dark in color (24, 26).

Smith (23) stated that conditioning at 65°-75°F for ten days to three weeks will destroy reducing sugars and alter other chemical constituents. Conditioning at 85°F may result in an accumulation, rather than a disappearance, of reducing sugars. Habid and Brown (8) reported a disappearance of reducing sugars at 75°F. There was a reduction of the basic amino acids at this same temperature.

Miyamoto et al. (17) in ventilation studies on Russet Rurals being conditioned at 70°F showed that poor ventilation and high humidity caused a rapid decay and the potatoes to produce dark chips. Russet Rurals stored with a humidity of 100% and good ventilation did not chip or keep well. Addition of carbon dioxide (10% in air) was somewhat detrimental to good conditioning. Smith (23) stated that for storing chipping potatoes bins should be smaller than bins for table stock storage in order to keep the potatoes from being in an area of no air circulation.

Post-harvest chemical treatments with sulfur dioxide gas and sodium bisulfite on potatoes that had been stored under conditions which prevented accumulation of reducing sugars, accumulated reducing sugars very slowly when placed in 40°F storage. Potatoes which were stored under conditions that would accumulate reducing sugars and then treated chemically would not recondition (28).

Early-crop potatoes - Heinze's (11) investigations with early-crop potatoes showed that storage at 50-55°F for 7-10 days caused sugars to build-up and dark chips resulted. Potatoes exposed to low temperatures for 1-5 days (32-40°F) maintained acceptable chip color. After this exposure, when the potatoes were placed at 70°F the chips produced were dark and unacceptable. Continuous storage at 70°F was recommended for early-crop potatoes.

Kushman (16) found that potatoes shipped by rail, van, or truck from Alabama to Wisconsin maintained satisfactory chip color in all samples. There was a tendency for the chips to be darker after transit than at harvest and still darker after 70°F storage than after the transit period.

Effect of variety.--Comparitive studies of the performance of thirty-three potato varieties by Wright and Whiteman (35) indicated high variability among varieties in their ability to chip from storage and to chip after reconditioning. Results by Watada and Kunkel (32) on fifty-four varieties showed that some varieties accumulate large amounts of reducing sugars and can readily reconvert these sugars back to starch. Other varieties will accumulate lesser amounts of reducing sugars, but still will not recondition. This variability demonstrates the importance in selecting varieties for chipping.

Irrigated and dryland trials by Werner (33) revealed great differences of chip color between varieties. Variety trials by Murphy et al. (18) showed that some varieties were better adapted for chipping than others. Akeley et al. (2) reported that some varieties will chip good regardless of the planting date while others need a longer growing season. Smith (27) found that varieties are influenced differently in chipping at harvest, before low temperatures and when subjected to low temperatures.

Effect of maturity.--Maturity is important in potatoes to be stored since chip yield and quality are affected. Maturity can best be obtained by early planting, late harvesting, and killing vines fairly slowly (23).

Research by Appleman and Miller (1) showed that reducing sugars and sucrose decreased and starch increased up to a time when about 80% of the leaves were dead, but the potatoes were still immature as judged by the skin. Sucrose predominated at all stages of development, but the ratio of sucrose to reducing sugars was highest when tubers were making their most rapid growth. In storage the ripening process continues, so that by the end of the rest period immature potatoes have practically the same percentage composition as mature potatoes.

Barker (3) reported that the hexose content of freshly harvested potatoes was low. Upon storage an initial rise in the hexose content of these potatoes was observed. Hexose in potatoes from the first harvest in July rose to approximately 1.00% (wet weight) through the first 150 days then slowly began to decline. Hexose in August harvested potatoes rose to 0.40% then dropped. September and October harvested potatoes were never above 0.25%. The sucrose content of potatoes was high on the first harvest date. With each succeeding harvest the sucrose content decreased. In storage generally there was a decrease in sucrose.

According to Sweetman (30), after a preliminary period of cold storage, immature potatoes will respond to warmth more slowly during reconditioning than do more mature potatoes. Smith (26) showed that mature potatoes chipped lighter than immature potatoes at harvest. After four months in storage at 40° and 50°F, both mature and immature potatoes produced unacceptable chips, but the more mature potatoes were lighter in color. At 80°F both stages of maturity produced highly acceptable potato chips. A date of planting study by Akeley _et al._ (2) showed that chips from seven varieties were lighter in color from early plantings than from late plantings.

Effect of fertilization.--Eastwood and Watts (7) reported that the use of excessive amounts of nitrogen did not consistently improve chip color. Data were weak in support of a nitrogen and variety interaction. There was no interaction of nitrogen and potassium oxide, but a possible interaction of nitrogen level and potassium oxide source was observed.

Smith (27) reported that chips became darker as the rate of nitrogen was increased. Increased rates of phosphorous tended to darken the color of chips slightly. Potassium caused potatoes to produce lighter colored chips.

Effects of other factors.--Irrigation studies by Smith (26, 27) showed that unirrigated potatoes produced the lightest colored chips. Potatoes lightly irrigated chipped lighter in color than heavily irrigated potatoes.

Application of D.D.T. at different times will affect chip color. Smith (27) reported that the lightest colored chips produced were from potatoes in which the sprayings were omitted during the last two weeks of growing. In another study (26), potato vines sprayed with D.D.T. were not killed and the potatoes produced dark chips. When the vines were cut off, the potatoes produced lighter colored chips. Potatoes from vines killed by chemical sprays produced chips that were intermediate in color.

Injury

Hopkins noted that potatoes that had been wounded changed in sugar content in a short period of time. Further studies (14) revealed that following wounding there was a marked increase in sugar content. The sugar content rose to a maximum in the first three to six hours. Four days later another maximum peak was reached. Total sugar and reducing sugars paralleled each other throughout. Microscopic observation and chemical analysis suggested that this increase in sugar content was brought about by activities leading to callus formation.

Smith (29) reported that weight loss was less when injured potatoes were stored initially at 40°F and then moved to 70°F than when stored continuously at 70°F. In all cases injured potatoes lost more weight than uninjured.

Respiration

Respiration increased at successive higher temperatures above 40°F (13,24). Wright (34) reported that respiration was more rapid at 36°F than at 40° or 32°F. Hopkins (13) showed that respiration decreased to about 37.4°F, increased at 32°F and again declined as the temperature was lowered further. He suggested that the acceleration of respiration at 32°F was dependent on the changing sugar concentration and that to a certain point the sugar increased respiration and beyond that limit the sugar inhibited respiration.

Respiration was found to be higher in immature potatoes than mature potatoes (1). This higher respiration appeared to be due to the fact that the skins are more permeable to gases. Respiration at the end of the rest period of immature and mature potatoes was approximately the same.

Hopkins (14) showed that respiration increased with injury. A peak respiration rate was reached within a few hours and then the rate declined. He proposed that this increase in respiration rate apparently was caused by an increase in sugars, although there may be other influential factors.

Chapter III

METHODS AND MATERIALS

Storage compartments

Three 6' x 8' x 8' walk-in storage compartments at the Colorado State University Horticulture farm were maintained at 50°, 70° and 90°F. Each compartment was maintained at a constant temperature (± 2°) with a Minneapolis-Honeywell thermostat regulating a Copelametic air-cooled condensing unit for lowering the temperature and a Chromalox electric heater for raising the temperature. The cooled or warmed air was kept circulating by a continuously running fan under the refrigerator coils.

The humidity was maintained above 85% using a Walton humidifier controlled by a Barber-Coleman humidistat. Generally the humidity was more than 90%

A continuous record of humidity and temperature was kept using a Forboro recorder on each compartment. The recorder for the 90°F box was adjusted to read 70° because 80° was the upper limit of the chart.

Method of cooking potato slices

Approximately four pounds of tubers were sliced with a motor driven vegetable slicer. The slices were mixed and a sample of 200 grams was weighed, washed in cold water, and allowed to drain.

The slices were cooked in pure vegetable fat (Veo), in a thermostatically controlled two-tray deep fat fryer. A starting temperature of 375°F was used and cooking continued until bubbling ceased. New fat was added to maintain a constant level as the chips absorbed fat during cooking. Once each week or after seven heatings, the fat was changed.

Laboratory analysis and measurements

Chip color.—The chip color was determined by crushing the chips and pressing them into flat tin lids which were 2 1/2 inches in diameter and 3/8 inches deep. A Hunter-Gardner colorimeter, standardized with a yellow standard plaque (Rd = 61.7, a = -1.9, b = +23.3), was used to determine the Rd value. An Rd value below 30.0 was considered unacceptable. Figure 1 illustrates the approximate range of color that may be observed and indicates their Rd values.

Sugars.—The remaining potato slices from which the 200 gram chipping sample had been removed were chopped and a 25 gram sample weighed. Enough 95% ethyl alcohol was added to the chopped sample for a total volume of 150 ml. The sample was then blended with a Waring blendor.

Reducing sugars were determined on the supernatant from the extract. The Hassid ferricyanide method was employed for these determinations. However, the clarification of the extract in this method was omitted. These sugars were then expressed as percent on the wet weight basis.

Figure 1.--The range of chip color that may be observed and their corresponding Rd value.

Non-reducing sugar was determined by hydrolyzing 25 ml. of the supernatant from the alcohol extract with 10 ml. of 6 N sulfuric acid at approximately 70°F for 24 hours. Methyl red indicator was added and the acid was neutralized with 6 N sodium hydroxide to the yellow end point. The hydrolysate was made to a final volume of 100 ml. with distilled water and reducing sugars determined. Subtracting the reducing sugars determined before hydrolysis from the reducing sugars determined after hydrolysis, was taken to equal the non-reducing sugar. The non-reducing sugar is expressed as percent on a wet weight basis.

Respiration.--One thousand gram samples of tubers were placed in 4.4 liter jars in the various storage compartments. On the day of a determination, each jar was aerated with atmospheric air using an air pump. For these determinations the carbon dioxide in the atmosphere was assumed negligible. Lids were placed on each jar and carbon dioxide was determined after an eight hour period with an Orsat gas analyzer. The amount of carbon dioxide obtained was then converted to milligrams carbon dioxide per hour per kilogram tubers.

Field notes

General comments were recorded as to the status of the terminal growing point of the potato vines and cultural procedures followed by the cooperator. The terminal growing points were used as an index for estimating when vegetative growth had ceased. This was possible because as the plants reached vegetative maturity, the growing points would cease to differentiate new leaves and with elongation continued, the tight clusters of newly formed leaves would disappear. The resulting spread out of growing points is a good visible measure of maturity. The degree of senescence was also estimated. A range of 1-10 was established with 1 - all foliage green and 10 - all foliage dead.

Field plots

Potatoes for this investigation were grown in the Gilcrest early potato producing area. The sandy soils of this area warm quickly in the spring allowing an early summer potato crop to be grown.

One plot was located on the Carl Linden farm three miles west of Gilcrest. The soil was sandy loam in texture. Previous crops were potatoes, 1958 and peas and green beans, 1959. Previous fertilizer applications were as follows: 1957 - 200 lbs. calcium metaphosphate per acre, 50 lbs. muriate of potash per acre and 100 lbs. of ammonium nitrate per acre; 1958 - 150 lbs. of urea per acre; 1959 - 80 lbs. of urea per acre May 8, and 100 lbs. of urea August 1; 1960 - 80 lbs. of urea per acre June 1. Results of a soil test are shown in Table 1.

Table 1.--SOIL TESTS OF LINDEN AND LOVE FARMS, 1960.

Location	Depth in.	pH	% sol. salts	% org. matter	% lime	lbs/A 6 in. P_2O_5	lbs/A 6 in. K_2O
Linden farm	7	7.4	0.02	1.4	0.1	265	175
Love farm	7	7.6	0.02	1.3	0.1	181	308

Two plots were located on the Royal Love farm three miles north of Gilcrest. The soil was loamy sand in texture. Previous crops were corn, 1958 and barley and alfalfa, 1959. The alfalfa was plowed under for a green manure crop. No commercial fertilizers had been applied for a least two years. Results of a soil test are in Table 1.

Experiment I

This experiment was designed to determine the effects of fertility levels, storage temperatures and the date of harvest on chip color of summer potatoes.

Three one-tenth acre plots were planted with the early maturing variety Irish Cobbler. The rows were 38 inches apart with a 10 inch spacing. One plot (Linden farm) was planted April 14, and two plots (Love farm) were planted April 18, 1960. From previous cropping and fertilizer practices, the plot on the Linden farm was considered of high overall fertility (Treatment I). The two plots on the Love farm were of low fertility. One of these plots was maintained at this low fertility level (Treatment II). Nitrogen was applied to the other plot at the rate of 120 lbs. per acre at planting time for a high nitrogen fertility level (Treatment III). All cultural practices were carried out by the cooperators.

Duplicate 100 lb. samples were harvested, with a potato fork, from each plot July 7, 11, 18, 25, August 1, and 8. The tubers were placed into 100 lb. burlap sacks and transported to the Horticulture farm at Ft. Collins. Each 100 lb. sample was divided into three equal lots and placed into slatted wood crates. The crates of potatoes were placed into storage with a lot from each sample at 50°, 70° and 90°F. No special precaution was taken to prevent bruising or skinning.

The storage period was for three weeks. On the harvest date and at three day intervals thereafter, approximately 4 lb. duplicate samples were taken for chipping purposes and chemical analysis.

Experiment II

A third 100 lb. sample was harvested July 25 from the Linden farm to study the effects of injury. This sample was injured by dropping the 100 lb. burlap sack of potatoes from a height of approximately four feet, four times turning the bag to a different side each time. The tubers in this sample were badly bruised and skinned. This sample was then handled as in Experiment I with the regular samples in Experiment I as the check.

Experiment III

Sugar analyses for each harvest date showed that non-reducing sugar was much higher for the July 7, 11, 18 harvests than for the July 25, August 1 and 8 harvests while reducing sugars remained about the same for all the harvests. Therefore, a more detailed study was undertaken to determine the effects of the non-reducing sugar in storage, especially in comparison with the reducing sugar content.

For this study, non-reducing sugar was determined on the samples from the July 18 and August 1 harvests over the seven storage periods. Only samples from Treatment II were used since all three treatments showed the same trend for each harvest.

Chapter IV

PRESENTATION OF DATA

Field observations

Field notes obtained on each harvest date are presented in Table 2. This table includes an estimation of the degree of senescence and general comments as to the status of the terminal growing point of the potato vines along with the cultural procedures.

The degree of senescence indicates that differences in plot performance may not be due entirely to the fertility level. Other inseparable cultural factors such as irrigation and vine killing may be involved.

Results of Experiment I

Harvest date.—Chip color was not significantly different for the various dates, Table 3. The colors ranged from an Rd value of 30.2 - 33.3 which is above the acceptable limit. Reducing sugars ranged from 0.15 - 0.24% for the harvest dates but no general trend was apparent. The statistical evaluation, however, was highly significant.

The effect of after harvest storage on chip color and reducing sugar content is illustrated in Table 4. As maturity increased with the later harvests less build-up of reducing sugars occurred

Table 2.--SUMMARY OF FIELD NOTES ON EACH HARVEST DATE.

Harvest Date	Treatment[1]	Degree of Senescence[2]	Comments
July 7	I	1	Through blooming, leaf clusters tight at the growing points, vines a good green color.
	II	1	Through blooming, leaf clusters tight at the growing points, vines a good light green color.
	III	1	Through blooming, leaf clusters exceptionally tight, vines a dark green color.
July 11	I	1	Leaf clusters not as tight due to growing points lengthening out, vines a good green color.
	II	3	Leaf clusters not tight, due to growing point lengthening out, vines light green with some yellowing of lower leaves.
	III	2	Leaf clusters tight, vines light green with some yellowing of lower leaves.
July 18	I	1	Vines a light green color and are errect, last irrigation, been irrigating every three days.
	II	5	Vines beginning to fall, leaves yellowing, rest light green.
	III	3	Vines fairly errect, leaves yellowing, rest dark green.
July 25	I	7	Large percent of leaves dried up, some stems drying.
	II	6	Still irrigating, irrigates about once a week, leaves drying up, stems green.

Table 2.--(continued)

Harvest Date	Treatment[1]	Degree of Senescence[2]	Comments
July 25	III	4	Some leaves drying up, stems green.
August 1	I	—	Vines beaten off.
	II	9	Most of the leaves dried up, stems drying up.
	III	8	A large percent of the leaves dried up, stems green.
August 8	I	—	——
	II	10	Stems and leaves dried up.
	III	10	Stems and leaves dried up.

[1] I, high fertility; II, low fertility, no nitrogen; III, low fertility plus 120 lbs. nitrogen.

[2] 1-all foliage green, 10-all foliage dead.

Table 3.--COMPARISON OF THE MEANS OF CHIP COLOR AND REDUCING SUGAR CONTENT OF TUBERS AS AFFECTED BY THE DATE THE POTATOES WERE HARVESTED.

Harvest Date		Mean Values[1]	
		Chip Color Rd	Reducing Sugars %
July	7	32.5	0.24
	11	32.0	0.17
	18	33.3	0.16
	25	31.2	0.20
August	1	30.5	0.15
	8	30.2	0.17
L.S.D.	5%	N S	0.008
	1%	N S	0.011

[1] 12 observations, 2 reps. x 3 treat.

Table 4.--COMPARISON OF THE MEANS OF CHIP COLOR AND REDUCING SUGAR CONTENT OF TUBERS AS AFFECTED BY HARVEST DATE. MEAN INCLUDE DATA FROM EACH STORAGE PERIOD.

Harvest Date	Mean Values[1/] Chip Color Rd	Reducing Sugars %
July 7	22.9	0.47
11	24.2	0.40
18	26.8	0.34
25	27.2	0.29
August 1	27.9	0.24
8	27.3	0.26
L.S.D. 5%	0.8	0.026
1%	1.1	0.034

[1/]144 observations, 2 reps. x 3 temp. x 3 treat. x 8(7 storage periods + day of harvest).

in storage and chip color was higher. The mean Rd color for each harvest became lighter until the July 18 harvest, and then remained fairly constant at the high level for the later harvests. Statistically, the mean color difference between the July 7 and July 11 harvests was highly significant. Each was also significantly different at the 1% level from the late harvests. The mean reducing sugar content after storage generally decreased with each later harvest. All were significantly different at the 1% level through the July 25 harvest.

The respiration rate decreased with each succeeding harvest indicating the potatoes were becoming more mature, Figure 2. A good correlation was found between the respiration rate and chip color for each harvest, Figure 3. The correlation coefficient was -0.73, which was highly significant indicating that as the potatoes

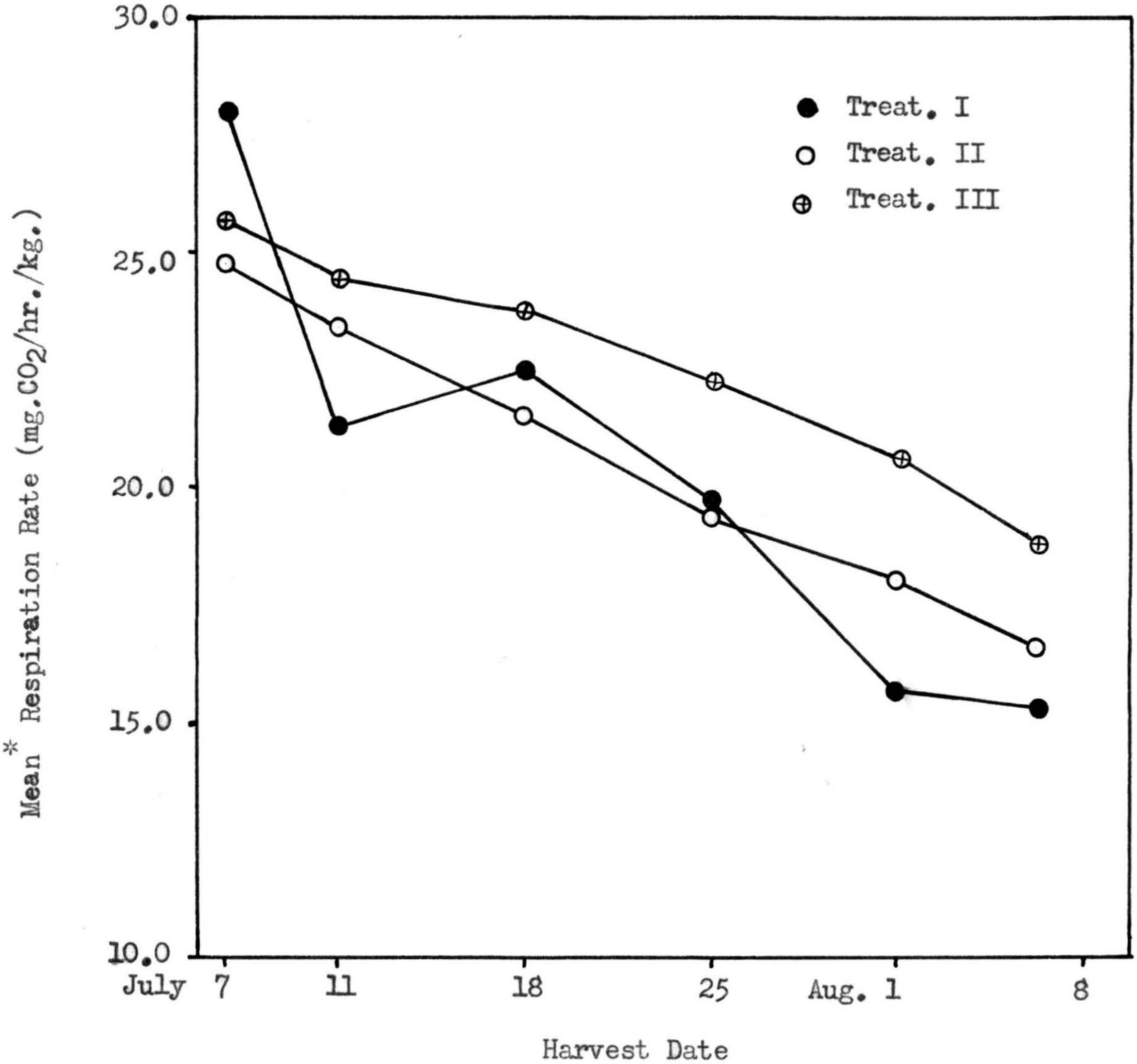

Figure 2.--The mean respiration rate of tubers of each treatment for each harvest.

*21 observations, 3 temp. x 7 storage periods.

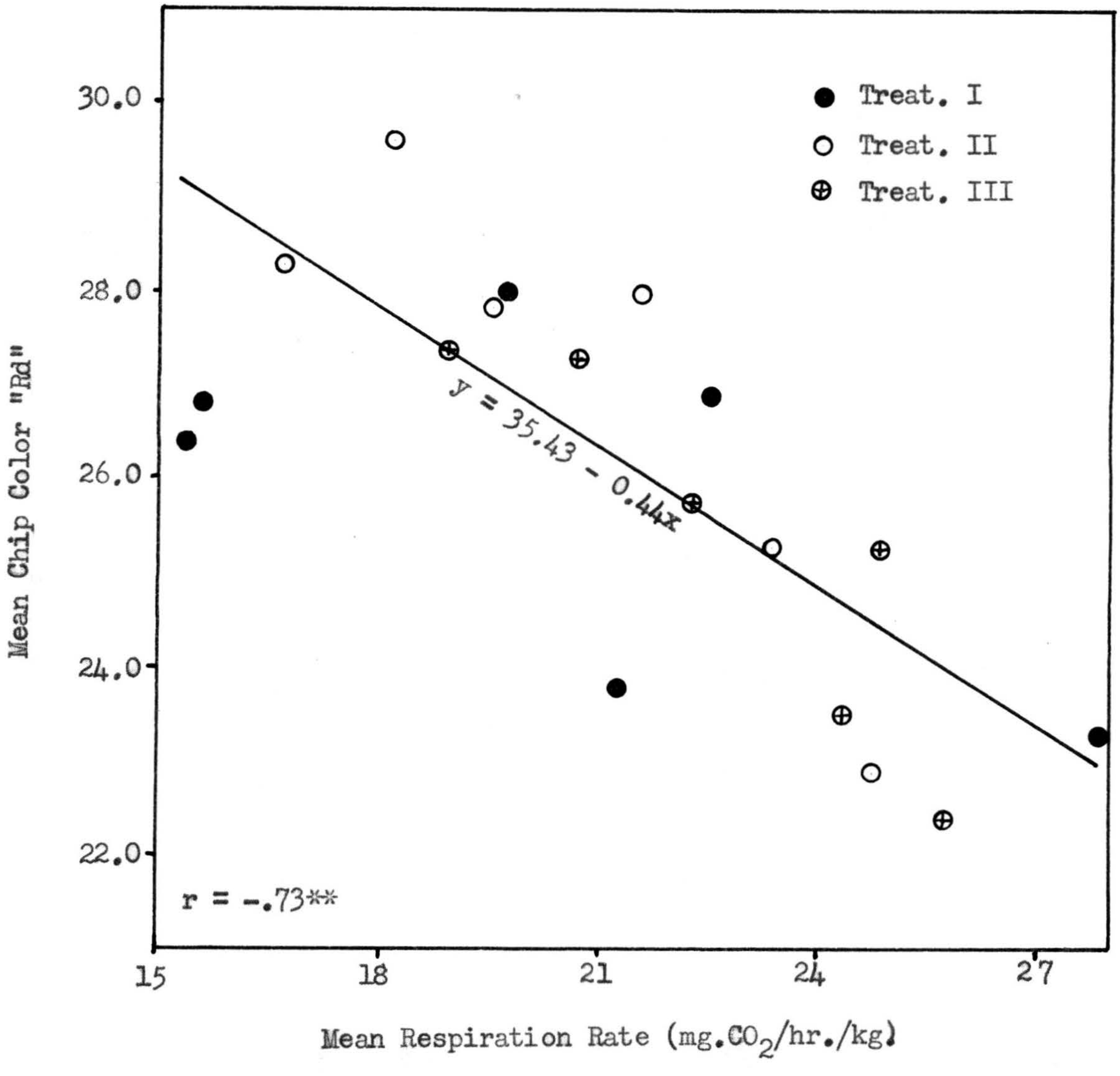

Figure 3.--Correlation of the mean respiration rate of tubers and mean chip color of each harvest.

became more mature their ability to chip out of storage increases.

Storage temperature.—Chip color from tubers stored at 50° was considerably darker than those stored at 70° and 90°F, Table 5. Each, however, was significantly different from the other at the 1% level, but the difference was visually less pronounced between 70° and 90°F storage. The interaction of harvests and storage temperatures was highly significant. Figure 4 illustrates this relationship. Generally, for each temperature, the mean chip color becomes increasingly higher with each successive harvest. Storing at 70°F gave the best chip color.

Table 5.—COMPARISON OF THE MEANS OF CHIP COLOR AND REDUCING SUGAR CONTENT OF TUBERS AS AFFECTED BY EACH TEMPERATURE.

Storage Temperature		Mean Values[1/]	
		Chip Color Rd	Reducing Sugars %
50°		21.2	0.51
70°		28.9	0.24
90°		28.0	0.25
L.S.D.	5%	0.6	0.018
	1%	0.8	0.024

[1/] 288 observations, 2 reps. x 3 treat. x 6 harvests x 8(7 storage periods + day of harvest).

The mean reducing sugar content is considerably higher at 50° than at 70° or 90°F, Table 5, and the interaction of harvests and storage temperature on reducing sugars was also highly significant.

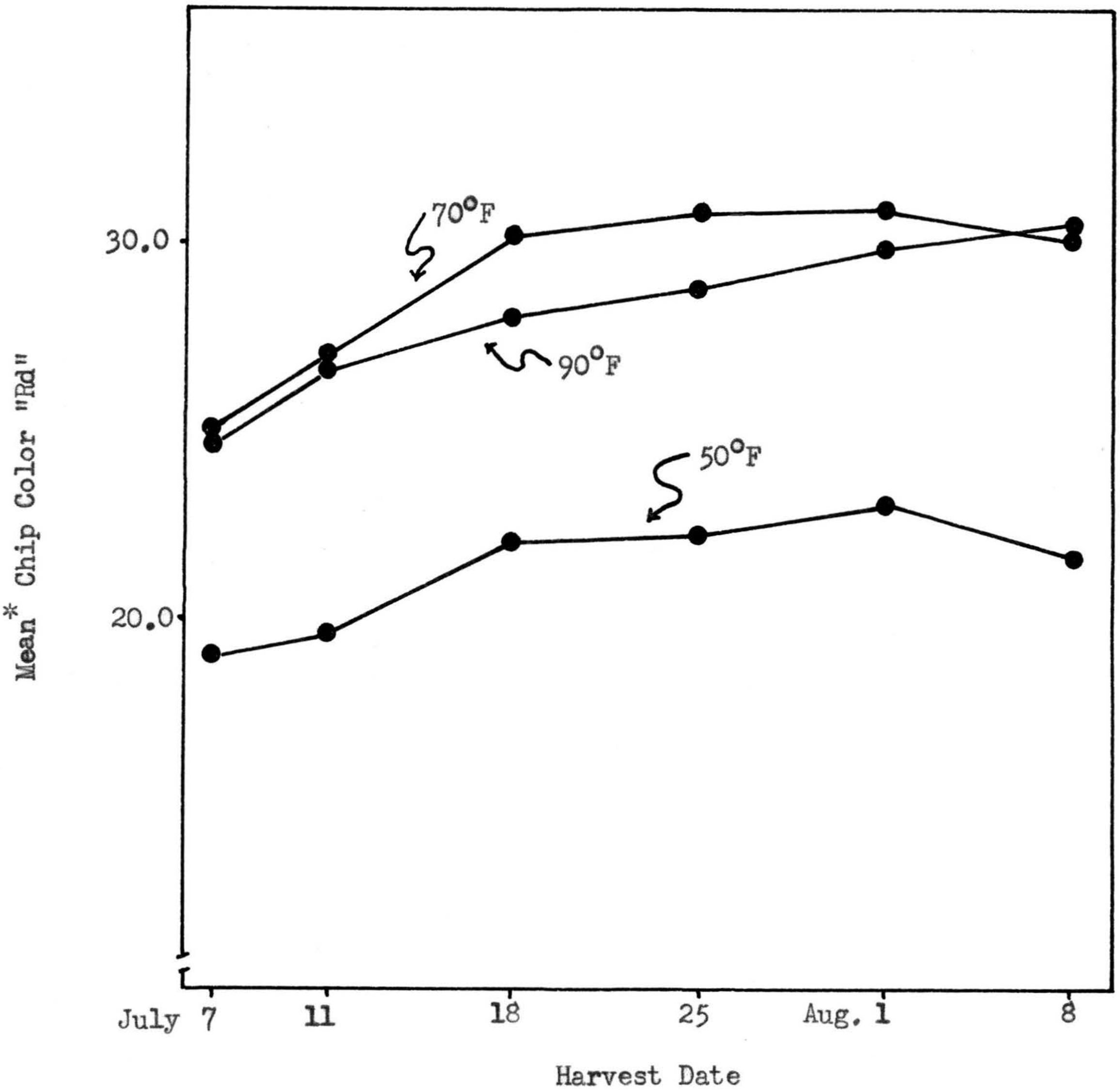

Figure 4.--Relationship of tuber storage temperature and each harvest date on "Rd" chip color.

*48 observations, 2 reps. x 3 treat. x 8(7 storage periods + day of harvest).

Storage period.—Generally, with each longer period of storage, chip color decreased and the reducing sugar content increased. This was particularly pronounced after 3, 6, 9 and 12 days in storage, Table 6.

Table 6.—COMPARISON OF THE MEANS OF CHIP COLOR AND REDUCING SUGAR CONTENT OF TUBERS AT THE END OF EACH STORAGE PERIOD.

Storage Days	Mean Values[1]	
	Chip Color Rd	Reducing Sugars %
0	31.6	0.18
3	29.5	0.23
6	27.3	0.28
9	26.1	0.35
12	24.3	0.38
15	24.7	0.39
18	22.7	0.43
21	22.2	0.41
L.S.D. 5%	1.5	0.030
1%	1.9	0.039

[1] 48 observations, 2 reps. x 3 treat. x 3 temp. x 6 harvests.

Treatment.—The treatment had no significant effect on chip color either on the day the potatoes were harvested or after being in storage, Tables 7 and 8. However, high fertility (I) caused darker colored chips and higher reducing sugar content of tubers than the other treatments. Low fertility (II) gave highest Rd readings and lowest reducing sugars. Similar trends were also apparent following storage of the tubers.

Table 7.—COMPARISON OF THE MEANS OF CHIP COLOR AND REDUCING SUGAR CONTENT OF TUBERS AS AFFECTED BY EACH TREATMENT ON THE DATE THE POTATOES WERE HARVESTED.

Treatment[1]		Mean Values[2] Chip Color Rd	Reducing Sugars %
I		30.4	0.21
II		32.7	0.16
III		31.7	0.18
L.S.D.	5%	N S	0.015
	1%	N S	0.016

[1] I, high fertility; II, low fertility, no nitrogen; III, low fertility plus 120 lbs. nitrogen.

[2] 12 observations, 2 reps. x 6 harvests.

Table 8.—COMPARISON OF THE MEANS OF CHIP COLOR AND REDUCING SUGAR CONTENT OF TUBERS AS AFFECTED BY EACH TREATMENT AFTER STORAGE.

Treatment[1]		Mean Values[2] Chip Color Rd	Reducing Sugars %
I		25.9	0.33
II		27.0	0.32
III		25.3	0.34
L.S.D.	5%	N S	N S
	1%	N S	N S

[1] I, high fertility; II, low fertility, no nitrogen; III, low fertility plus 120 lbs. nitrogen.

[2] 288 observations, 2 reps, x 3 temps. x 6 harvests x 8(7 storage periods + day of harvest).

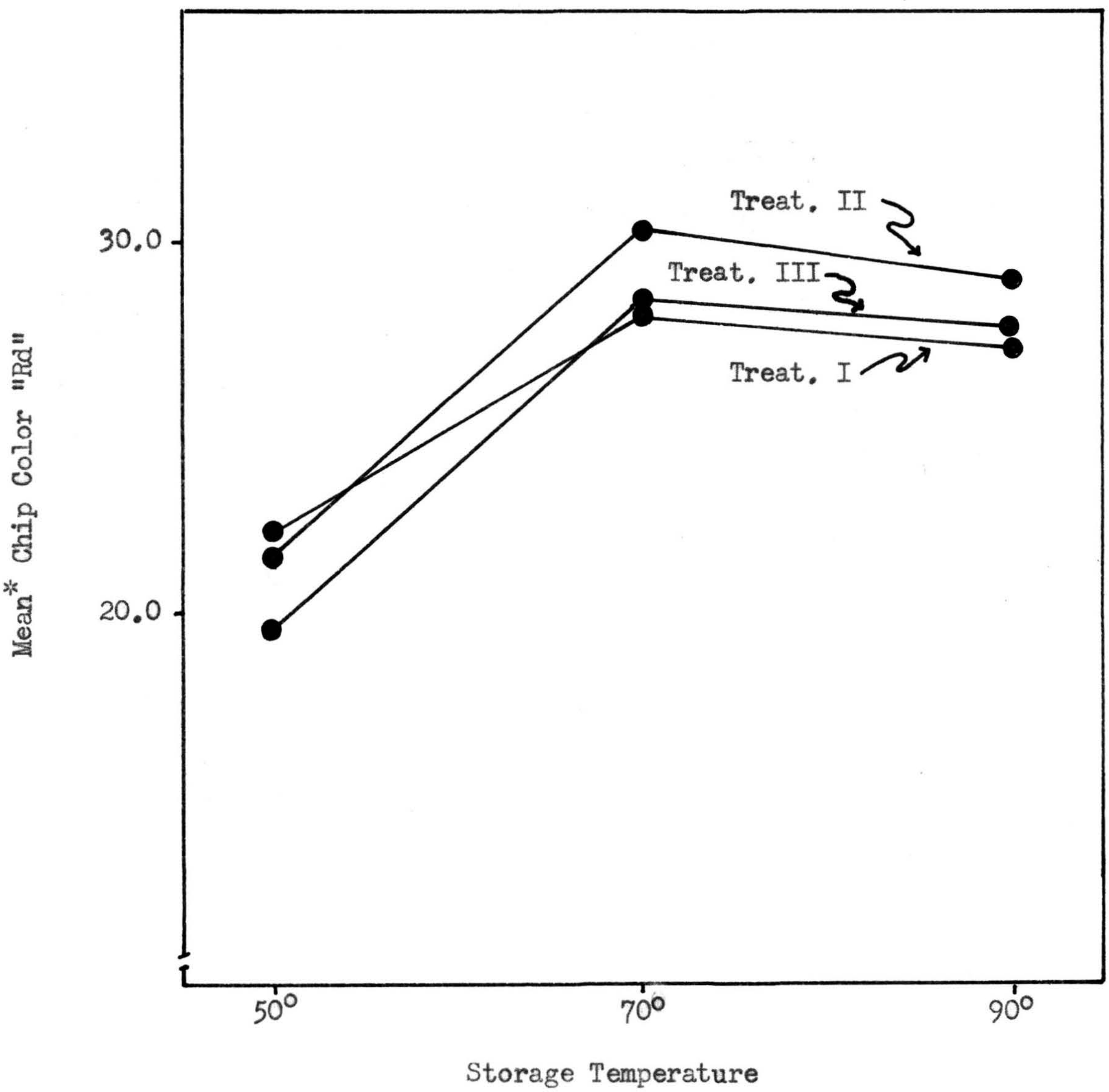

Figure 5.--Relationship of treatments and storage temperatures on "Rd" chip color.

*96 observations, 2 reps. x 6 harvests x 8(7 storage periods + day of harvest).

The interaction of treatments and temperatures for both chip color and reducing sugars was highly significant. Figure 5 illustrates this relationship for chip color. A ready explanation for this result has not been proposed.

Correlation of chip color and reducing sugars.--The comparable measurements of chip color and reducing sugars (864 observations) for this experiment were correlated. The correlation coefficient was found to be -0.83 which was highly significant.

Results of Experiment II

Tuber injury.--The chips made from potatoes which were severely injured were significantly darker in color than uninjured potatoes. They also accumulated higher amounts of reducing sugars than uninjured potatoes and this difference was highly significant. Respiration rates likewise were significantly higher for injured potatoes than for the check, Table 9.

Table 9.--COMPARISON OF THE MEANS OF CHIP COLOR, REDUCING SUGAR CONTENT AND RESPIRATION OF TUBERS AS AFFECTED BY TUBER INJURY. JULY 25, HARVEST.

Treatment		Mean Values[1/]		
		Chip Color	Reducing Sugars	Respiration Rate[2/]
		Rd	%	$mgCO_2$/hr./kg.
Check		27.8	0.27	19.7
Injury		25.6	0.33	23.0
L.S.D.	5%	1.6	0.04	0.8
	1%	---	0.05	1.1

[1/] 24 observations, 3 temp. x 8(7 storage periods + day of harvest).
[2/] 21 observations.

Low storage temperatures, of course, resulted in dark colored chips as reported in Experiment I and chips were darker in color following storage. But the general level of these effects was lowered by mechanical injury to the potatoes.

Results of Experiment III

Figure 6 illustrates the reducing and non-reducing sugar content of Treatment II on the dates of harvest as well as the means of Treatments I, II and III. The general trend is for the non-reducing sugar content to decrease with each harvest date through July 25, then remain about the same with a tendency to increase when the vines were dead.

Results of non-reducing sugar determinations of samples from Treatment II for the July 18 harvest (early harvest) and August 1 harvest (late harvest) stored at 50°, 70° and 90°F are shown in Figures 7, 8 and 9 respectively. Non-reducing sugar decreased and reducing sugars increased when stored at 50°F. The amount of reducing sugar build-up was much greater for the early harvest than for the late harvest. In all instances, the amount of reducing and non-reducing sugars were higher for the early harvest, Figure 7.

Non-reducing sugar decreased in storage at 70°F while the reducing sugars remained fairly constant. Generally the sugars for the early harvest were higher than for the later harvest, Figure 8.

The effect of 90°F storage was quite different. Non-reducing sugar showed a decrease then tended to increase. This was much greater for the early harvest than for the later harvest. Reducing sugars increased slightly with little difference between the early or late harvests, Figure 9.

A correlation of the non-reducing sugar on the date of harvest and mean chip color for each harvest was highly significant, Figure 10. This is essentially a correlation of maturity (higher the non-reducing sugar the more immature are the tubers) and chip color.

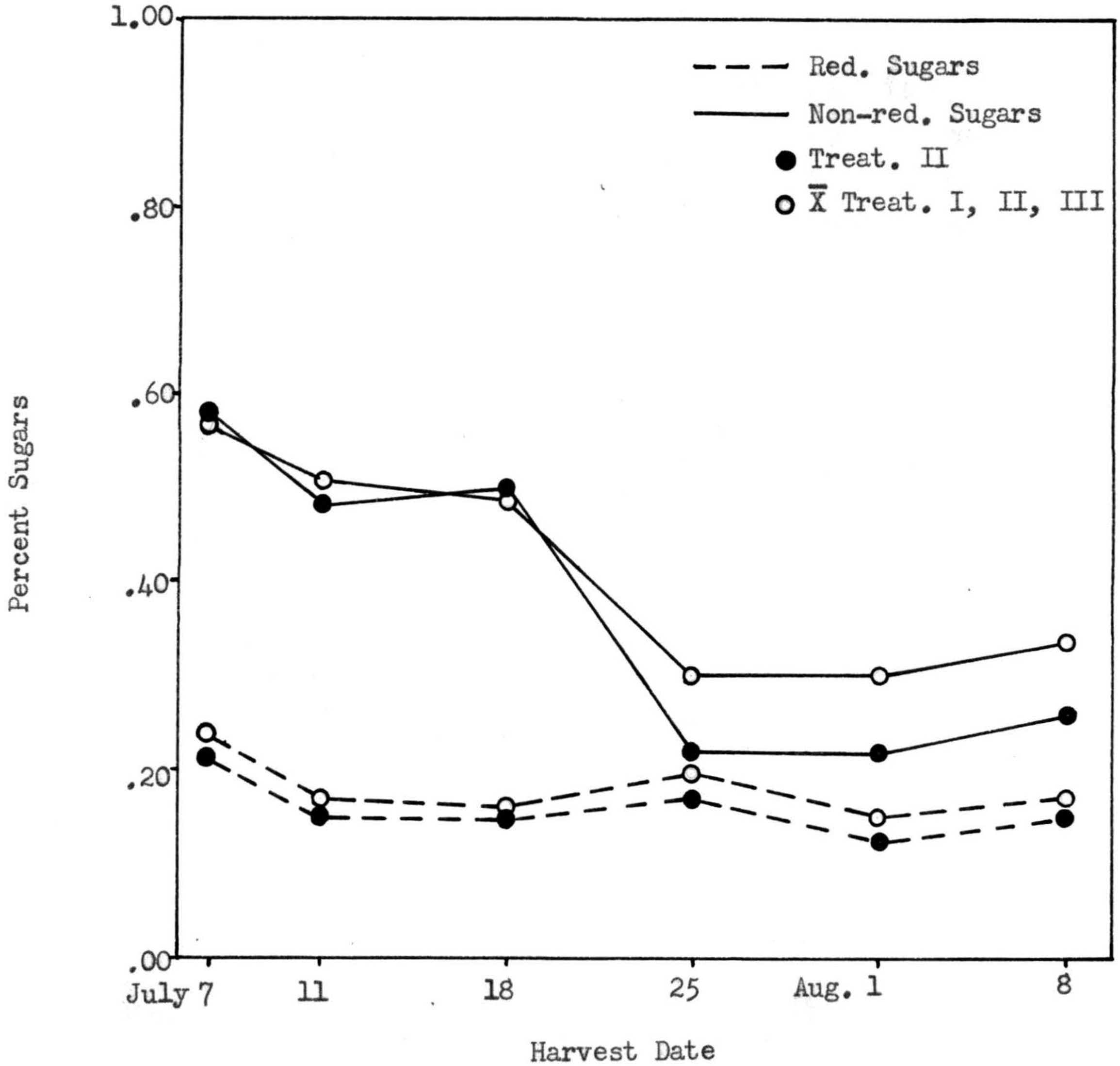

Figure 6.--Percent reducing and non-reducing sugar of potato tubers from Treatment II and the means of Treatment I, II and III on the date they were harvested.

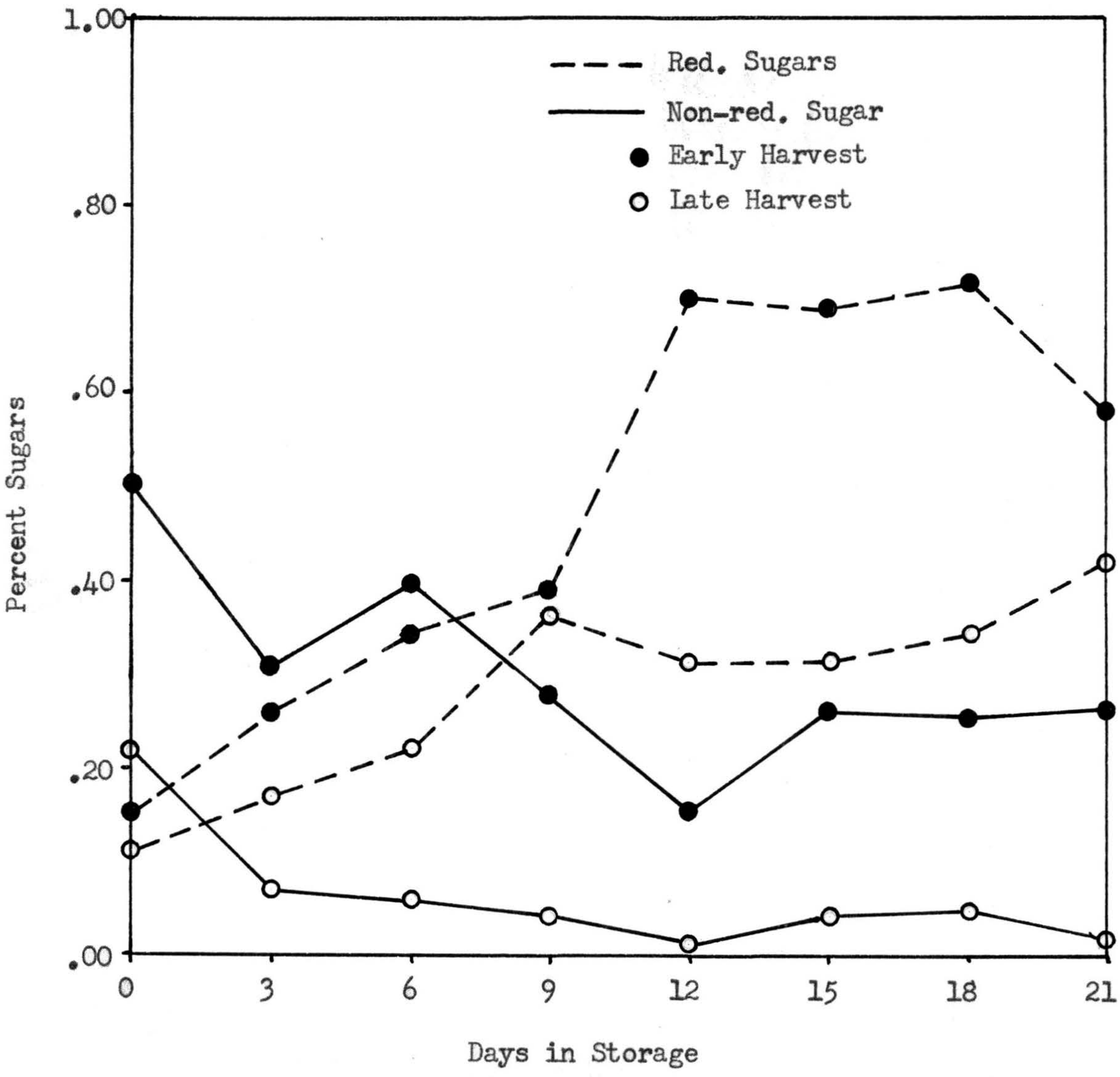

Figure 7.--The effect of 50°F storage on the reducing and non-reducing sugar content of potato tubers from an early and a late harvest.

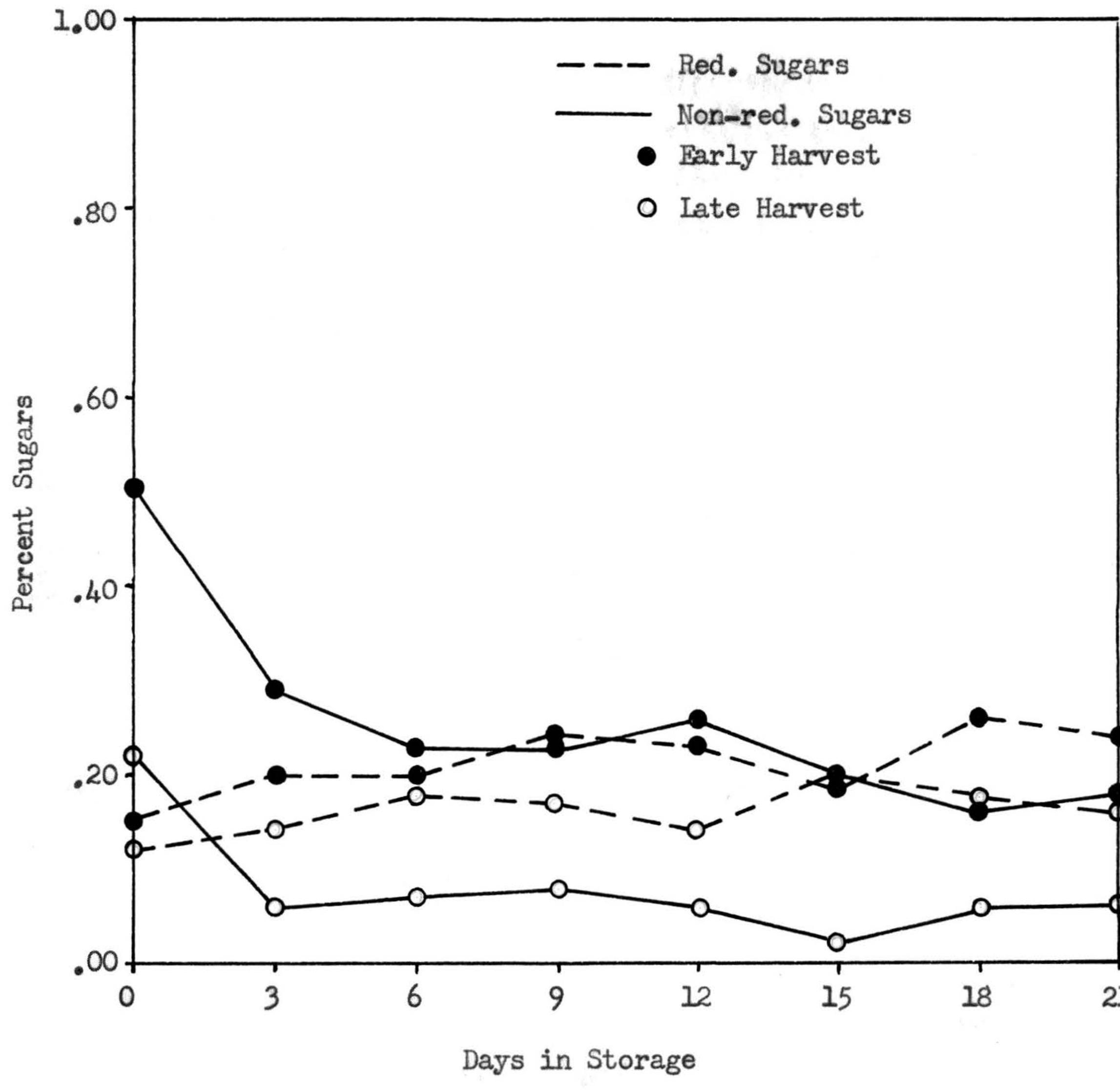

Figure 8.—The effect of 70°F storage on the reducing and non-reducing sugar content of potato tubers from an early and a late harvest.

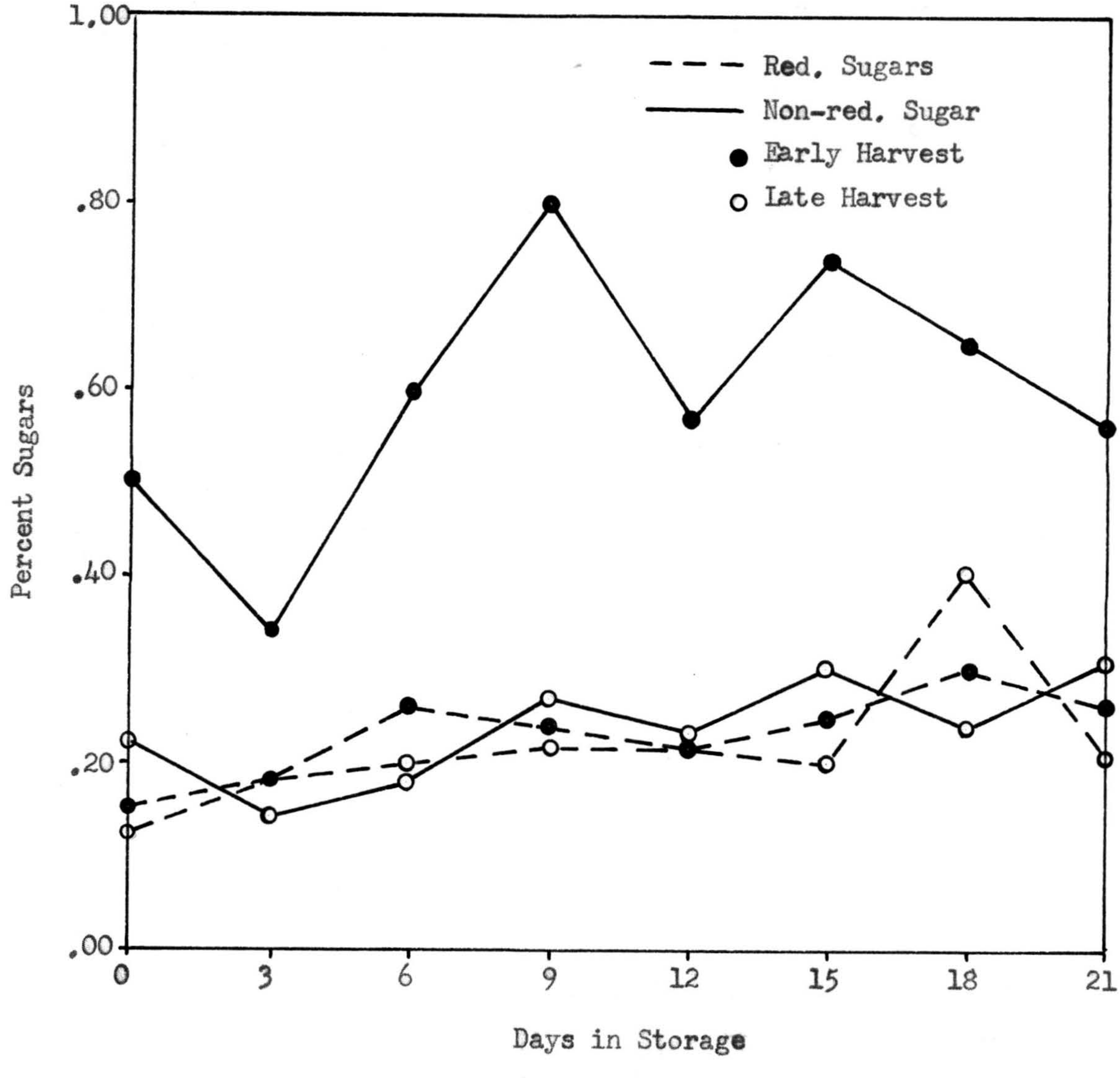

Figure 9.--The effect of 90° storage on the reducing and non-reducing sugar content of potato tubers from an early and a late harvest.

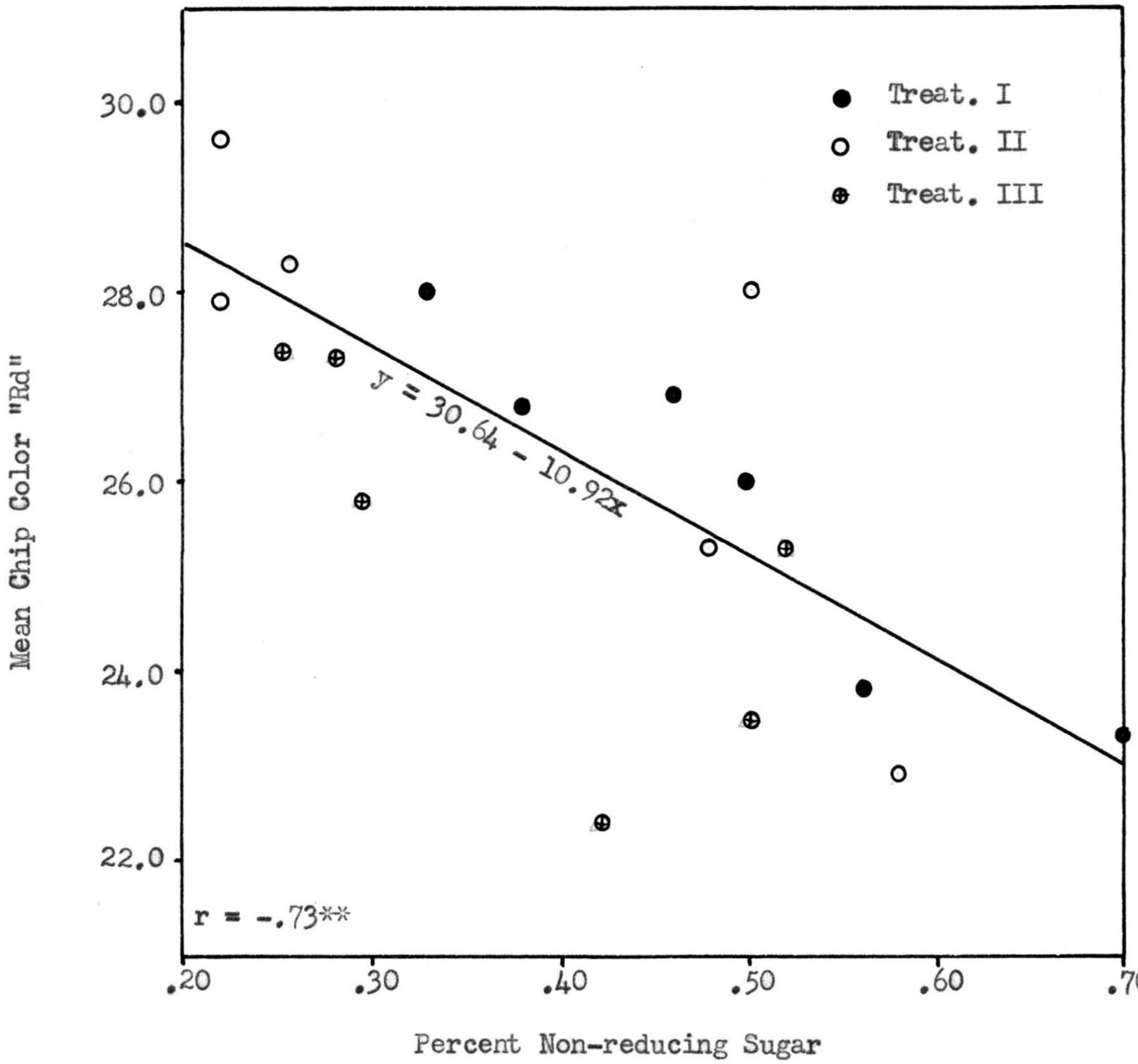

Figure 10.—Correlation of non-reducing sugar of potato tubers on the date they were harvested and mean chip color for each harvest.

Chapter V

DISCUSSION

The importance of after harvest darkening of potato chips is clearly shown by comparing the chip color of potatoes on the day of harvest (Table 3), and the corresponding chip color of each harvest after storage (Table 4). In every case, chip color is acceptable on the day of harvest regardless of the date harvested but after being in storage the potatoes produced darker chips. The degree of darkening in storage is less with each successive harvest through the third harvest and then remains about the same. This degree of darkening seems to be a maturity effect. The correlation between the respiration rate and corresponding chip color is highly significant ($r = -0.73$) indicating that mature potatoes will produce lighter colored chips out of storage.

Storage at 50°F is detrimental to summer potatoes for chipping purposes regardless of when they were harvested. Storage at 70° and 90° resulted in potatoes producing much lighter colored chips. Potatoes can be harvested more immature and stored at 70°F as Figure 4 indicates. Also it would be much better to store potatoes at 70° or above than below 70°F. This is in agreement with Heinze (11).

Generally, longer storage periods for summer potatoes cause the production of darker colored chips. This effect is increased greatly be immaturity and 50° storage.

The fertility level did not affect chip color statistically, but the trend was for potatoes from Treatment II (low fertility, no nitrogen) to produce the lightest colored chips.

Severely injured potatoes produced darker colored chips after short storage periods than uninjured potatoes due to a higher accumulation of reducing sugars. Respiration was higher for injured potatoes. The results of reducing sugars accumulation and respiration are in agreement with Hopkins (14). He also suggested that the increase in reducing sugars was due to increased activity in callus formation. This effect of injury on chip color may be an important factor to the early potato grower. His potatoes are usually harvested as early as possible, thus resulting in immature potatoes which are easily injured.

Correlations of reducing sugars and chip color for Experiment I ($r = -0.83$) and Experiment II ($r = -0.77$) were highly significant. Therefore, the effects of harvests (maturity), storage temperatures, storage periods, fertility level and injury to tubers influence the reducing sugar content. This in turn is expressed as color when the potatoes are chipped.

The non-reducing sugar content of immature potatoes is much higher than in mature potatoes, Figure 6. This may essentially be the main cause of after harvest darkening of summer chipping potatoes. This high sugar content appears to be readily available for conversion to reducing sugars. The non-reducing sugar when stored at 50° and 70° decreases while the reducing sugars increase.

This effect is much greater at 50° than at 70°F. Storage at 50°F appears to be an optimum temperature for reducing sugars to build-up. Comparison of an early and late harvest showed that sugars of each harvest tended to parallel each other with the early harvest always being higher. Non-reducing sugar does not perform the same at 90°F storage. There is a decrease in this sugar followed by an increase. The reducing sugars increase slightly. The non-reducing sugar of the early harvest increased much more readily than the later harvest, while the reducing sugars were apparantly the same for both harvests. This high non-reducing sugar content could easily be the reason for potatoes stored at high temperatures to chip darker than potatoes stored at 70°F, if some hydrolysis to reducing sugars takes place while the potatoes are being cooked.

A correlation of non-reducing sugar the day the potatoes were harvested with the corresponding mean chip color for each harvest through storage was highly significant, Figure 10. This indicates that as the non-reducing sugar decreases the storage ability of potatoes increases. This would also show that an analysis for non-reducing sugar may be a method of predicting the storability of early summer potatoes.

Suggestions for further study

1. A continuation of this type of study using other chipping varieties.

2. A more intensive study of the effect of injury on chip color.

3. A study using non-reducing sugar as an index for

predicting the storage ability of summer potatoes and also fall potatoes.

Chapter VI

SUMMARY

Three plots (a high fertility, a low fertility and a low fertility plus 120 lbs. of nitrogen) were planted using the variety Irish Cobbler. These plots were located in the Gilcrest early potato producing area. Potatoes were harvested July 7, 11, 18, 25, August 1 and 8, and placed into 50°, 70° and 90° storage. An injury treatment was added to the July 25 harvest. At three day intervals over a period of 21 days, respiration, chip color, and some chemical analyses were determined.

1. Immature potatoes can not be held in storage for chipping purposes. Delaying the date of harvest will improve the storage capability.

2. Storage at 50°F is detrimental to summer chipping potatoes. Storage at 70°F or above is recommended.

3. The trend of treatment was that potatoes from Treatment II (low fertility, no nitrogen) produce the lightest colored chips.

4. Injury to tubers increases sugar accumulation and results in darker chips.

5. The high non-reducing sugar content of early potatoes may be the main cause of after harvest darkening of potato chips. This high sugar content may be a readily available

source of sugar, easily converted into reducing sugars, which in turn cause the potatoes to darken when chipped.

A P P E N D I X

APPENDIX A.—SUMMARIES OF THE ORIGINAL DATA AND STATISTICAL ANALYSES FOR CHIP COLOR, SUGARS AND RESPIRATION RATES.

LIST OF TABLES

For the analysis of variances, a single asterisk * designates significance at the 5% level and double asterisks ** designates significance at the 1% level.

Table 1.--Rd VALUES OF CHIP COLOR FOR EACH TREATMENT ON EACH DATE OF HARVEST. (MEAN OF DUPLICATE SAMPLES).

Harvest Date	Treatments[1/]			Harvest Mean
	I	II	III	
July 7	30.4	33.5	33.6	32.5
11	31.6	32.5	31.9	32.0
18	32.5	35.9	31.5	33.3
25	30.4	31.0	32.2	31.2
August 1	29.2	31.2	31.0	30.5
8	28.2	32.0	30.4	30.2
Treatment Mean	30.4	32.7	31.7	

[1/] I, high fertility; II, low fertility; III, low fertility + 120 lbs nitrogen.

Analysis of Variance

Source	df	SS	MS
Total	35	199.32	
Subtotal	17	103.29	
Treatment	2	32.74	16.37
Harvest	5	44.07	8.81
Tr. x H.	10	26.48	2.65
Residual	18	96.03	5.33

Table 2.--PERCENT REDUCING SUGARS FOR EACH TREATMENT ON EACH DATE OF HARVEST. (MEAN OF DUPLICATE SAMPLES).

Harvest Date	Treatments[1]			Harvest Mean
	I	II	III	
July 7	0.29	0.22	0.20	0.24
11	0.18	0.15	0.18	0.17
18	0.15	0.15	0.18	0.16
25	0.24	0.17	0.20	0.20
August 1	0.19	0.12	0.15	0.15
8	0.20	0.16	0.16	0.17
Treatment Mean	0.21	0.16	0.18	

[1] See Table 1.

Analysis of Variance

Source	df	SS	MS
Total	35	0.0075	
Subtotal	17	0.0058	
Treatment	2	0.0014	0.0007**
Harvest	5	0.0029	0.0006**
Tr. x H.	10	0.0015	0.0002
Residual	18	0.0017	0.0001

Table 3.--PERCENT NON-REDUCING SUGAR FOR EACH TREATMENT ON EACH DATE OF HARVEST. (MEAN OF DUPLICATE SAMPLES).

Harvest Date	Treatments[1/]			Harvest Mean
	I	II	III	
July 7	0.71	0.58	0.42	0.57
11	0.56	0.48	0.50	0.51
18	0.46	0.50	0.52	0.49
25	0.40	0.22	0.29	0.30
August 1	0.38	0.22	0.28	0.30
8	0.50	0.26	0.26	0.34
Treatment Mean	0.50	0.37	0.38	

1/ See Table 1.

Analysis of Variance

Source	df	SS	MS
Total	35	0.729	
Subtotal	17	0.666	
Treatment	2	0.125	0.062**
Harvest	5	0.431	0.086**
Tr. x H.	10	0.110	0.011*
Residual	18	0.063	0.004

Table 4a.--RdVALUES OF CHIP COLOR AS AFFECTED BY TREATMENTS, DATES OF HARVEST, STORAGE TEMPERATURES AND STORAGE PERIODS. (MEAN OF DUPLICATE SAMPLES).

Temperature	Treatment	Storage Days 0	3	6	9	12	15	18	21	Mean
					July 7 Harvest					
50°	I	30.4	27.4	21.0	20.2	18.8	17.6	13.4	16.6	20.7
	II	33.5	24.4	19.0	15.7	15.8	13.3	10.2	15.2	18.4
	III	33.6	23.8	19.2	15.6	13.6	12.8	10.6	13.2	17.8
70°	I	30.4	29.4	27.6	24.0	24.2	24.2	17.8	23.2	25.1
	II	33.5	28.2	28.0	23.8	25.2	24.2	17.7	23.0	25.4
	III	33.6	28.6	25.3	22.4	23.2	21.8	22.3	20.5	24.7
90°	I	30.4	29.4	26.7	22.8	24.1	21.5	17.6	19.8	24.0
	II	33.5	28.4	27.2	25.2	21.4	21.8	16.8	24.6	24.9
	III	33.6	27.6	26.4	24.2	23.4	23.4	18.8	21.3	24.8
			247.2	220.4	193.9	189.7	180.6	145.2	177.4	
			27.5	24.5	21.5	21.1	20.1	16.1	19.7	
					July 11 Harvest					
50°	I	31.6	27.0	21.6	20.6	17.8	15.8	16.7	11.8	20.4
	II	32.5	28.0	21.0	17.5	16.0	15.2	15.9	11.6	19.7
	III	31.9	25.4	21.9	15.6	13.3	13.2	12.7	10.4	18.0
70°	I	31.6	27.7	30.6	23.7	23.0	24.6	24.4	23.5	26.2
	II	32.5	30.4	31.1	28.0	25.8	28.0	29.9	23.4	28.6
	III	31.9	30.4	27.2	26.1	23.2	24.5	23.2	22.2	26.1
90°	I	31.6	27.4	24.8	26.0	24.1	21.4	22.7	21.0	24.9
	II	32.5	33.2	27.8	29.4	24.3	27.0	25.0	22.4	27.7
	III	31.9	30.2	27.8	28.2	24.7	27.2	22.3	20.0	26.5
			259.7	233.8	215.1	192.2	196.9	192.8	166.3	
			28.9	26.0	23.9	21.4	21.9	21.4	18.5	

Table 4a.—(continued)

Temperature	Treatment	Storage Days 0	3	6	9	12	15	18	21	Mean
					July 18 Harvest					
50°	I	32.5	27.2	26.7	24.2	24.0	22.0	14.0	13.0	23.0
	II	35.9	29.6	23.6	22.8	21.8	19.6	15.2	14.8	22.9
	III	31.5	25.6	24.4	17.0	19.6	16.6	12.6	12.6	20.0
70°	I	32.5	31.6	29.2	31.2	30.4	33.0	25.2	27.4	30.1
	II	25.9	30.8	31.7	33.3	30.4	35.8	27.9	27.0	31.6
	III	31.5	29.7	31.7	28.3	31.6	28.3	26.0	23.5	28.8
90°	I	32.5	29.4	29.0	29.9	28.0	29.6	21.8	21.0	27.6
	II	35.9	32.2	28.1	28.5	31.0	31.2	25.5	24.7	29.6
	III	31.5	29.8	29.6	26.4	24.8	26.6	28.6	20.3	27.2
			265.9	254.0	241.6	241.6	242.7	196.8	184.3	
			29.5	28.2	26.8	26.8	27.0	21.9	20.0	
					July 25 Harvest					
50°	I	30.4	27.2	26.5	26.1	23.0	20.6	21.4	21.0	24.5
	II	31.0	32.0	22.7	25.6	16.7	18.4	15.1	15.1	22.1
	III	32.2	28.7	21.0	19.6	14.6	15.6	15.4	14.8	20.2
70°	I	30.4	33.0	32.3	30.9	28.6	30.2	28.8	29.4	30.4
	II	31.0	33.6	34.8	34.5	32.7	30.3	31.0	30.8	32.3
	III	32.2	32.8	26.4	30.0	26.8	29.8	27.2	29.6	29.3
90°	I	30.4	31.4	30.2	29.2	27.6	30.6	23.4	28.2	28.9
	II	31.0	32.2	32.4	29.4	28.2	30.2	24.0	27.5	29.4
	III	32.2	30.9	29.3	31.0	25.2	27.4	24.0	23.2	27.9
			281.8	255.6	256.3	223.4	233.1	210.3	219.6	
			31.2	28.4	28.5	24.8	25.9	23.4	24.4	

Table 4a.—(continued)

Temperature	Treatment	Storage Days 0	3	6	9	12	15	18	21	Mean
						August 1 Harvest				
50°	I	29.2	28.2	26.4	20.1	22.0	22.9	18.2	15.8	22.8
	II	31.2	31.4	30.1	23.9	21.7	22.8	21.0	19.4	25.2
	III	31.0	27.6	24.2	19.2	16.7	16.9	17.8	17.7	21.4
70°	I	29.2	28.8	28.7	29.8	27.4	27.2	29.2	26.4	28.4
	II	31.2	34.1	31.2	34.5	31.9	34.8	32.7	32.7	32.9
	III	31.0	28.2	32.6	33.4	30.6	31.3	30.8	27.8	30.7
90°	I	29.2	30.0	32.6	30.4	26.0	30.0	27.6	28.4	29.3
	II	31.2	32.4	32.8	31.2	30.6	32.0	28.7	27.0	30.7
	III	31.0	31.6	28.1	31.2	28.2	29.3	27.6	30.2	29.7
			272.3	266.7	253.7	235.1	247.2	233.6	225.4	
			30.3	29.6	28.2	26.1	27.5	26.0	25.0	
						August 8 Harvest				
50°	I	28.2	24.0	24.1	22.1	21.7	19.3	23.0	17.4	22.5
	II	32.0	27.2	22.1	20.3	16.0	17.2	17.8	17.0	21.2
	III	30.4	26.4	22.1	19.3	16.6	17.2	17.6	15.3	20.6
70°	I	28.2	28.4	27.6	30.4	27.2	28.8	26.8	25.6	27.8
	II	32.0	32.3	31.2	31.8	31.5	29.6	34.6	29.4	31.6
	III	30.4	32.8	30.3	32.7	32.4	30.4	33.0	31.0	31.0
90°	I	28.2	30.4	29.2	30.3	27.9	27.2	31.6	26.4	28.9
	II	32.0	34.6	30.4	31.8	31.8	31.5	33.4	30.7	32.0
	III	30.4	31.4	27.0	32.2	28.6	28.0	30.4	31.2	29.9
			267.5	244.0	250.9	233.1	229.2	248.2	224.0	
			29.7	27.1	27.9	26.0	25.5	27.6	24.9	

Table 4b.--ANALYSIS OF VARIANCE FOR CHIP COLOR

Source	df	SS	MS
Total	863	30998.497	
Harvest	5	4787.078	957.416**
Temperature	2	3248.231	1624.115**
Treatment	2	40.096	20.048
Storage period	7	1992.280	284.611**
H. x T.	10	4907.829	490.783**
H. x Tr.	10	173.480	17.348
H. x S.	35	609.900	17.426
T. x Tr.	4	771.772	192.943**
T. x S.	14	272.113	19.437
Tr. x S.	14	77.984	5.570
H. x T. x Tr.	20	5720.408	286.020**
H. x T. x S.	70	544.617	7.780
H. x Tr. x S.	70	368.715	5.267
T. x Tr. x S.	28	375.050	13.395
Remainder	140	1265.651	9.040
Residual	432	5843.293	13.526

Table 5a.—PERCENT REDUCING SUGARS OF TUBERS AS AFFECTED BY TREATMENTS, DATES OF HARVEST, STORAGE TEMPERATURES AND STORAGE PERIODS. (MEAN OF DUPLICATE SAMPLES).

Temperature	Treatment	Storage Days 0	3	6	9	12	15	18	21	Mean
					July 7 Harvest					
50°	I	0.29	0.32	0.53	0.56	0.77	0.78	0.88	0.96	0.64
	II	0.22	0.40	0.49	0.84	0.88	1.16	1.08	1.03	0.76
	III	0.20	0.36	0.58	0.77	0.90	1.02	1.31	1.05	0.78
70°	I	0.29	0.28	0.36	0.43	0.41	0.38	0.52	0.36	0.38
	II	0.22	0.34	0.34	0.32	0.34	0.30	0.42	0.33	0.32
	III	0.20	0.30	0.36	0.31	0.38	0.36	0.44	0.40	0.34
90°	I	0.29	0.24	0.32	0.38	0.35	0.37	0.48	0.32	0.34
	II	0.22	0.24	0.26	0.32	0.40	0.39	0.42	0.36	0.33
	III	0.20	0.28	0.27	0.36	0.32	0.34	0.40	0.38	0.32
			2.76	3.51	4.29	4.75	5.10	5.95	5.19	
			.31	.39	.48	.53	.57	.66	.58	
					July 11 Harvest					
50°	I	0.18	0.30	0.45	0.63	0.84	0.93	0.88	0.98	0.65
	II	0.15	0.28	0.44	0.68	0.87	0.92	0.84	1.12	0.66
	III	0.18	0.31	0.48	0.68	0.88	1.10	0.92	1.01	0.69
70°	I	0.18	0.20	0.25	0.28	0.32	0.30	0.42	0.28	0.28
	II	0.15	0.18	0.24	0.26	0.26	0.30	0.28	0.31	0.25
	III	0.18	0.22	0.28	0.26	0.28	0.38	0.28	0.26	0.27
90°	I	0.18	0.30	0.30	0.28	0.30	0.38	0.32	0.34	0.30
	II	0.15	0.20	0.28	0.24	0.31	0.32	0.32	0.29	0.26
	III	0.18	0.23	0.24	0.24	0.32	0.30	0.36	0.35	0.28
			2.22	2.96	3.55	4.38	4.93	4.62	4.94	
			.25	.33	.39	.49	.55	.51	.55	

Table 5a.—(continued)

Temperature	Treatment	Storage Days 0	3	6	9	12	15	18	21	Mean
					July 18 Harvest					
50°	I	0.15	0.26	0.42	0.53	0.68	0.64	0.86	0.83	0.55
	II	0.15	0.26	0.34	0.39	0.70	0.70	0.72	0.58	0.48
	III	0.18	0.26	0.32	0.62	0.77	0.72	0.78	0.92	0.57
70°	I	0.15	0.20	0.22	0.26	0.29	0.26	0.27	0.23	0.23
	II	0.15	0.20	0.20	0.24	0.22	0.19	0.26	0.24	0.21
	III	0.18	0.20	0.26	0.28	0.23	0.26	0.22	0.34	0.25
90°	I	0.15	0.24	0.27	0.20	0.28	0.22	0.36	0.30	0.25
	II	0.15	0.18	0.26	0.24	0.22	0.25	0.30	0.26	0.23
	III	0.18	0.18	0.22	0.31	0.30	0.26	0.24	0.29	0.25
			1.98	2.51	3.07	3.69	3.50	4.01	3.99	
			.22	.28	.34	.41	.39	.45	.44	
					July 25 Harvest					
50°	I	0.24	0.28	0.35	0.57	0.42	0.46	0.40	0.42	0.39
	II	0.17	0.20	0.34	0.42	0.54	0.54	0.66	0.51	0.42
	III	0.20	0.26	0.33	0.56	0.52	0.54	0.69	0.60	0.46
70°	I	0.24	0.20	0.21	0.24	0.20	0.20	0.18	0.20	0.21
	II	0.17	0.17	0.16	0.20	0.20	0.18	0.20	0.20	0.18
	III	0.20	0.20	0.24	0.22	0.31	0.19	0.29	0.20	0.23
90°	I	0.24	0.16	0.20	0.24	0.24	0.24	0.22	0.21	0.22
	II	0.17	0.18	0.20	0.20	0.20	0.26	0.26	0.25	0.22
	III	0.20	0.24	0.22	0.26	0.26	0.28	0.28	0.26	0.25
			1.89	2.25	2.91	2.89	2.89	3.18	2.85	
			.21	.25	.32	.32	.32	.35	.32	

Table 5a.--(continued)

Temperature	Treatment	Storage Days 0	3	6	9	12	15	18	21	Mean
					August 1 Harvest					
50°	I	0.19	0.28	0.34	0.56	0.38	0.43	0.48	0.38	0.38
	II	0.12	0.17	0.22	0.37	0.31	0.31	0.34	0.42	0.28
	III	0.15	0.24	0.28	0.40	0.44	0.44	0.50	0.40	0.35
70°	I	0.19	0.22	0.17	0.20	0.18	0.24	0.22	0.20	0.20
	II	0.12	0.14	0.18	0.17	0.14	0.22	0.17	0.16	0.16
	III	0.15	0.19	0.18	0.19	0.18	0.19	0.16	0.20	0.18
90°	I	0.19	0.14	0.22	0.18	0.24	0.18	0.20	0.20	0.19
	II	0.12	0.14	0.16	0.20	0.18	0.19	0.19	0.24	0.18
	III	0.15	0.18	0.20	0.22	0.22	0.20	0.42	0.22	0.23
					August 8 Harvest					
50°	I	0.20	0.22	0.28	0.44	0.63	0.44	0.33	0.34	0.36
	II	0.16	0.23	0.36	0.40	0.40	0.42	0.49	0.52	0.37
	III	0.16	0.30	0.32	0.48	0.24	0.42	0.48	0.67	0.38
70°	I	0.20	0.20	0.22	0.32	0.19	0.21	0.22	0.22	0.22
	II	0.16	0.18	0.17	0.20	0.18	0.18	0.18	0.20	0.18
	III	0.16	0.18	0.20	0.24	0.22	0.20	0.17	0.19	0.20
90°	I	0.20	0.23	0.18	0.20	0.18	0.19	0.19	0.22	0.20
	II	0.16	0.18	0.20	0.24	0.20	0.22	0.21	0.22	0.20
	III	0.16	0.20	0.20	0.24	0.23	0.20	0.26	0.20	0.21

Table 5b.--ANALYSIS OF VARIANCE FOR REDUCING SUGARS.

Source	df	SS	MS
Total	863	38.88828	
Harvest	5	7.53378	1.50676**
Temperature	2	3.75834	1.87917**
Treatment	2	0.00182	0.00091
Storage period	7	1.31302	0.18757**
H. x T.	10	5.21917	0.52192**
H. x Tr.	10	0.08862	0.00886
H. x S.	35	0.69610	0.01989
T. x Tr.	4	2.38099	0.59525**
T. x S.	14	0.29096	0.02078
Tr. x S.	14	0.05954	0.00425
H. x T. x Tr.	20	4.47504	0.22375**
H. x T. x S.	70	0.56217	0.00803
H. x Tr. x S.	70	0.28212	0.00403
T. x Tr. x S.	28	0.35199	0.01257
Remainder	140	1.22771	0.00877
Residual	432	10.64692	0.02465

Table 6.--RESPIRATION RATES (mg. CO_2/hr./kg.) OF TUBERS AS AFFECTED BY TREATMENTS, DATES OF HARVEST, STORAGE TEMPERATURES AND STORAGE PERIODS.

Temperature	Treatment	Storage Days 3	6	9	12	15	18	21	Mean
					July 7 Harvest				
50°	I	17.9	14.7	14.7	13.9	13.6	10.2	——	14.2
	II	20.0	17.0	15.3	15.1	12.8	15.3	——	15.9
	III	19.6	15.3	16.4	16.4	13.2	15.3	——	16.0
70°	I	31.1	23.3	20.2	18.7	17.0	17.0	——	21.2
	II	34.1	27.8	21.5	19.3	17.9	15.3	——	22.7
	III	30.2	19.8	20.7	19.0	19.2	16.2	——	20.9
90°	I	51.5	38.6	32.9	30.6	28.9	23.8	——	34.4
	II	53.4	42.6	35.2	31.8	27.7	24.7	——	35.9
	III	59.6	45.4	38.9	37.2	34.9	——	——	43.2
					July 11 Harvest				
50°	I	17.6	17.0	18.1	16.2	14.9	11.9	12.8	15.5
	II	18.1	16.8	15.9	15.3	14.5	11.1	15.3	15.3
	III	17.6	18.5	16.4	15.3	16.2	11.9	14.9	15.8
70°	I	26.6	21.0	18.7	17.9	14.5	13.6	15.3	18.2
	II	31.2	24.4	21.5	19.6	17.9	16.2	16.2	21.0
	III	30.7	24.9	22.7	21.5	17.9	17.0	16.2	21.6
90°	I	44.3	36.9	29.8	28.7	24.3	24.7	22.1	30.1
	II	51.7	42.8	34.9	31.5	28.1	25.5	23.8	34.0
	III	56.2	44.0	37.7	32.6	28.9	25.5	24.7	35.7

Table 6.--(continued)

Temperature	Treatment	Storage Days 3	6	9	12	15	18	21	Mean
					July 18 Harvest				
	I	19.3	15.6	17.0	15.6	16.2	16.2	13.6	16.2
50°	II	16.4	16.2	15.1	15.3	15.3	13.6	14.5	15.2
	III	20.4	15.9	16.8	16.8	17.3	17.0	15.3	17.1
	I	29.8	23.2	18.5	17.9	17.0	17.0	14.0	19.6
70°	II	27.2	21.9	19.8	17.0	17.3	15.3	13.2	18.8
	III	35.2	26.4	21.5	20.7	20.7	17.0	17.0	22.6
	I	48.8	37.7	30.9	28.1	27.0	25.5	24.3	31.8
90°	II	47.7	38.1	28.1	28.7	26.4	25.5	21.7	30.9
	III	55.9	41.5	33.8	31.5	27.2	28.1	24.7	34.7
					July 25 Harvest				
	I	17.6	15.9	16.4	14.2	15.3	11.9	13.6	15.0
50°	II	11.9	12.5	13.4	12.5	11.9	11.9	10.2	12.0
	III	17.9	16.8	16.8	15.9	14.5	16.2	14.0	16.0
	I	23.6	19.6	17.6	17.0	14.5	13.6	11.9	16.8
70°	II	23.0	19.8	17.6	14.5	15.3	13.6	11.5	16.5
	III	25.3	21.3	20.4	20.2	18.3	17.0	14.5	19.6
	I	39.8	31.5	28.9	25.5	23.8	20.4	20.9	27.3
90°	II	45.4	35.8	30.4	27.8	26.4	23.8	22.1	30.2
	III	48.3	36.2	29.5	28.1	27.2	24.7	24.7	31.2

Table 6.—(continued)

Temperature	Treatment	Storage Days 3	6	9	12	15	18	21	Mean
					August 1 Harvest				
50°	I	14.7	12.5	12.5	11.7	11.1	11.9	9.8	12.0
	II	15.3	14.2	13.0	13.0	12.8	11.9	11.9	13.2
	III	19.0	16.8	14.2	15.1	14.5	13.6	12.8	15.1
70°	I	17.6	16.4	11.9	13.0	10.2	11.9	11.5	13.2
	II	22.7	18.5	15.9	15.1	14.0	10.2	11.9	15.5
	III	27.8	21.0	19.3	16.4	14.9	15.3	12.8	18.2
90°	I	28.7	23.0	22.1	20.7	20.0	18.7	18.7	21.7
	II	34.3	28.7	25.5	24.1	23.4	22.1	22.6	25.8
	III	40.3	32.9	38.9	27.2	25.5	23.8	23.4	28.9
					August 8 Harvest				
50°	I	11.9	11.7	10.5	11.9	10.2	11.9	9.4	11.1
	II	13.4	11.9	11.9	11.7	11.9	11.9	10.2	11.8
	III	16.4	14.2	13.4	13.4	12.8	12.8	11.9	13.6
70°	I	15.9	16.2	13.9	13.4	12.8	13.6	11.5	13.9
	II	15.9	14.2	12.2	13.0	13.6	13.6	12.3	13.5
	III	19.6	17.0	15.3	14.7	13.6	13.6	13.2	15.3
90°	I	26.1	22.1	19.8	19.6	20.4	20.4	17.9	20.9
	II	30.1	27.2	24.4	23.2	23.8	22.1	22.1	24.7
	III	36.9	30.9	27.8	26.6	25.5	25.5	22.1	27.9

Table 7.--Rd VALUES OF CHIP COLOR AS AFFECTED BY INJURY. JULY 25 HARVEST.

Temper-ature	Treat-ment	Storage Days								Mean
		0	3	6	9	12	15	18	21	
50°	Check	29.4	27.2	26.5	26.1	23.0	20.6	21.4	21.0	24.4
	Injury	29.4	29.2	22.8	29.4	14.6	17.5	16.5	19.5	22.4
70°	Check	29.4	33.0	32.3	30.9	28.6	30.2	28.8	29.4	30.4
	Injury	29.4	27.6	25.9	27.2	26.4	28.8	30.0	26.8	27.8
90°	Check	29.4	31.4	30.2	29.2	27.6	30.6	23.4	28.2	28.8
	Injury	29.4	33.2	28.0	21.2	27.6	25.0	25.4	25.0	26.8

Analysis of Variance

Source	df	SS	MS
Total	47	850.08	
Treatment	1	49.38	49.38*
Storage period	7	209.17	29.88**
Temperature	2	276.44	138.22**
Tr. x S.	7	33.12	4.73
Tr. x T.	2	7.93	3.96
S. x T.	14	188.72	13.48
Residual	14	85.32	6.09

Table 8.--PERCENT REDUCING SUGARS AS AFFECTED BY INJURY. JULY 25 HARVEST.

Temperature	Treatment	Storage Days 0	3	6	9	12	15	18	21	Mean
50°	Check	0.24	0.28	0.35	0.57	0.42	0.46	0.40	0.42	0.39
	Injury	0.24	0.27	0.37	0.52	0.55	0.59	0.73	0.47	0.47
70°	Check	0.24	0.20	0.21	0.24	0.20	0.20	0.18	0.20	0.21
	Injury	0.24	0.21	0.22	0.26	0.30	0.28	0.40	0.25	0.27
90°	Check	0.24	0.16	0.20	0.24	0.24	0.24	0.22	0.21	0.22
	Injury	0.24	0.19	0.22	0.46	0.22	0.22	0.30	0.26	0.26

Analysis of Variance

Source	df	SS	MS
Total	47	0.7843	
Treatment	1	0.0438	0.0438**
Storage period	7	0.1495	0.0214**
Temperature	2	0.3838	0.1919**
Tr. x S.	7	0.0461	0.0066
Tr. x T.	2	0.0018	0.0009
S. x T.	14	0.1133	0.0081
Residual	14	0.0460	0.0033

Table 9.--RESPIRATION RATES (mg.CO_2/hr/kg.) OF TUBERS AS AFFECTED BY INJURY. JULY 25 HARVEST.

Temperature	Treatment	Storage Days							Mean
		3	6	9	12	15	18	21	
50°	Check	17.6	15.9	16.4	14.2	15.3	11.9	13.6	15.0
	Injury	18.1	19.3	17.9	17.0	16.2	17.0	15.8	17.3
70°	Check	23.6	19.6	17.6	17.0	14.5	13.6	11.9	16.8
	Injury	28.1	22.1	22.4	19.8	17.9	15.3	16.2	20.2
90°	Check	39.8	31.5	28.9	25.5	23.8	20.4	20.9	27.2
	Injury	43.4	37.2	31.2	27.2	28.9	25.5	26.0	31.3

Analysis of Variance

Source	df	SS	MS
Total	41	2278.51	
Treatment	1	113.34	113.34**
Storage period	6	582.69	97.12**
Temperature	2	1372.66	686.33**
Tr. x S.	6	3.88	0.65
Tr. x T.	2	5.44	2.72
S. x T.	12	185.39	15.45**
Residual	12	15.11	1.26

APPENDIX B.--SUMMARIES OF THE ORIGINAL DATA AND STATISTICAL ANALYSES FOR SPECIFIC GRAVITY, AMINO-NITROGEN AND CHIP YIELD DETERMINED AS A REGULAR LABORATORY PROCEDURE IN CONJUNCTION WITH CHIP, COLOR, SUGARS AND RESPIRATION RATES.

LIST OF TABLES

For the analysis of variance, a single asterisk * designates significance at the 5% level and a double asterisk ** designates significance at the 1% level.

Table 1.--SPECIFIC GRAVITY* FOR EACH TREATMENT ON EACH HARVEST DATE, (MEAN OF DUPLICATE SAMPLES).

Harvest Date	Treatment 1/ I	II	III	Harvest Mean
July 7	1.066	1.062	1.060	1.063
11	1.071	1.066	1.064	1.067
18	1.076	1.073	1.066	1.071
25	1.079	1.070	1.066	1.071
August 1	1.078	1.072	1.066	1.072
8	1.082	1.071	1.066	1.073
Treatment Mean	1.075	1.069	1.064	

1/ I, high fertility; II low fertility, no nitrogen; III, low fertility plus 120 lbs. nitrogen.

Analysis of Variance

Source	df	SS	MS
Total	35	0.0014	
Subtotal	17	0.0013	
Treatment	2	0.0008	0.0004000**
Harvest	5	0.0005	0.0001000**
T. x H.	10	0.0000	0.0000000
Residual	18	0.0001	0.0000055

* Determined by dividing the weight of the sample in air by the weight of the sample in air minus the weight of the sample in water.

Table 2.--AMINO NITROGEN* (MG AMINO-N/100 GM) CONTENT OF TUBERS OF EACH TREATMENT ON EACH DATE OF HARVEST, (MEAN OF DUPLICATE SAMPLES).

Harvest Date	Treatment 1/ I	II	III	Harvest Mean
July 7	21.3	27.2	36.4	28.3
11	21.9	18.5	26.4	22.2
18	17.8	26.4	37.7	27.2
25	26.0	26.4	36.9	29.7
August 1	29.4	31.0	43.4	34.6
8	32.4	32.4	37.3	34.0
Treatment Mean	24.8	27.0	36.3	

1/ See Table 1.

Analysis of Variance

Source	df	SS	MS
Total	35	2151.74	
Subtotal	17	1794.82	
Treatment	2	956.46	478.23**
Harvest	5	683.83	136.76**
T. x H.	10	154.53	15.45
Residual	18	356.92	19.83

* Determined by the Kemm and Cocking method (36). Amino acids, glycine and alanine were used for a standard curve.

Table 3a.--SPECIFIC GRAVITY OF TUBERS AS AFFECTED BY TREATMENTS, DATES OF HARVEST, STORAGE TEMPERATURES AND STORAGE PERIODS. (MEAN OF DUPLICATE SAMPLES).

Temper-ature	Treat-ment	Storage Days 0	3	6	9	12	15	18	21	Mean
					July 7 Harvest					
50°	I	1.066	1.070	1.070	1.071	1.072	1.074	1.068	1.070	1.070
	II	1.062	1.066	1.065	1.066	1.067	1.065	1.068	1.065	1.066
	III	1.060	1.062	1.062	1.064	1.064	1.062	1.066	1.062	1.063
70°	I	1.066	1.074	1.069	1.069	1.072	1.072	1.074	1.068	1.071
	II	1.062	1.065	1.066	1.067	1.068	1.068	1.068	1.068	1.067
	III	1.060	1.065	1.060	1.060	1.060	1.062	1.066	1.060	1.062
90°	I	1.066	1.074	1.068	1.066	1.066	1.068	1.071	1.070	1.069
	II	1.062	1.069	1.062	1.062	1.065	1.064	1.068	1.064	1.065
	III	1.060	1.063	1.058	1.058	1.060	1.060	1.066	1.061	1.061
					July 11 Harvest					
50°	I	1.071	1.075	1.076	1.073	1.076	1.074	1.077	1.076	1.075
	II	1.066	1.069	1.070	1.070	1.072	1.072	1.076	1.072	1.071
	III	1.064	1.067	1.068	1.065	1.067	1.070	1.072	1.072	1.068
70°	I	1.071	1.072	1.074	1.072	1.076	1.075	1.075	1.077	1.074
	II	1.066	1.068	1.069	1.070	1.072	1.070	1.072	1.073	1.070
	III	1.064	1.066	1.066	1.068	1.072	1.068	1.069	1.070	1.068
90°	I	1.071	1.070	1.071	1.074	1.079	1.073	1.076	1.074	1.074
	II	1.066	1.065	1.068	1.071	1.071	1.070	1.070	1.070	1.069
	III	1.064	1.062	1.066	1.064	1.070	1.068	1.065	1.060	1.066

Table 3a.--(continued)

Temper-ature	Treat-ment	Storage Days 0	3	6	9	12	15	18	21	Mean
					July 18 Harvest					
50°	I	1.076	1.078	1.083	1.083	1.084	1.086	1.081	1.081	1.081
	II	1.073	1.078	1.080	1.080	1.080	1.081	1.078	1.081	1.079
	III	1.066	1.072	1.074	1.072	1.080	1.074	1.071	1.074	1.073
70°	I	1.076	1.083	1.082	1.082	1.079	1.080	1.080	1.086	1.081
	II	1.073	1.077	1.078	1.078	1.081	1.079	1.074	1.082	1.078
	III	1.066	1.070	1.074	1.072	1.073	1.074	1.070	1.073	1.071
90°	I	1.076	1.078	1.078	1.083	1.080	1.082	1.076	1.072	1.078
	II	1.073	1.073	1.074	1.076	1.077	1.077	1.077	1.080	1.076
	III	1.066	1.072	1.068	1.069	1.068	1.070	1.071	1.080	1.070
					July 25 Harvest					
50°	I	1.079	1.082	1.080	1.082	1.088	1.087	1.090	1.083	1.084
	II	1.070	1.079	1.074	1.074	1.072	1.077	1.078	1.078	1.075
	III	1.066	1.072	1.073	1.070	1.072	1.077	1.080	1.078	1.073
70°	I	1.079	1.086	1.086	1.082	1.080	1.086	1.087	1.085	1.084
	II	1.070	1.074	1.074	1.076	1.072	1.076	1.074	1.078	1.074
	III	1.066	1.072	1.071	1.072	1.072	1.076	1.074	1.076	1.072
90°	I	1.079	1.082	1.082	1.077	1.078	1.084	1.080	1.083	1.081
	II	1.070	1.072	1.072	1.071	1.073	1.072	1.070	1.074	1.072
	III	1.066	1.071	1.070	1.070	1.066	1.072	1.068	1.073	1.070

Table 3a.—(continued)

Temperature	Treatment	Storage Days 0	3	6	9	12	15	18	21	Mean
					August 1 Harvest					
	I	1.078	1.082	1.084	1.078	1.084	1.084	1.080	1.082	1.082
50°	II	1.072	1.078	1.076	1.076	1.074	1.080	1.077	1.078	1.076
	III	1.066	1.074	1.068	1.068	1.070	1.075	1.072	1.071	1.071
	I	1.078	1.083	1.079	1.082	1.082	1.082	1.086	1.082	1.082
70°	II	1.072	1.078	1.070	1.073	1.076	1.078	1.080	1.078	1.076
	III	1.066	1.069	1.069	1.070	1.070	1.076	1.076	1.072	1.071
	I	1.078	1.086	1.080	1.082	1.078	1.084	1.086	1.084	1.082
90°	II	1.072	1.079	1.073	1.073	1.073	1.078	1.076	1.076	1.075
	III	1.066	1.072	1.067	1.068	1.074	1.072	1.074	1.070	1.070
					August 8 Harvest					
	I	1.082	1.082	1.084	1.080	1.084	1.080	1.082	1.083	1.082
50°	II	1.071	1.073	1.072	1.074	1.070	1.074	1.076	1.075	1.073
	III	1.066	1.070	1.070	1.074	1.072	1.076	1.072	1.072	1.072
	I	1.082	1.082	1.083	1.084	1.083	1.086	1.084	1.084	1.083
70°	II	1.071	1.072	1.071	1.074	1.072	1.074	1.077	1.076	1.073
	III	1.066	1.069	1.071	1.069	1.072	1.075	1.074	1.074	1.071
	I	1.082	1.080	1.080	1.082	1.082	1.082	1.081	1.084	1.081
90°	II	1.071	1.072	1.070	1.074	1.074	1.072	1.077	1.082	1.074
	III	1.066	1.066	1.068	1.072	1.070	1.072	1.073	1.074	1.070

Table 3b.--ANALYSIS OF VARIANCE FOR SPECIFIC GRAVITY.

Source	df	SS	MS
Total	863	0.03775	
Harvest	5	0.00571	0.00114**
Temperature	2	0.00011	0.00005
Treatment	2	0.00316	0.00158**
Storage period	7	0.00088	0.00013**
H. x T.	10	0.00500	0.00050**
H. x Tr.	10	0.00080	0.00008**
H. x S.	35	0.00037	0.00001
T. x Tr.	4	0.00002	0.00001
T. x S.	14	0.00008	0.00001
Tr. x S.	14	0.00013	0.00001
H. x T. x Tr.	20	0.00469	0.00023**
H. x T. x S.	70	0.00052	0.00001
H. x Tr. x S.	70	0.00052	0.00001
T. x Tr. x S.	28	0.00020	0.00001
Remainder	140	0.00123	0.00001
Residual	432	0.01433	0.00003

Table 4a.--PERCENT CHIP YIELD* OF TUBERS AS AFFECTED BY TREATMENTS, DATES, OF HARVEST, STORAGE TEMPERATURES AND STORAGE PERIODS. (MEAN OF DUPLICATE SAMPLES).

Temperature	Treatment	Storage Days 0	3	6	9	12	15	18	21	Mean
					July 7 Harvest					
50°	I	31.8	32.2	31.2	30.6	30.2	31.2	31.9	30.8	31.2
	II	30.4	30.4	30.2	29.9	29.6	29.0	30.2	29.0	29.8
	III	29.3	30.0	29.9	28.4	29.8	27.8	30.1	28.5	29.2
70°	I	31.8	37.7	37.7	31.8	31.6	31.8	33.5	32.0	32.2
	II	30.4	31.4	32.0	31.7	30.8	31.4	33.0	31.8	31.6
	III	29.3	30.5	30.7	31.2	30.4	30.4	31.6	30.0	30.5
90°	I	31.8	32.5	31.7	31.6	30.5	31.3	32.6	31.3	31.6
	II	30.4	31.5	31.2	31.6	31.2	30.4	31.3	31.5	31.2
	III	29.3	30.5	30.2	29.4	31.0	30.4	31.8	30.2	30.3
					July 11 Harvest					
50°	I	33.8	32.2	32.3	30.4	31.3	31.1	30.6	32.4	31.7
	II	32.0	31.4	31.2	31.4	30.9	30.6	30.4	31.8	31.2
	III	31.5	31.0	30.6	29.6	29.5	30.1	29.0	31.2	30.3
70°	I	33.8	31.7	32.2	34.4	32.4	34.4	32.2	34.0	33.1
	II	32.0	32.0	31.2	33.9	33.0	33.1	32.3	33.8	32.7
	III	31.5	32.2	31.0	34.6	32.2	32.0	31.2	33.0	32.2
90°	I	33.8	32.1	32.8	34.0	33.1	32.3	31.8	34.4	33.0
	II	32.0	31.8	31.9	33.8	31.4	32.4	32.3	33.6	32.4
	III	31.5	30.9	27.5	31.8	32.6	32.0	31.5	32.4	31.3

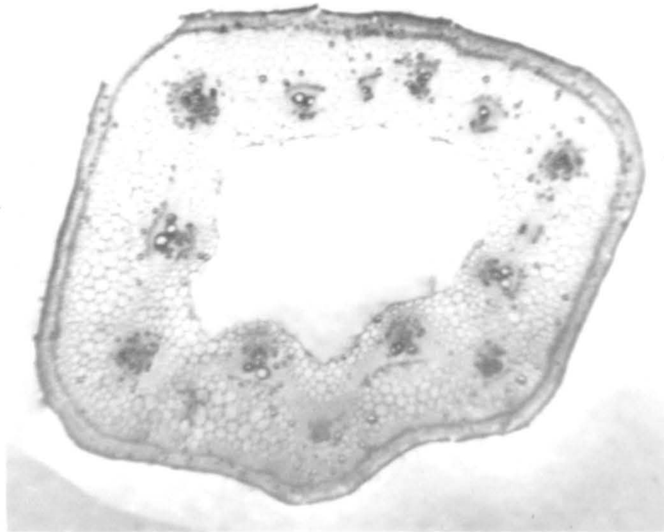

Figure 7. The distribution of peroxidase in the stem of vine *Cucurbita pepo*, line Cornell 51-26-7 (S-1). Guaiacol used as the hydrogen donor.

Figure 8. The distribution of peroxidase in the stem of vine muskmelon, variety Rocky Ford (M-6). Ortho-anisidine used as the hydrogen donor.

Table 4a.—(continued)

Temperature	Treatment	Storage Days 0	3	6	9	12	15	18	21	Mean
					July 18 Harvest					
50°	I	33.5	32.4	33.9	32.9	31.2	33.1	30.7	32.0	32.5
	II	32.6	33.2	32.8	32.6	31.7	32.7	30.6	32.7	32.4
	III	31.8	31.0	31.4	30.6	30.2	30.8	28.9	31.3	30.8
70°	I	33.5	35.8	34.0	34.2	33.9	33.8	32.6	35.8	34.2
	II	32.6	33.4	33.4	33.5	33.3	32.6	31.3	35.6	33.2
	III	31.8	31.4	33.2	32.6	32.2	32.9	31.0	32.7	32.2
90°	I	33.5	34.1	34.3	34.4	33.6	34.0	31.8	32.6	33.6
	II	32.6	33.2	33.6	34.8	33.9	33.8	31.5	34.0	33.4
	III	31.8	34.0	33.2	33.1	31.9	32.2	31.0	33.6	32.6
					July 25 Harvest					
50°	I	33.9	32.9	32.3	31.6	31.5	31.8	32.4	31.0	32.2
	II	33.0	32.8	31.4	31.1	30.2	30.8	30.3	30.6	31.3
	III	32.2	31.8	31.6	30.2	29.4	29.8	30.2	30.4	30.7
70°	I	33.9	36.4	33.5	33.0	32.0	32.6	32.2	31.8	33.2
	II	33.0	33.6	34.5	33.0	32.3	31.6	30.4	31.5	32.5
	III	32.2	32.6	32.8	33.1	31.4	32.1	30.8	30.4	31.9
90°	I	33.9	32.4	33.2	33.4	31.0	31.6	31.6	31.6	32.4
	II	33.0	33.3	33.2	32.6	30.8	30.8	31.0	31.4	32.0
	III	32.2	33.5	31.5	32.0	30.0	30.4	30.4	30.1	31.3

Table 4a.—(continued)

Temperature	Treatment	Storage Days 0	3	6	9	12	15	18	21	Mean
					August 1 Harvest					
50°	I	34.6	31.3	30.6	29.8	32.0	31.6	31.0	31.4	31.5
	II	32.6	32.0	30.9	30.6	30.8	31.3	30.8	30.0	31.1
	III	32.0	31.1	29.8	29.2	29.1	29.6	28.6	28.8	29.8
70°	I	34.6	31.2	32.0	32.4	32.4	31.6	33.3	31.4	32.4
	II	32.6	33.2	31.7	32.0	31.9	31.2	32.7	31.5	32.1
	III	32.0	31.5	31.6	29.7	30.3	31.0	31.2	30.6	31.0
90°	I	34.6	32.3	32.4	32.2	32.3	31.9	31.4	32.4	32.4
	II	32.6	31.8	32.8	31.6	30.2	31.3	31.4	31.5	31.7
	III	32.0	30.6	31.9	30.1	29.7	31.2	31.4	29.2	30.8
					August 8 Harvest					
50°	I	34.2	31.2	31.6	30.8	30.6	30.2	29.8	31.2	31.2
	II	31.9	31.0	30.9	31.2	29.6	29.9	30.1	30.2	30.6
	III	31.1	30.6	29.9	29.7	29.4	29.8	29.9	29.5	30.0
70°	I	34.2	31.4	32.4	32.1	31.4	31.4	32.6	31.2	32.1
	II	31.9	31.7	32.6	31.5	29.9	30.6	31.1	31.6	31.4
	III	31.1	30.4	31.7	31.2	30.1	31.6	29.8	30.1	30.7
90°	I	34.2	31.1	32.6	31.6	32.0	31.1	30.2	31.2	31.7
	II	31.9	31.0	32.4	30.6	30.2	30.4	31.3	31.6	31.2
	III	31.1	30.4	31.0	30.0	30.0	30.5	29.7	29.5	30.3

[a] Determined by dividing the fresh weight of potato slices into the weight of cooked slices and multiplying by 100.

Table 4b.--ANALYSIS OF VARIANCE FOR CHIP YIELD.

Source	df	SS	MS
Total	863	2001.812	
Harvest	5	54.487	10.898**
Temperature	2	63.909	31.954**
Treatment	2	73.806	36.903**
Storage period	7	11.840	1.691
H. X T.	10	476.472	47.647**
H. x Tr.	10	8.860	0.886
H. x S.	35	62.803	1.794
T. x Tr.	4	1.470	0.367
T. x S.	14	18.544	1.325
Tr. x S.	14	15.894	1.135
H. x T. x Tr.	20	53.377	2.669
H. x T. x S.	70	64.621	0.923
H. x Tr. x S.	70	75.072	1.072
T. x Tr. x S.	28	34.450	1.230
Remainder	140	175.229	1.252
Residual	432	810.978	1.877

Table 5a.--AMINO-NITROGEN (mg.Amino-N/100g) CONTENT OF TUBERS AS AFFECTED BY TREATMENTS, DATES OF HARVEST, STORAGE TEMPERATURES AND STORAGE PERIODS. (MEAN OF DUPLICATE SAMPLES).

Temperature	Treatment	Storage Days 0	3	6	9	12	15	18	21	Mean
					July 7 Harvest					
50°	I	21.3	26.0	13.0	16.6	18.6	18.6	17.8	20.0	19.0
	II	27.2	25.8	17.8	23.5	27.4	24.1	27.1	25.1	24.7
	III	36.4	33.3	20.3	23.1	27.2	29.0	34.6	32.1	29.5
70°	I	21.3	21.7	15.2	18.2	19.8	20.3	26.2	19.0	20.2
	II	27.2	26.0	20.1	21.9	28.0	23.0	29.9	25.3	25.2
	III	36.4	30.0	29.8	32.2	30.2	30.2	33.2	31.2	31.6
90°	I	21.3	21.3	22.9	21.7	24.1	24.1	26.4	28.2	23.7
	II	27.2	26.6	24.7	25.5	32.3	29.2	33.7	33.4	29.1
	III	36.4	28.8	30.2	31.2	32.4	32.2	47.4	37.8	34.5
					July 11 Harvest					
50°	I	21.9	17.0	20.4	21.0	21.5	28.5	22.1	22.1	21.2
	II	18.5	22.1	27.9	22.7	26.4	24.9	25.4	24.7	23.4
	III	26.4	28.8	28.6	34.2	36.2	35.9	37.7	32.8	32.6
70°	I	21.9	17.6	19.4	22.7	21.2	21.2	23.9	22.7	21.3
	II	18.5	19.4	21.9	22.7	22.1	25.1	23.1	24.1	22.1
	III	26.4	27.2	26.6	35.4	29.7	35.6	34.0	36.6	31.4
90°	I	21.9	20.4	22.5	23.7	26.4	31.2	24.1	27.8	24.7
	II	18.5	21.7	26.6	25.1	30.0	31.7	31.6	29.3	26.8
	III	26.4	28.4	32.0	30.8	35.6	38.1	38.7	38.2	33.5

Table 5a.--(continued)

Temperature	Treatment	Storage Days 0	3	6	9	12	15	18	21	Mean
					July 18 Harvest					
50°	I	17.8	20.4	24.3	25.1	24.0	20.6	24.2	24.8	22.6
	II	26.4	29.0	32.6	32.4	37.2	30.0	31.6	32.0	31.4
	III	37.7	42.4	47.0	49.4	49.0	45.8	41.7	42.8	44.6
70°	I	17.8	24.8	26.6	23.5	19.8	23.4	28.0	21.4	23.2
	II	26.4	30.2	30.4	34.6	31.2	35.2	35.2	32.8	32.0
	III	37.7	43.4	40.5	40.6	41.7	48.6	46.6	54.3	44.2
90°	I	17.8	23.7	28.6	25.8	29.0	30.0	39.3	28.0	27.8
	II	26.4	28.2	29.6	39.3	38.4	37.6	43.4	39.7	35.3
	III	37.7	38.4	43.5	49.5	44.1	51.8	53.5	48.2	45.8
					July 25 Harvest					
50°	I	26.0	29.2	29.2	25.8	30.4	26.8	27.2	25.1	27.4
	II	26.4	26.2	30.8	35.4	32.0	30.8	28.0	25.5	29.4
	III	36.9	34.2	36.2	37.6	34.4	32.4	36.4	38.1	35.8
70°	I	26.0	31.0	27.8	29.6	31.2	25.8	30.8	26.8	28.6
	II	26.4	27.4	28.2	35.6	29.6	30.8	29.6	28.3	29.5
	III	36.9	36.1	35.9	36.9	34.1	37.3	38.1	43.8	37.4
90°	I	26.0	31.8	31.6	30.7	31.2	28.0	31.6	37.8	30.4
	II	26.4	31.0	30.8	34.4	36.0	30.4	30.8	37.3	32.1
	III	36.9	37.1	39.8	43.7	45.0	36.4	42.6	41.7	40.4

Table 5a.—(continued)

Temperature	Treatment	Storage Days 0	3	6	9	12	15	18	21	Mean
					<u>August 1 Harvest</u>					
50°	I	29.4	32.0	30.8	25.0	32.0	24.6	26.4	30.4	28.8
	II	31.0	30.0	30.4	29.5	30.8	28.8	34.8	32.4	31.0
	III	43.4	43.4	40.8	34.9	38.0	32.6	44.1	43.4	40.2
70°	I	29.4	30.0	29.6	28.4	24.6	25.4	33.7	33.2	29.3
	II	31.0	27.6	31.6	28.8	28.8	31.2	32.4	31.2	30.3
	III	43.4	47.0	40.5	38.0	43.0	40.8	43.0	43.8	42.4
90°	I	29.4	28.3	35.2	30.4	31.6	29.2	39.2	32.0	31.9
	II	31.0	30.8	30.8	33.6	32.8	34.8	35.2	38.1	33.4
	III	43.4	48.2	49.8	43.8	39.8	45.0	49.9	50.6	45.5
					<u>August 8 Harvest</u>					
50°	I	32.4	29.3	27.1	28.0	28.8	39.5	32.0	28.4	29.4
	II	32.4	32.4	31.6	32.8	31.7	31.2	30.0	34.0	32.0
	III	37.3	42.9	40.5	39.3	40.2	39.2	39.4	38.8	39.7
70°	I	32.4	35.2	28.8	31.2	32.0	33.9	32.0	34.8	32.6
	II	32.4	34.9	32.0	35.2	32.0	33.2	33.5	36.0	33.7
	III	37.3	37.6	37.3	39.7	44.0	41.4	39.3	43.4	40.0
90°	I	32.4	30.0	28.0	36.4	34.9	38.6	32.0	34.4	32.7
	II	32.4	32.4	34.9	38.8	40.2	41.0	39.7	41.0	37.5
	III	37.3	44.2	41.0	45.4	47.8	43.8	46.6	54.7	45.1

Table 5b.—ANALYSIS OF VARIANCE FOR AMINO-NITROGEN.

Source	df	SS	MS
Total	863	55527.360	
Harvest	5	11276.969	2255.394**
Temperature	2	769.800	384.900**
Treatment	2	4887.538	2443.769**
Storage period	7	535.288	76.470*
H. x T.	10	14034.962	1403.496**
H. x Tr.	10	506.790	50.679
H. x S.	35	1013.630	23.961
T. x Tr.	4	414.852	103.713*
T. x S.	14	169.161	12.083
Tr. x S.	14	332.095	23.721
H. x T. x Tr.	20	1551.152	77.558**
H. x T. x S.	70	964.065	13.772
H. x Tr. x S.	70	933.942	13.342
T. x Tr. x S.	28	290.250	10.366
Remainder	140	1923.703	13.741
Residual	432	15923.165	36.859

Table 6.--SPECIFIC GRAVITY OF TUBERS OF THE VARIETY IRISH COBBLER, AS AFFECTED BY INJURY. JULY 25 HARVEST.

Temperature	Treatment	Storage Days								
		0	3	6	9	12	15	18	21	Mean
50°	Check	1.078	1.082	1.080	1.082	1.088	1.087	1.090	1.083	1.084
	Injury	1.078	1.086	1.090	1.091	1.081	1.089	1.082	1.088	1.086
70°	Check	1.078	1.086	1.086	1.082	1.080	1.086	1.087	1.085	1.084
	Injury	1.078	1.087	1.086	1.084	1.084	1.096	1.089	1.088	1.086
90°	Check	1.078	1.082	1.082	1.077	1.078	1.084	1.080	1.083	1.080
	Injury	1.078	1.085	1.080	1.080	1.087	1.084	1.085	1.084	1.083

Analysis of Variance

Source	df	SS	MS
Total	47	0.00084	
Treatment	1	0.00007	0.000070*
Storage period	7	0.00034	0.000049*
Temperature	2	0.00012	0.000060*
Tr. x S.	7	0.00002	0.000003
Tr. x T.	2	0.00000	0.000000
S. x T.	14	0.00008	0.000006
Residual	14	0.00021	0.000015

Table 7.--AMINO-NITROGEN (MG AMINO-N/100 GM) CONTENT OF TUBERS OF THE VARIETY IRISH COBBLER, AS AFFECTED BY INJURY. JULY 25 HARVEST.

Temperature	Treatment	Storage Days								
		0	3	6	9	12	15	18	21	Mean
50°	Check	26.4	29.2	29.2	25.8	30.4	26.8	27.2	25.1	27.5
	Injury	26.4	25.1	30.3	30.0	26.6	25.9	25.1	23.4	26.6
70°	Check	26.4	31.0	27.8	29.6	31.2	25.8	30.8	26.8	28.6
	Injury	26.4	32.0	28.4	22.6	29.3	27.6	30.0	35.7	29.0
90°	Check	26.4	31.8	31.6	30.7	31.2	28.0	31.6	37.8	31.2
	Injury	26.4	37.2	33.1	34.8	35.7	25.1	33.9	30.8	32.1

Analysis of Variance

Source	df	SS	MS
Total	47	594.29	
Treatment	1	0.21	0.21
Storage period	7	134.46	19.21
Temperature	2	170.18	85.09**
Tr. x S.	7	3.63	0.52
Tr. x T.	2	7.44	3.72
S. x T.	14	126.43	9.03
Residual	14	151.94	10.85

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THESIS ABSTRACT

CAUSES OF POST HARVEST DISCOLORATION OF POTATO CHIPS FROM SUMMER POTATOES

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ABSTRACT

Early summer potatoes are harvested from the Gilcrest and Rockyford areas in Colorado. Potato chip processors use these newly harvested potatoes and have found them to be erratic in performance, some lots producing light colored chips, others making a dark undesirable product. Information is lacking on the causes of this after harvest darkening.

Three plots (a high fertility, a low fertility and a low fertility plus 120 lbs. of nitrogen) were planted using the variety Irish Cobbler. These plots were located in the Gilcrest early potato producing area. Potatoes were harvested July 7, 11, 18, 25, August 1 and 8, and placed into 50°, 70° and 90°F storage. An injury treatment was added to the July 25 harvest. At three day intervals over a period of 21 days, respiration, chip color and some chemical analyses were determined.

Results show that immature potatoes can not be held in storage for chipping purposes. Delaying the date of harvest will improve the storage capability.

Storage at 50°F is detrimental to summer chipping potatoes. Storage at 70°F or above is recommended.

The trend of treatment was that potatoes from Treatment II (low fertility, no nitrogen) produce the lightest colored chips.

Injury to tubers increases sugar accumulation and results in darker chips.

The high non-reducing sugar content of early potatoes may be the main cause of after harvest darkening of potato chips. This high sugar content may be a readily available source of sugar, easily converted into reducing sugars, which in turn causes the potatoes to darken when chipped.