THE EFFECTS OF NITROGEN PHOSPHORUS AND POTASSIUM FERTILIZATION ON THE QUALITY AND CHEMICAL COMPOSITION OF POLE BEANS

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INTRODUCTION

The growing of pole beans for canning and freezing is a major industry in Western Washington and in the Willamette Valley of Western Oregon. Much expansion of acreage has occurred since World War II.

The well-being of the industry is dependent on a high yield per acre of a high quality product. Publications of both the Oregon and Washington Agricultural Experiment Stations have pointed out the necessity of correctly fertilizing the crop to secure large yields (9, 15). More recently, the Oregon Agricultural Experiment Station has undertaken a comprehensive study of the yield responses of pole beans to several nutrient elements. This work has now progressed sufficiently that one can estimate the needs of pole beans for nitrogen, phosphorus, and potassium to produce maximum yields.

During the course of the research on the effect of fertilizers on yield, several interested processors and growers have inquired about the effect of the various fertilizer elements on the quality of the bean crop. There have been claims, for example, that the use of potassium improves the quality of processed beans, and also results in a minimum of deterioration when beans are stored during periods of peak harvest. For those reasons many growers use potassium as a part of their soil fertility program, even though resultant yield increases have often been insufficient to justify the expense.

A study of the effect of fertilizers on the quality of canned and frozen beans was initiated in 1952. Although growers' and processors' inquiries have centered about the effect of potassium on quality, the study was organized to include the effects of nitrogen and phosphorus as well.

In this study "quality" is defined as an "integration of those factors in a food which affect its utilization by the consumer". To implement this definition, numerous factors having relationship to quality of beans were evaluated. These included objective determinations of color, seed content, crude fiber, and resistance to shear; and subjective grading of color, texture and maturity, and absence of defects. The latter information was supplemented by subjective scoring of appearance and flavor.

"Chemical composition" as used in this study refers to the nitrogen, phosphorus, potassium, calcium, magnesium and total ash content of the beans. Determinations of the first three elements were made to see if fertilization had significantly affected the composition of the beans in respect to these elements. Calcium was determined because of its nutritional importance. Determination of magnesium was made because its behavior is often similar to that of calcium. Total ash content was determined as an aid to interpretation of data from determinations of the several individual elements.

The results of two years' study are reported in this dissertation.

REVIEW OF LITERATURE

A survey of the literature was undertaken in 1951. The decision to accept the project, the methods used, and the interpretation of the results were affected to a considerable degree by pertinent findings in the literature.

Basic Concepts of Role of Potassium in Plant Nutrition

There have been many attempts to establish the role of potassium in plant nutrition. Mulder (39, p.10) credited to Hoagland the statement that "at one time or another almost every important physiological process in the plant has been attributed to potassium". Hewitt (30, p.25) pointed out the fact that apparently no one has been able to definitely establish the role of this element. He did state, however, that it was his opinion that potassium, and to some extent calcium in complementary fashion, serves to maintain cell organization, hydration, and permeability. In this way, enzyme systems are affected. Cooil and Slattery (17, p.432) observed that condensation of carbohydrates was restricted in low-potassium plants. This was interpreted by Hewitt (30, p.25) to be due to an effect of potassium on enzymes. Reduced condensation activity resulted in accumulation of simple sugars. Naturally higher molecular weight carbohydrates are limited under such conditions. As early as 1907 Reed (44, p.520) made this observation. Several workers have found carbohydrate changes due to potassium, but they do not always agree. Gregory (27, pp.565-568) reported that potassium deficiency in barley lowered reducing sugar and led to a very low total sugar content. He further stated that the effect of potassium deficiency is largely dependent on the presence of other cations, particularly calcium and sodium. Gregory also found that potassium affects nitrogen metabolism, potassium deficiency being characterized by (a) a marked increase in soluble nitrogen, and (b) a very rapid break-down of protein during senescence of leaves. He held that potassium is not primarily associated with protein synthesis but is necessary for maintaining the protoplasmic complex, and in the absence of potassium proteolysis occurs. This was interpreted by Hewitt, cited earlier, as an effect on "cell organisation, hydration, and permeability".

Potassium absorption has been observed to be related to the absorption of other cations by plants. Liebig's concept was cited by Bear, Toth, and Prince (3, p.380) in a discussion of this point. They stated that a modern statement of Liebig's concept would be: "under uniform conditions for growth, except for limited variations in the relative amounts of the several cations in the nutrient media; the sum of the Ca, Mg, K, and Na expressed as milliequivalents of dry matter is a constant for any given plant variety". According to these same authors, the highest degree of constancy is found in the terminal leaves. York, Bradfield and Peech (54, pp.53-63) found this relationship to be generally true, although there often was divergency resulting from potassium fertilization. This led them to conclude that potassium appeared to play a dominant role in regulation of absorption of cations in plants.

Drake and Scarseth (20, p.201) stated that relationships between potash fertilization and the growth, quality, and composition of different crop plants were similar. In tobacco they found that as the percent of potassium oxide increased, the percent of calcium oxide and magnesium oxide decreased. Their data showed that calcium oxide and magnesium oxide percentages were above 1% in potassium deficient plants, whereas magnesium oxide dropped to a level of about .4% and calcium oxide dropped to below 1% in plants of sufficient potassium content. Potassium oxide percentage increased from about .25% to more than 2% with increased fertilization. Hoagland (31, p.164) pointed out that "Many researches have shown that alteration of soil or culture medium to increase potassium absorption reduces absorption of calcium and magnesium. Increase of calcium and magnesium also reduce potassium absorption, but the effect is far less marked."

In a general review of the effect of mineral concentration on the chemical composition of plants, Beeson (5, p.429) stated that there seems to be general agreement that the phosphorus content is either unchanged, or lower, where potassium has been supplied as a fertilizer. This review further pointed out that high applications of nitrogen, particularly ammonium sulfate, have been associated with a lower calcium concentration.

Potassium Deficiency Effects on Plant Composition and Structure

Burns (14, pp.314,315) studied the effect of nitrogen and potassium deficiency on the composition and structure of tobacco stems. Percentage dry weight, percentage of parenchyma, and percentage of carbohydrates were depressed due to potassium deficiency. Nitrogen deficiency, on the other hand, was characterized by an increase in the dry weight content of the pith and an increase in the carbohydrate content of pith and cortex. The percentage nitrogen in the pith and cortex was low in these plants. However, the percentage potassium was very high in the cortex. Plants lacking potassium had a lower percentage of potassium in pith and cortex, but a higher nitrogen content. The potassium and nitrogen deficiency was so severe in this experiment that growth was severely retarded. Burns' observation that increase in carbohydrate content resulted from nitrogen deficiency was perhaps first pointed out by Kraus and Kraybill (36) and has been the conclusion of many investigations made since that time.

Nightingale, Schermerhorn, and Robbins (40, p.12) observed that young tomato plants grown under conditions of potassium deficiency exhibited stiff, woody stems with high starch content. Thus, a depressed carbohydrate content does not always occur as a symptom of potassium deficiency. Tomato plants receiving high amounts of potassium exhibited symptoms usually attributed to high nitrogen conditions such as soft, succulent stems and delayed fruiting.

The degree of potassium deficiency may govern the effect of potassium on carbohydrate accumulation, according to Nightingale, Schermerhorn, and Robbins (40, p.33). They pointed out that potassium may be essential for carbon dioxide assimilation, and therefore carbohydrate concentration may be low. However, if nitrate assimilation is inhibited through lack of potassium, carbohydrates may accumulate.

Janssen and Bartholomew (32, pp.255, 259) called attention to the effect of concentration of potassium on the production of carbohydrates. Tabular data in their report indicated that dry weight, sugar, and starch percentages did not necessarily increase with increased potassium. More potassium was absorbed from nutrient solutions containing large amounts of this ion than was actually required for the needs of the plant. They concluded that the greatest percentage of sugars and starch occurred in solution cultures of two and three parts per million potassium, which was below the concentration of maximum absorption of potassium. Their data also indicated a difference in species requirement for potassium. Soy beans and oats responded well in solutions up to ten parts per million, while cotton did best on nutrient solutions containing two to three parts per million.

Effects of Potassium and Other Nutrient Elements on Crop Quality

Beeson (5, p.424) observed that most fertilizer experiments have been concerned with crop yield rather than with crop quality.

Methods of determination of quality have also been slow to develop.

Beaumont and Chandler (4, pp.37,38) studied the effect of potassium on the firmness and keeping quality of apples and peaches over a period of six years. Firmness was measured with a pressure tester. Their data indicated that freshly harvested fruits grown on trees fertilized with nitrogen were slightly firmer than those from trees which received potassium or potassium plus phosphorus. After storage, the fruit grown on trees receiving nitrogen and five pounds of potassium chloride per tree were the softest, being softer than those receiving nitrogen and ten pounds of potassium chloride per tree. The differences were small.

Peaches from trees receiving only nitrogen were more firm when picked than were peaches from trees receiving potassium or potassium plus phosphorus. After storage, the fruit from trees receiving nitrogen alone and nitrogen plus five pounds of potassium chloride per tree were less firm than those receiving nitrogen plus ten pounds of potassium chloride per tree, or those receiving nitrogen, potassium, and phosphorus. It thus appeared that potassium was an aid in keeping peaches firmer during storage. Again, the differences were relatively small.

Gourley and Howlett (26, p.156) discussed the frequent lack of response of tree fruits to potassium and phosphorus. They suggested that much of the potassium may be reutilized. The large root system of trees plus storage reserves were cited by these writers as reasons for the many failures to secure yield responses to potassium and phosphorus. They stated that many orchardists have for years used only nitrogen, and even in the case of nitrogen, there were conflicting results. Most nitrogen experiments reported an increase in fruit size, but a reduction in number of fruits. Thus, the overall effect on yield was not always favorable, and the effect of nitrogen on color was usually unfavorable. Hence, some compromise often had to be made between color and yield. Boynton (10, pp.279-280) presented an excellent discussion of the nitrogen problem on McIntosh apple in New York. He stated that:

"Nitrogen is more apt to limit the productivity of apples under sod conditions than any other nutrient. It has also been realized that apple trees receiving heavy doses of nitrogen fertilizer may produce fruit of markedly less color and quality than trees not receiving added nitrogen." In some experiments, even though the size of the apples was increased by nitrogen, the yield of fancy fruit was less. This was due to the marked effect of nitrogen on color. Growth phenomena that were most important in determining yield occurred early in the growing season. Thus, a relatively high nitrogen status of the tree, favoring high yield, was desired early in the season, and a relatively low nitrogen status, favoring high fruit quality, was desired late in the season.

In an investigation of factors influencing yield and quality of peas, Boswell (8, 352) studied potash in particular. Growers at that time (1929) were of the opinion that large amounts of potash caused peas to mature very rapidly and to produce a product that was hard and starchy. Boswell reported that he could find no consistent response to muriate of potash in respect to yield, rate of maturity, or quality. This work was carried on for five years at various locations in Maryland.

Sayre, Willaman, and Kertesz (46, pp.45-57) reported some interesting work on potassium effects on peas in New York. There was a conviction among growers at that time (1929) that potassium chloride fertilization caused tough peas. Fertilizer plots were established in the field and were followed by nutrient solution experiments in the greenhouse. Judges could find no significant quality differences in the product in the 1929 experiments. The experiments were repeated in 1930, the data indicating that (1) when potassium content of peas increased, calcium content decreased, and (2) higher calcium content resulted in tougher peas. Marked differences in calcium and potassium content of pea plants was found in greenhouse experiments established as a part of this study. A high calcium content in any part of the plant was always accompanied by a low potassium content, and vice-versa (p.57).

Hester (29, pp.306-307) reported a similar case in scotch peas being used for soup manufacture. The soil in which the peas were grown had a pH of between 7.0 and 8.5 and was very high in replaceable calcium and magnesium, and very low in replaceable potassium. The peas were difficult to cook, sometimes becoming harder after cooking. Greenhouse tests indicated a yield and a quality response to potassium. Peas on potassium-treated soil were more pleasingly green and cooked more rapidly than peas from the check plots.

Canners have known for years that blanching peas in hard water causes toughening. This is due to intake of calcium and magnesium and may be corrected by use of treated water or addition of sodium or potassium to the water used for blanching and quality grading. Common table salt is a practical treatment.

Hester (29, p.300-304) stated that the two most important factors which influence the quality of tomatoes are soil and climatic conditions. He showed fruit quality data to illustrate a good, fair, and poor season. Fruits harvested during "good" seasons were characterized by higher total solids, higher sugars, higher titrable acids, and higher ascorbic acid content. Soil type influenced yield and quality of tomatoes, Sassafras loam producing better quality tomatoes than Edgemont stony loam. This influence of soil types was believed by Hester to be primarily a question of difference in fertility factors. In the way of specific effects Hester pointed out defoliation of tomatoes caused by potassium deficiency. Exposed tomatoes were sun-burned. High calcium applications often brought about loss in quality due to magnesium deficiency. The sugar content of such fruits was low.

Workers at Ohio State University conducted a three-year study on the effect of fertilizers on the quality of table beets.

The results were published by Blackmore, et al (7, pp.545-548). The elements studied were nitrogen, phosphorus, and potassium, at different levels and in different combinations. Although the plots were not replicated and some of the quality observations were purely descriptive, the results reported are of considerable interest. Red table beets from the minus potassium plots were "woody" and those from the minus phosphorus plots had little flavor. Those from minus nitrogen plots had a strong, bitter flavor. Phosphorus and nitrogen applications had the greatest effect on yield, this being expressed as an increase in size of the beets. Starch was lowest in the double potassium plot, which received 160 pounds per acre of potassium oxide. The nitrogen content of the beets was lowest in the minus nitrogen plots. Phosphorus was a little higher in beets from the plots receiving the highest phosphorus treatment of 400 pounds per acre of phosphoric acid. There was a wide range in potassium content, this being much lower in plots not receiving potassium and much higher in plots receiving high amounts of potassium-containing fertilizer.

Patton, Gorrell, and Brown (42, p.226) measured hardness of these beets, using a penetrometer on cooked slices. Hardness of beets is a common horticultural problem. Although the results showed considerable variation, the writers stated that beets from plots which did not receive nitrogen and potassium were the least tender, as measured by the penetrometer. These fertilizers resulted in a yield response in both an early and a late planting.

Perhaps these effects on beets can be attributed to known effects of nitrogen and potassium on succulence and carbohydrate content. In vegetables this effect has been found in leaves, stems, tubers, hypocotyls, and roots, according to literature already cited.

Storage Time and Temperature Effects on Green Beans

Parker and Stuart (41, pp.299-312) conducted a study on the effect of temperature of storage and time of storage using two sieve size groupings of beans. They did not directly measure quality changes or grade changes, but determined such chemical constituents as sugars, starch, pectin, protein nitrogen, non-protein nitrogen, and hemicellulose. While these factors do not measure quality directly, some of them have quality implications. The variables in this study were as follows:

(A) Size of beans: Sieve sizes No. 2 and 3 vs. sieve sizes 4 and 5
(B) Time and temperature of storage:
  Lot 1. Sampled fresh
  Lot 2. Stored at 82.4° F., sampled at 48 hours and 91 hours
  Lot 3. Stored at 40° F., sampled at 48 hours and 95 hours
  Lot 4. Stored at 36° F., sampled at 48 hours and 95 hours

Chemical changes of the beans in the various lots were as follows:

(a) At 82.4° soluble nitrogen fractions increased in the small beans, but protein nitrogen increased in the large beans. This indicated proteolysis in the small beans, while somewhat normal protein synthesis continued in the large beans.

(b) At 36° and 40° the protein nitrogen fraction of both small and large beans increased slightly, while soluble nitrogen fractions remained the same or decreased slightly. This indicated that nitrogen metabolism was stabilized by these storage temperatures.

(c) The percentage loss in weight was much greater at 82° F. storage than at the low temperatures (p.298). There was no noticeable difference between small and large beans in this respect. Although respiration was high, the data on carbon dioxide evolution indicated that 99% of the weight loss was actually due to water loss.

(d) Sugar changes were also very important. Percentage sucrose was greatly increased during the first 48 hours at 82° F., then decreased slightly at 91 hours. Reducing sugars were much higher in the fresh beans and decreased steadily when the beans were held at 82° F. When the beans were stored at low temperatures the total sugars, reducing sugars, and sucrose increased throughout the storage period.

(e) Starch decreased very rapidly when the small beans were held for 48 hours at 82° F. There was some increase in the 91 hour sampling. In the case of the large beans, the original starch content was higher and a gradual, slower decrease in starch occurred at 82° F.

(f) Storage at low temperatures (36° F. and 40° F.) did not alter the starch changes in small beans. The loss in starch percentage was greater than 60%. The loss in starch in large beans stored at low temperatures was much more moderate (up to 25%).

Quality Measurement of Green Beans

The United States standards for canned green beans (51) gives the following credit to the quality factors listed below:

Factor	Maximum Score	Limiting Rule
1. Clearness of Liquor	10	4 or below—D grade
2. Color	15	11 or below—C grade 9 or below—D grade
3. Absence of Defects	35	26 or below—C grade 21 or below—D grade
4. Maturity	40	34 or below—B grade 28 or below—C grade 22 or below—D grade

The United States standards for frozen green beans (50) are set up slightly differently. The scores, subjectively determined by professional graders, are as follows:

Factor	Maximum Score	Limiting Rule
1. Color	20	17 or below—B grade 15 or below—C grade 13 or below—D grade
2. Absence of Defects	40	35 or below—B grade 31 or below—C grade 27 or below—D grade
3. Texture and Maturity	40	31 or below—C grade 27 or below—D grade

Rowe and Bonney (45, pp.621-628) developed the seed-weight method for determining green bean maturity and the alkali digestion method for determining crude fiber. They also developed a method for determining the toughness of bean strings. Their data indicate the relationship of these values to grade. They found .08% fiber to be the maximum for standard grade. The maximum seed percentage for standard grade was 6%. Furthermore, not more than one tough string per two ounces of beans was allowable in standard grade.

These methods were widely used. However, the technique for crude fiber was found to give variable results. To clarify the situation, the Federal Food and Drug Administration (52, pp.3727, 3728) redescribed the methods in detail.

Kramer (33, p.60) has stated that the important factors of quality for green and wax beans are maturity, fibrousness, and color. Although there are varietal differences, in general, maturity may be determined by the proportion of seeds to pods. This proportion is on the weight basis. Kramer cites the official alkali digestion method as suitable for fibrousness. The Federal Food and Drug limit on fiber is .15% determined by this method. Kramer mentioned his blender-fiber method as being more rapid, and in a later paper (34, pp.32-33) presented details of the method.

Gould (24, p.68) suggested that the maximum seed tolerance for grade A should be 8%, by weight; for grade B, 16%; and for grade C, 25%. In respect to percentage of fiber he suggested that the maximum for grade A should be .05%; for grade B should be .10%; and for grade C, .15%. All percentages are on the fiber weighed in the dry condition; the pods being de-seeded and weighed in the wet condition.

In a later paper (25, p.42-44) Gould presented data on fiber as affected by variety and maturity. In his experiments, variety was more important than maturity in determining the fiber level. The effect of maturity was also conditioned by variety. The beans of some varieties became fibrous earlier than others, and some were more fibrous than others over a wide maturity range. The percentages reported by Gould from Ohio-grown beans were much higher than those from Oregon (1, p.24).

The paper of Guyer, Kramer, and Ide (28, p.308) presented some very interesting correlations between several different quality measurements on fresh and canned beans. Some of these are as follows:

% Seed, Fresh beans vs. % Seed, Canned beans	r of .900
% Seed, Fresh beans vs. % Moisture	r of .555
% Seed, Canned beans vs. % Moisture	r of -.881
% Seed, Fresh beans vs. Organoleptic maturity	r of -.790
% Fiber, F.D.A. Method vs. Organoleptic maturity	r of -.620
% Seeds, Canned beans vs. Organoleptic maturity	r of -.647
% Fiber, Blender Method vs. Organoleptic maturity	r of -.933
% Fiber, F.D.A. Method vs. % Seed, Canned beans	r of .869
% Fiber, Blender Method vs. % Seed, Canned beans	r of .837
% Moisture vs. Organoleptic maturity	r of -.754

Shah and Worthington (47) used the Hunter Color and Color Difference Meter for objective determination of color in strawberries. Wiley (53) used the same instrument for measurement of color in prunes.

Kramer (35) developed the Maryland shear press for use in determining resistance to shear. This property is believed to be related to organoleptic quality in some food products.

MATERIALS AND METHODS

Production of Beans Used in this Study

The pole beans were grown at the Beach farm of the Horticulture Department, two miles east of Corvallis, Oregon. The crops of both 1952 and 1953 were grown on Chehalis silt loam, which is widely used for pole beans in the Willamette Valley. The variety used was Associated 231, a high-quality pole variety. Crops were grown with sprinkler irrigation, and culture was such that good growth was obtained. Yields were commensurate with the fertilizer practice used.

In the 1952 plots 28 different treatments were used. These were replicated five times, in randomized blocks. Basically, the design was factorial; with three levels of nitrogen (0-50-100 pounds N per acre), three levels of phosphorus (0-120-240 pounds P_2O_5 per acre), and two levels of potassium (0-100 pounds K_2O as KCl per acre). Four extra treatments of potassium as the sulphate were added and, also, four miscellaneous treatments. All these treatments, together with yields and sieve size data, are to be found in Appendix Table 1 of this dissertation.

The treatments chosen for studies of quality and chemical composition formed a 2 x 2 x 3 factorial experiment with four replications in a randomized block design. The nitrogen levels were 0 and 100 pounds, as N; phosphorus levels, 0 and 120 pounds as P_2O_5; potassium levels, 0 and 100 pounds as K_2O. There were two sources of potassium, the chloride and the sulphate. In addition, a treatment designed to test the effect of sulphur was included. This treatment was made up of sulphur-free diammonium phosphate and was applied to furnish nitrogen at 100 pounds per acre and phosphoric acid at the rate of 120 pounds per acre.

The 1953 field plots differed from the 1952 plots as follows:

1. Potassium chloride was used as the only source of potassium.
2. Phosphorus levels were 0, 60, and 120 pounds of P_2O_5 per acre.
3. All plots received a uniform application of 50 pounds of N per acre (calcium cyanamid) prior to plowing under the cover crop.
4. Levels of potassium used were 0 and 60 pounds of K_2O per acre.

The basic design of the field fertility experiment was a 2 x 3 x 2 factorial, with two extra treatments and six miscellaneous treatments. The factorial treatments were two levels N (0-50 pounds N per acre), three levels phosphorus (0-60-120 pounds P_2O_5 per acre), and two levels of potassium (0-60 pounds K_2O per acre). These were replicated five times, in randomised blocks. All are to be found, together with yields and sieve sizes of harvested beans in Appendix Table 3.

The treatments chosen for studies of quality and chemical composition form a 2 x 2 x 2 factorial design with two extra treatments and four replications, randomized block design. Nitrogen levels were 0 and 50 pounds as N; phosphorus, 0 and 120 pounds as P_2O_5; and potassium, 0 and 60 pounds as K_2O. Extra treatments were 100-0-0 ($N - P_2O_5 - K_2O$) and 100-120-0.

Handling and Processing of the Beans

Harvesting always began in the early morning. After plot weights were taken, the beans were brought to the Food Technology building and graded into sieve sizes 1, 2, 3, 4, 5, 6 and larger. This grading was done on a mechanically operated grader. After weights of the different grades were taken, beans of sizes 4 and 5 were combined to form the "4 and 5" combination used in this study. Sieve size 3 was studied by itself. The small beans of sizes 1 and 2 and the large beans of size 6 and larger were not studied. Beans to be stored were placed in net bags and transferred to the 36° F. storage room. The storage period was six days in all cases. "Fresh" beans were processed the day they were harvested, in all cases.

Mechanical snipping followed grading. As the beans passed out of the snipper, crooked and misshapen beans were picked out and weighed. Percentage by weight was recorded. The beans were then cut to one-inch lengths and passed over a screen to remove as many fragments of seeds and end-cuts of pods as possible.

Washing and blanching in steam followed. The blanching time for the 1952 pack was four minutes. Since some sloughing of the epidermis was noted, the time was cut to three minutes for the 1953 pack. Immediately after blanching, the beans were cooled with cold water; then transferred to a stainless steel packing table.

Type L plain tin cans of 301 x 411 size were filled to 9½ ounces and a 30 grain salt tablet added. The cans were then filled with water and heat exhausted to a center temperature of 180° F. The cans were next closed and processed for twenty minutes at 240° F. Afterwards, they were water-cooled and placed in storage at 60°-65° F.

Beans to be frozen were put into cellophane liners fitted into Marathon cartons. The fill was 9½ ounces. After heat sealing, the packages were placed in an air blast freezer at -15° F. overnight, then stored at -5° F.

Beans from four replications of each fertility treatment were kept separate throughout processing, so that the data could be evaluated statistically. Samples were secured from pickings made both early and late in the harvest season.

During 1952, 520 lots of beans were packed for quality and chemical composition studies. The handling and processing groups included the following:

(1) Sieve size - size 3 and size 4 and 5 combined

(2) Harvest season - early and late

(3) Storage - processed while fresh and processed after storage for six days at 36° F.

(4) Process - canned and frozen

The number of lots packed under each of these groups of lots are listed in groups as follows:

Number of lots	Sieve Size	Harvest Season	Storage Condition	Process Used
52	3	early	fresh	canned
52	3	early	fresh	frozen
26	3	late	fresh	canned
26	3	late	fresh	frozen
26	3	late	stored	canned
26	3	late	stored	frozen
52	4 and 5	early	fresh	canned
52	4 and 5	early	fresh	frozen
52	4 and 5	late	fresh	canned
52	4 and 5	late	fresh	frozen
52	4 and 5	late	stored	canned
52	4 and 5	late	stored	frozen

Since the supply of the size 3 beans in the late harvest was very limited, only two replications were possible; thus reducing the lots packed in those groups to 26.

The number of lots packed under each of these groupings in 1953 was 400, listed as follows:

Number of lots	Sieve Size	Harvest Season	Storage Condition	Process Used
40	3	—	fresh	canned
40	3	—	fresh	frozen
40	3	—	stored	canned
40	3	—	stored	frozen
40	4 and 5	early	fresh	canned
40	4 and 5	early	fresh	frozen
40	4 and 5	early	stored	canned
40	4 and 5	early	stored	frozen
40	4 and 5	late	fresh	canned
40	4 and 5	late	fresh	frozen

The supply of size 3 beans was not sufficient to obtain lots from all fertilizer treatments at any one harvest period. Therefore, they were not classified as to time of harvest.

The handling and processing of the product was sufficiently good that high quality was maintained, as indicated by Agricultural Marketing Service Grades.

Quality Determinations Made on the Processed Beans

Quality determinations were started about four weeks after packing. Frozen beans were thawed by boiling for eight minutes, then were cooled in a refrigerated room before being examined for quality.

Color determination - Color was objectively determined with the Hunter Color and Color Difference Meter (23). The color was evaluated by three readings, the "Rd", "a", and "b". "Rd" is luminous reflectance at 45°. Its increase indicates a higher degree of reflectance. It can be converted into Munsell "value", but this was not done since the "Rd" readings are meaningful without conversion. However, the Hunter "a" and "b" readings have no meaning until they are converted into some psycho-physical system such as the Munsell. In this system "a" and "b" are coordinates for Munsell "hue" and "chroma". In this study, readings were taken as "a" and "b" and statistical analysis of these readings were made. However, any significant changes were interpreted in terms of Munsell "hue" and "chroma".

National Bureau of Standards plate SKC-15 ("Kitchen Green") was used as the color standard. There was no information on methods to be used for beans; therefore, methods had to be developed in this investigation.

Blending of beans was tried, but since it was necessary to add water to the beans for proper blending, the color was diluted. Water ratio was thus a variable in this procedure. Color determinations on the whole pieces, placed in clear plastic exposure dishes, appeared to be more satisfactory; so this procedure was used.

Another problem was whether the cut beans should be placed side by side in the dish in orderly arrangement or should be poured in, to fall in random fashion. A number of preliminary color determinations were made using both methods of arrangement. It was found that the variances of readings made by the two methods were not significantly different. Certainly, the systematic arrangement did not reduce variation among readings. Therefore, random arrangement was used.

Variation among individual readings was known to be considerable, hence it was necessary to take several readings on each sample. Four readings per sample were made in 1952, as follows:

Two 3" x 2.5" x 1.5" plastic dishes, matched to give equal Rd readings, were filled with beans. Liquid brine from the can, or water used for thawing, was added to fill the dishes. Two Hunter readings for Rd, "a", and "b" were taken on each dish, the rectangular dishes being turned between the two readings. Beans were then poured back into the original container. The dishes were then refilled and a second set of readings taken. The average of these four readings for "Rd", "a", and "b" constitute a single observation.

In 1953, a simpler method was devised. Beans were poured into a clear plastic sandwich tray of the dimensions, $1\frac{1}{2}$" x 4.5" x 4.5". Five readings were taken - one from the center and one from each of the four corners. The average of these five readings constituted a single observation statistically.

Seed determinations - Pods were de-seeded by hand, and the weight of wet seeds per 100 grams of wet pods determined, according to the method of Rowe and Bonney (45, pp.621-628). This determination provided the source of de-seeded pods for the crude fiber determination, which requires 100 grams of de-seeded pods. Seed results are thus not "percent" but "grams of seed per 100 grams of de-seeded pods". Determinations were made on the canned product only.

Crude fiber determinations - The alkali digestion method of Rowe and Bonney (45, p.621) was used, with use of the interpretation made by the Federal Food and Drug Administration (52, pp.3727-3728), and with suggestions from Arat (1, pp.12-13). The essentials of the determination are: (1) pulping of a known weight, usually 100 grams, of de-seeded pods (2) digestion in 50% sodium hydroxide solution for five minutes (3) rapid stirring with a malted-milk mixer for five minutes (4) pouring the resultant slurry onto a tared screen and washing it free of alkali and digested material. The remaining residue is the fiber.

With some practice this determination can be made with fair precision. Transfers must be made without waste, overflow of the container must be avoided, and all of the sample must be brought into contact with the alkali. Care in washing appeared to be more important than the amount of water used or time spent in washing. This is in contrast to Arat's remarks on the subject (1, p.14).

Fiber determinations were run on the canned product in 1952, only.

Shear press readings - Difficulties were encountered in establishing a method for using this instrument. It was recognized that the fill of the sample box probably would influence the readings, and for this reason a uniform fill of the box was adopted. Preliminary determinations indicated that variations in readings could result from letting the beans stand after opening. Therefore, canned beans were put through the shear press soon after the cans were opened. Cooked beans from the frozen samples were cooled at 34° F. for several hours before shear press readings were made, to equalize the temperatures of the various lots. However, in spite of these precautions, unexplainable differences in shear press readings often occurred.

A.M.S. determinations of grade - The term "A.M.S." refers to the grading service of the Agricultural Marketing Service, an agency of the United States Department of Agriculture. All samples were scored for "color" and for "texture and maturity" by an official grader at the regional A.M.S. office in Salem, Oregon. Certain of the 1952 samples were scored for "absence of defects". Samples were always coded, and the official A.M.S. grader did not know the identity of the samples. After grading had been done, the scores for these factors were assigned to the appropriate treatments and replications. These data were then statistically analyzed.

Evaluation by panel - This type of evaluation was done by preference scoring, followed by statistical analysis of the resulting scores. Factors used were "appearance" and "flavor". Scores were controlled to the extent that only five scores were permitted, with the untreated plots being set at 0. "Slightly preferred" over the untreated was 1; "moderately preferred", being 2. "Slightly less preferred" than the untreated was represented by the score of -1; "moderately less preferred" by the score of -2.

The panel was composed of members of the Horticulture and Food Technology departments. Only the 1953 lots were evaluated in this manner.

Chemical Determinations Made on the Frozen Beans

Chemical determinations were made for: nitrogen, phosphorus, potassium, calcium, magnesium, and total ash.

The beans used in the analyses were held in the frozen condition and were from the same frozen sample lots used in quality studies. Technique of preparation has been described.

The packages of frozen beans were weighed on a balance with a sensitivity of 0.1 gram, then opened, and the package and contents placed in a laboratory forced draft oven at a temperature of 75° - 80° C. About 24 hours were required for drying in this manner. Package and dry contents were then re-weighed. Dry material was then ground to a suitable degree of fineness in a laboratory mill and afterwards transferred to glass screw-top bottles. The empty package was weighed and by deduction of package weight the wet weight and dry weight values were determined, thus obtaining percentage dry weight of the beans used in the analyses.

All dry samples were opened and subjected to five hours at 75° C. before analytical samples were weighed from them. This was to insure that the samples used in the analysis would be of the same moisture content.

The elements nitrogen, phosphorus, and potassium were determined on a single wet-ash solution. Approximately one-tenth gram of dry bean tissue was weighed on cigarette paper, the actual weight being recorded to the fourth decimal. The folded paper and sample was then thrust into a 50 ml. Erlenmeyer flask and 2 ml. of concentrated sulphuric acid added. The sample was then digested on an electric hot plate under a ventilated hood, using 30% hydrogen-peroxide as the oxidizing agent. Not more than five drops of peroxide were added at one time, to avoid oxidation of the nitrogenous compounds. Marbles were placed on top of the flasks to prevent loss of sample fragments by spattering. Twenty-four to twenty-six samples were digested at the same time. With each set a "reagent blank" was digested. In addition, a "known" sample containing definite amounts of nitrogen, phosphorus, and potassium added from standard solutions; and a "combination" sample containing about half the normal amount of bean tissue plus half the amount of nitrogen, phosphorus, and potassium added to the "known" sample were digested. Thus, it was possible to check on contamination by use of the blank and recovery from a "known" alone and from a "known" in the presence of bean tissue.

Nitrogen determinations - The nitrogen method used was nesslerization as modified by Lindner (37, pp.76-89). The Nessler solution was that of Umbreit, Burris, and Stauffer (49, p.191) which is easier to prepare than that described by Lindner. Readings were made on a Klett-Summerson colorimeter, using a No. 42 filter. Although Lindner (37, p.79) suggests a Wratten No. 49, tests with the Beckman Model DU spectrophotometer indicated that maximum absorption occurred at a lower wave-length. Therefore, the No. 42 filter was used. Sensitivity of two on the Klett scale was equal to one microgram of nitrogen from ammonium sulphate standard solutions.

Phosphorus determinations - Total phosphorus was determined by the Fisk-Subbarow method (22). Readings were taken on the Klett-Summerson colorimeter. A red filter, No. 66, was used. The standards were made up from potassium dihydrogen phosphate and two milliliters of sulphuric acid were added to each 100 milliliters of standard. The acid used in making up the ammonium molybdate solution was reduced to compensate for the acid used in digesting the samples.

Potassium determinations - This element was determined on the Beckman flame photometer attached to the Beckman DU spectrophotometer. Suggestions from the two papers of Brown, Lilleland, and Jackson (12, 13) were very helpful. Hydrogen was used as fuel, and readings were taken at 768 millimicrons wave-length. The standards used were made up from potassium di-hydrogen phosphate and contained approximately the average amounts of calcium and magnesium expected in bean tissue. Two milliliters of sulphuric acid were added to each 100 milliliters of standard solution. One part per million of sodium was also added. This follows the balanced solution system suggested by Brown, Lilleland, and Jackson (13, pp.18,19).

After many preliminary determinations, proper adjustments of slit width and sensitivity were found. Maximum sensitivity was found to be impractical since the readings then varied with minor pulsations of the flame. Sensitivity was reduced and slit width adjusted to fit the readings to a suitable range.

Calcium and magnesium determinations - Total ash, calcium, and magnesium were determined together, using dry-ashed material. Two grams of dried, ground bean tissue were weighed into 50 milliliters tared beakers. They were then ashed 16-18 hours at 932° F. A powdery, very white ash resulted. After cooling in a desiccator, the beakers were re-weighed and the percent total ash computed. Weights were made to the fourth decimal place with an accuracy of .0002 to .0004 grams.

The ash was moistened with distilled water. Five milliliters of concentrated hydrochloric acid were then added and the contents of the beakers evaporated to dryness on a hot plate, with cover glasses being used to prevent loss from spattering. A second treatment with three milliliters of concentrated hydrochloric acid was then made and the contents again evaporated to dryness. The residue was moistened with distilled water and 1.5 milliliters of concentrated nitric acid. After the beakers had been filled with distilled water, they were allowed to stand for 24 hours before being filtered and diluted to volume.

Determinations were made on the flame photometer used for potassium. Readings for calcium were taken at 554 millimicrons, and for magnesium at 383 millimicrons wave-length. Trials were made at other wave-lengths but sensitivity was greatest at those indicated. The filter slide of the instrument was fitted with a didymium filter to reduce interference from sodium, which exhibits maximum intensity at 589 millimicrons. Standards contained about the average amounts of potassium, and calcium, or magnesium expected in plant tissue solutions of that dilution. Ten parts per million of sodium were added, and also nitric acid to compensate for that added in preparation of the tissue samples.

After a number of preliminary determinations were made, proper adjustments for sensitivity and slit width were obtained. Recovery of magnesium was normally satisfactory. There was often difficulty with calcium recoveries, however. It was found that addition of phosphate to the solutions would greatly depress the apparent calcium reading, thus phosphate addition was avoided in preparation of the standard solutions. However, the tissue solutions contained phosphorus compounds appropriate to the treatments concerned.

Statistical Methods

Conventional methods for analysis of variance were used. In 1952, the twelve treatments forming the 2 x 2 x 3 factorial design were considered first. If the "interaction" mean square was significant, a search was made for the sources of this variation. Once they were found, the appropriate tables were made. Next, the mean squares of the main effects were tested against the interaction mean square.

If the "interaction" mean square was not significant, the mean squares of the main effects were tested against the pooled mean square of error plus "interaction".

Means of quality and chemical determinations of the sulphurless plots were compared to those of the 100-120-0 treatment (containing sulphur) directly. If the difference between the means of the two treatments was greater than the least significant difference of the means of the individual treatments in the whole experiment (of 13 treatments), then the difference was so indicated and a table of these means was set up.

In 1953, the procedures were modified by changes in design. The basic design was 2 x 2 x 2 factorial, with two extra treatments. The significance of the difference between means of individual treatments was first considered. If significant differences were found, then least significant difference values were calculated. These values were of most use in consideration of the two extra treatments. The second phase was the analysis of the 2 x 2 x 2 factorial section, which was done in the same manner as in the analysis of the 2 x 2 x 3 factorial experiment of 1952.

RESULTS

Each quality factor and chemical component is considered separately in the presentation of the results. Certain abbreviations are used in presenting the data. N, P, and K are common chemical abbreviations for these elements. The cipher "0" indicates no fertilization with that particular element. "1" represents level one, which is 100 pounds nitrogen per acre in 1952 and 50 pounds nitrogen in 1953 in the case of that element (N), or 120 pounds phosphoric acid per acre in the series (P). When used with reference to potassium, in 1952, level "1" indicates treatment with potassium chloride at the rate of 100 pounds per acre of potassium oxide. Level "2" indicates corresponding treatment with potassium sulphate supplying 100 pounds of potassium oxide per acre. In 1953, level "1" of potassium indicates treatment with 60 pounds of potassium oxide per acre.

The term "L.S.D." is that of Tukey's "Least Significant Difference" between means. "N.S.D." is the abbreviation used for "No Significant Difference." The fractions ".05" and ".01" refer to those probability levels.

Chemical composition is expressed in percentage of dry weight. Crude fiber values are in percentage of wet weight. Other values used are self-explanatory.

The Effects of Nitrogen, Phosphorus, and Potassium Fertilization on the Nitrogen Content of Pole Beans

1952 Crop - Nitrogen determinations were made on six groups of beans in 1952. Results are tabulated in Tables 1-6. The data in Tables 1 and 3 show that nitrogen fertilization increased the percentage of nitrogen in both size groups of beans of the early harvest. Similar effects of nitrogen fertilization were evident in size 4 and 5 beans of the late harvest which were stored at 36° F. for six days before processing. There was no significant effect of nitrogen fertilization on the nitrogen content of size 3 beans of the late harvest, regardless of storage treatment before freezing, or on the nitrogen content of size 4 and 5 beans of the late harvest, frozen while fresh (Tables 2, 4, 5).

The main effects of phosphorus fertilization on the nitrogen content, expressed as percentage of dry weight, were significant in only two of the six groups. The nitrogen percentage was significantly increased in one group and decreased in the other. Both groups were size 3 beans (Table 1, 5).

Main effects of potassium fertilization on the nitrogen content were not significant (Tables 1-6).

Significant interactive effects of N x P and P x K on the nitrogen content of "4 and 5" beans of the late harvest are indicated in Table 4. In the N x P interaction, nitrogen fertilization significantly increased the nitrogen content when phosphorus was not used. In the P x K interaction, the combination of potassium sulphate (K-2) and phosphorus fertilization resulted in significant reduction in nitrogen content of the beans.

Table 1

Percentage Nitrogen Content of Size 3 Beans
(1952 Early Harvest, Frozen While Fresh)

Level	Means of Individual Treatments					
	P-0			P-1		
	K-0	K-1	K-2	K-0	K-1	K-2
N-0	3.39	3.44	3.43	3.19	3.32	3.22
N-1	3.55	3.69	3.57	3.43	3.42	3.40

Level	Means of Main Effects		
	N-Means	P-Means	K-Means
0	3.33	3.51	3.39
1	3.51	3.33	3.46
2			3.40
L.S.D. (.05)	.062	.062	N.S.D.
L.S.D. (.01)	.084	.084	N.S.D.

Interactive effects not significant

Table 2

Percentage Nitrogen Content of Size 3 Beans
(1952 Late Harvest, Frozen While Fresh)

Level	Means of Individual Treatments					
	P-0			P-1		
	K-0	K-1	K-2	K-0	K-1	K-2
N-0	3.43	3.54	3.47	3.58	3.51	3.37
N-1	3.56	3.48	3.51	3.52	3.46	3.53

Level	Means of Main Effects		
	N-Means	P-Means	K-Means
0	3.48	3.50	3.52
1	3.51	3.50	3.49
2			3.47

Main and interactive effects not significant

Table 3

Percentage Nitrogen Content of Size 4 and 5 Beans
(1952 Early Harvest, Frozen While Fresh)

Level	Means of Individual Treatments					
	P-0			P-1		
	K-0	K-1	K-2	K-0	K-1	K-2
N-0	3.43	3.54	3.47	3.58	3.51	3.37
N-1	3.56	3.48	3.51	3.52	3.46	3.53

Means of Main Effects

Level	N-Means	P-Means	K-Means
0	3.32	3.41	3.39
1	3.44	3.35	3.42
2			3.32
L.S.D. (.05)	.104	N.S.D.	N.S.D.
L.S.D. (.01)	N.S.D.	N.S.D.	N.S.D.

Interactive effects not significant

Table 4

Percentage Nitrogen Content of Size 4 and 5 Beans
(1952 Late Harvest, Frozen While Fresh)

Level	Means of Individual Treatments					
	P-0			P-1		
	K-0	K-1	K-2	K-0	K-1	K-2
N-0	3.26	3.25	3.54	3.46	3.32	3.22
N-1	3.40	3.38	3.44	3.34	3.42	3.24

Means of Main Effects

Level	N-Means	P-Means	K-Means
0	3.28	3.34	3.34
1	3.37	3.32	3.34
2			3.30

Means of N x P Combinations

	P-0	P-1
N-0	3.27	3.30
N-1	3.41	3.33

L.S.D. (.05) — .069; L.S.D. (.01) — .093

Table 4 (Cont'd)

Means of P x K Combinations	K-0	K-1	K-2
P-0	3.33	3.32	3.36
P-1	3.35	3.37	3.23

L.S.D. (.05) — .083; L.S.D. (.01) — .111

Main effects not significant

Table 5

Percentage Nitrogen Content of Size 3 Beans
(1952 Late Harvest, Frozen After Storage)

Level	Means of Individual Treatments					
	P-0			P-1		
	K-0	K-1	K-2	K-0	K-1	K-2
N-0	3.61	3.66	3.51	3.65	3.62	3.63
N-1	3.47	3.57	3.62	3.62	3.76	3.72

Level	Means of Main Effects N-Means	P-Means	K-Means
0	3.61	3.57	3.59
1	3.63	3.66	3.65
2			3.62
L.S.D. (.05)	N.S.D.	.07	N.S.D.
L.S.D. (.01)	N.S.D.	N.S.D.	N.S.D.

Interactive effects not significant

Table 6

Percentage Nitrogen Content of Size 4 and 5 Beans
(1952 Late Harvest, Frozen After Storage)

Level	Means of Individual Treatments					
	P-0			P-1		
	K-0	K-1	K-2	K-0	K-1	K-2
N-0	3.46	3.46	3.41	3.47	3.43	3.44
N-1	3.51	3.51	3.65	3.42	3.51	3.48

Table 6 (Cont'd)

Level	N-Means	P-Means	K-Means
		Means of Main Effects	
0	3.41	3.46	3.44
1	3.50	3.46	3.45
2			3.48
L.S.D. (.05)	.06	N.S.D.	N.S.D.
L.S.D. (.01)	.08	N.S.D.	N.S.D.

Interactive effects not significant

1953 Crop - Significant differences due to fertilizer treatment were found in only one of the three groups studied (Tables 7-9). Nitrogen fertilization resulted in an increase in nitrogen content of beans of this group, which were from the early harvest of size 4 and 5, frozen while fresh (Table 8). On the other hand, nitrogen fertilization resulted in no significant increases or decreases in the nitrogen percentages in the other two lots (Tables 7, 9).

Neither phosphorus nor potassium fertilization had significant effects on the nitrogen percentage of the harvested beans (Tables 7-9).

Table 7

Percentage Nitrogen Content of Size 3 Beans
(1953, Early Harvest, Frozen While Fresh)

Level	Means of Individual Treatments			
	P-0		P-1	
	K-0	K-1	K-0	K-1
N-0	3.03	3.12	3.12	3.13
N-1	3.26	3.15	3.13	3.21
N-2	3.24		3.23	

Level	N-Means	P-Means	K-Means
		Means of Main Effects (Factorial Treatments)	
0	3.10	3.14	3.13
1	3.19	3.15	3.15

Individual treatment differences not significant, main and interactive effects not significant

Table 8

Percentage Nitrogen Content of Size 4 and 5 Beans
(1953, Early Harvest, Frozen While Fresh)

Level	Means of Individual Treatments			
	P-0		P-1	
	K-0	K-1	K-0	K-1
N-0	2.95	3.02	2.97	3.03
N-1	3.35	3.18	3.19	3.25
N-2	3.22		3.17	
L.S.D. (.05) — .207; L.S.D. (.01) — .280				

Level	N-Means	P-Means	K-Means
	Means of Main Effects (Factorial Treatments)		
0	2.99	3.10	3.08
1	3.19	3.08	3.10
L.S.D. (.05)	.095	N.S.D.	N.S.D.
L.S.D. (.01)	.128	N.S.D.	N.S.D.

Interactive effects not significant

Table 9

Percentage Nitrogen Content of Size 4 and 5 Beans
(1953, Late Harvest, Frozen While Fresh)

Level	Means of Individual Treatments			
	P-0		P-1	
	K-0	K-1	K-0	K-1
N-0	3.22	3.34	3.19	3.20
N-1	3.21	3.19	3.16	3.41
N-2	3.20		3.40	

Level	N-Means	P-Means	K-Means
	Means of Main Effects (Factorial Treatments)		
0	3.23	3.24	3.19
1	3.22	3.21	3.26

Individual treatment differences not significant, main and interactive effects not significant

The Effects of Nitrogen, Phosphorus, and Potassium Fertilization on the Phosphorus Content of Pole Beans

1952 Crop - The data in Tables 10-15 show that nitrogen fertilization reduced the percentage of phosphorus in the bean tissue. This effect was significant in all groups excepting the size 3 beans of early harvest which were frozen while fresh (Table 10). In that group the difference required for significance was short by .001 percent.

The data in Tables 10-15 also show that no significant increases or decreases in phosphorus percentage could be attributed to phosphorus or potassium fertilization as main effects. However, in one group the effect of potassium fertilization on the phosphorus percentage was dependent on the nitrogen fertilizer used, being significantly depressive when nitrogen fertilizer was used but having no significant effect when no fertilizer was used (Table 11). The group in which this interaction was noted was the size 3 beans of the late harvest, which were frozen while fresh.

Table 10

Percentage Phosphorus Content of Size 3 Beans
(1952, Early Harvest, Frozen While Fresh)

Level	Means of Individual Treatments					
	P-0			P-1		
	K-0	K-1	K-2	K-0	K-1	K-2
N-0	.371	.394	.394	.357	.384	.365
N-1	.375	.378	.355	.368	.350	.358

Table 10 (Cont'd)

Level	N-Means	P-Means	K-Means
		Means of Main Effects	
0	.377	.378	.368
1	.364	.364	.376
2			.368
L.S.D. (.05)	.014	.014	N.S.D.
L.S.D. (.01)	N.S.D.	N.S.D.	N.S.D.

Interactive effects not significant

Table 11

Percentage Phosphorus Content of Size 3 Beans
(1952, Late Harvest, Frozen While Fresh)

Level	Means of Individual Treatments					
	P-0			P-1		
	K-0	K-1	K-2	K-0	K-1	K-2
N-0	.423	.430	.432	.465	.450	.434
N-1	.416	.391	.396	.394	.384	.381

Level	N-Means	P-Means	K-Means
		Means of Main Effects	
0	.438	.415	.425
1	.394	.418	.414
2			.411
L.S.D. (.05)	.023	N.S.D.	N.S.D.
L.S.D. (.01)	.035	N.S.D.	N.S.D.

	Means of N x K Combinations		
	K-0	K-1	K-2
N-0	.444	.440	.433
N-1	.405	.388	.389
	L.S.D. (.05) — .018	L.S.D. (.01) — .025	

Table 12

Percentage Phosphorus Content of Size 4 and 5 Beans
(1952, Early Harvest, Frozen While Fresh)

Level	Means of Individual Treatments					
	P-0			P-1		
	K-0	K-1	K-2	K-0	K-1	K-2
N-0	.392	.385	.392	.383	.376	.373
N-1	.390	.396	.348	.385	.365	.370

Means of Main Effects

Level	N-Means	P-Means	K-Means
0	.384	.384	.382
1	.372	.372	.380
2			.371
L.S.D. (.05)	.009	.009	N.S.D.
L.S.D. (.01)	N.S.D.	N.S.D.	N.S.D.

Interactive effects not significant

Table 13

Percentage Phosphorus Content of Size 4 and 5 Beans
(1952, Late Harvest, Frozen While Fresh)

Level	Means of Individual Treatments					
	P-0			P-1		
	K-0	K-1	K-2	K-0	K-1	K-2
N-0	.417	.400	.427	.435	.416	.427
N-1	.380	.383	.388	.376	.383	.363

Means of Main Effects

Level	N-Means	P-Means	K-Means
0	.420	.399	.401
1	.379	.400	.396
2			.402
L.S.D. (.05)	.010	N.S.D.	N.S.D.
L.S.D. (.01)	.014	N.S.D.	N.S.D.

Interactive effects not significant

Table 14

Percentage Phosphorus Content of Size 3 Beans
(1952, Late Harvest, Frozen After Storage)

Level	Means of Individual Treatments					
	P-0			P-1		
	K-0	K-1	K-2	K-0	K-1	K-2
N-0	.421	.421	.455	.430	.414	.451
N-1	.383	.402	.388	.366	.397	.406

Means of Main Effects

Level	N-Means	P-Means	K-Means
0	.432	.413	.402
1	.392	.410	.408
2			.425
L.S.D. (.05)	.012	N.S.D.	N.S.D.
L.S.D. (.01)	.017	N.S.D.	N.S.D.

Interactive effects not significant

Table 15

Percentage Phosphorus Content of Size 4 and 5 Beans
(1952, Late Harvest, Frozen After Storage)

Level	Means of Individual Treatments					
	P-0			P-1		
	K-0	K-1	K-2	K-0	K-1	K-2
N-0	.415	.393	.428	.436	.415	.443
N-1	.404	.389	.381	.360	.384	.392

Means of Main Effects

Level	N-Means	P-Means	K-Means
0	.422	.402	.404
1	.385	.405	.395
2			.411
L.S.D. (.05)	.015	N.S.D.	N.S.D.
L.S.D. (.01)	.020	N.S.D.	N.S.D.

Interactive effects not significant

<u>1953 Crop</u> - Significant differences in percentage of phosphorus as affected by nitrogen, phosphorus or potassium fertilization were noted in only one of the three groups studied (Tables 16-18). In this group, Size 4 and 5, early harvest, the use of phosphorus fertilizer increased the percentage of phosphorus by a small but significant amount (Table 17).

Table 16

Percentage Phosphorus Content of Size 3 Beans
(1953, Frozen While Fresh)

Level	Means of Individual Treatments			
	P-0		P-1	
	K-0	K-1	K-0	K-1
N-0	.459	.470	.473	.461
N-1	.469	.450	.487	.496
N-2	.493		.459	

Level	Means of Main Effects (Factorial Treatments)		
	N-Means	P-Means	K-Means
0	.466	.462	.472
1	.475	.479	.469

Main and interactive effects not significant

Table 17

Percentage Phosphorus Content of Size 4 and 5 Beans
(1953, Early Harvest, Frozen While Fresh)

Level	Means of Individual Treatments			
	P-0		P-1	
	K-0	K-1	K-0	K-1
N-0	.445	.437	.457	.455
N-1	.462	.421	.465	.457
N-2	.459		.423	

L.S.D. (.05) — .029 L.S.D. (.01) — .039

Table 17 (Cont'd)

Level	Means of Main Effects (Factorial Treatments) N-Means	P-Means	K-Means
0	.448	.441	.457
1	.451	.459	.442
L.S.D. (.05)	N.S.D.	.009	N.S.D.
L.S.D. (.01)	N.S.D.	.013	N.S.D.

Interactive effects not significant

Table 18

Percentage Phosphorus Content of Size 4 and 5 Beans
(1953, Late Harvest, Frozen While Fresh)

Level	Means of Individual Treatments			
	P-0		P-1	
	K-0	K-1	K-0	K-1
N-0	.477	.491	.477	.491
N-1	.471	.460	.490	.486
N-2	.469		.473	

Level	Means of Main Effects (Factorial Treatments) N-Means	P-Means	K-Means
0	.484	.475	.479
1	.477	.486	.482

Individual treatment differences not significant, main and interactive effects not significant

The Effects of Nitrogen, Phosphorus, and Potassium Fertilization on the Potassium Content of Pole Beans

1952 Crop - The data in Tables 19-24 show that phosphorus fertilization significantly affected the percentage of potassium in five of the six groups studied. A significant reduction of potassium content occurred in the size 3 beans of the early harvest, which were frozen while fresh (Table 19); and also in the size 3 beans of late harvest, which were frozen after storage (Table 23). In the third group of size 3 beans (late harvest, frozen while fresh) a significant N x P interaction was noted. In this interaction a significant reduction in percentage of potassium occurred when phosphorus fertilizer was applied without nitrogen. This reduction did not occur when nitrogen was used in combination with phosphorus (Table 20).

In the size 4 and 5 beans, phosphorus fertilization resulted in effects somewhat dissimilar to those found in size 3 beans. In the late harvest group, frozen while fresh, the use of phosphorus caused a small but significant increase in potassium content (Table 22). In beans of the same harvest, but frozen after storage, a significant N x P interaction was noted. Significant depression of potassium content by phosphorus fertilization was evident at the N-0, but not at the N-1 level (Table 24). In the early harvested group of size 4 and 5 beans which were frozen while fresh, a significant interaction of P x K was noted, with potassium sulphate fertilization (K-2) causing a significant increase in percentage of potassium when it was used in the absence of phosphorus fertilization (Table 21).

The use of nitrogen was associated with an interactive effect with potassium in size 4 and 5, late harvested beans, frozen after storage. In this group, nitrogen fertilization significantly reduced the percentage of potassium (1) when no potassium fertilizer was used and (2) when potassium sulphate was used (Table 24). An alternate interpretation of this interaction is that potassium chloride fertilization (K-1) maintained a significantly higher potassium content in the presence of nitrogen treatment than was maintained by potassium sulphate (K-2) or by the absence of potassium (K-0).

The effects of potassium on the percentage of potassium found in the beans were limited to the interactions already noted (Tables 21, 24).

Table 19

Percentage Potassium Content of Size 3 Beans
(1952, Early Harvest, Frozen While Fresh)

Level	Means of Individual Treatments					
	P-0			P-1		
	K-0	K-1	K-2	K-0	K-1	K-2
N-0	2.04	2.21	2.15	2.02	1.95	1.99
N-1	2.12	1.97	2.09	1.89	1.78	1.99

Means of Main Effects

Level	N-Means	P-Means	K-Means
0	2.06	2.10	2.01
1	2.01	1.97	2.03
2			2.06
L.S.D. (.05)	N.S.D.	.082	N.S.D.
L.S.D. (.01)	N.S.D.	.109	N.S.D.

Interactive effects not significant

Table 20

Percentage Potassium Content in 24 Lots of Size 3 Beans
(1952, Late Harvest, Frozen While Fresh)

Level	Means of Individual Treatments					
	P-0			P-1		
	K-0	K-1	K-2	K-0	K-1	K-2
N-0	2.20	2.41	2.26	2.04	1.92	2.06
N-1	2.05	2.34	2.08	2.06	2.21	2.15

Means of Main Effects

Level	N-Means	P-Means	K-Means
0	2.14	2.22	2.08
1	2.14	2.07	2.21
2			2.14

Means of N x P Combinations

	P-0	P-1
N-0	2.29	2.00
N-1	2.15	2.14
L.S.D. (.05) — 0.12	L.S.D. (.01) — 0.16	

Main effects not significant

Table 21

Percentage Potassium Content of Size 4 & 5 Beans
(1952, Early Harvest, Frozen While Fresh)

Level	Means of Individual Treatments					
	P-0			P-1		
	K-0	K-1	K-2	K-0	K-1	K-2
N-0	2.06	2.05	2.32	2.22	1.98	1.91
N-1	2.07	1.94	2.22	1.92	2.15	1.98

Means of Main Effects

Level	N-Means	P-Means	K-Means
0	2.09	2.11	2.07
1	2.05	2.03	2.03
2			2.11

Means of P x K Combinations

	K-0	K-1	K-2
P-0	2.06	1.99	2.27
P-1	2.07	2.06	1.95

L.S.D. (.05) — .168 L.S.D. (.01) — .226
Main effects not significant

Table 22

Percentage Potassium Content of Size 4 & 5 Beans
(1952, Late Harvest, Frozen While Fresh)

Level	Means of Individual Treatments					
	P-0			P-1		
	K-0	K-1	K-2	K-0	K-1	K-2
N-0	2.05	2.21	2.03	1.91	1.95	2.00
N-1	2.00	2.13	1.96	1.92	2.01	1.95

Means of Main Effects

Level	N-Means	P-Means	K-Means
0	2.02	1.85	1.97
1	1.99	1.96	2.07
2			1.98
L.S.D. (.05)	N.S.D.	.069	.083
L.S.D. (.01)	N.S.D.	.093	.111

Interactive effects not significant

Table 23

Percentage Potassium Content of Size 3 Beans
(1952, Late Harvest, Frozen After Storage)

Level	Means of Individual Treatments					
	P-0			P-1		
	K-0	K-1	K-2	K-0	K-1	K-2
N-0	2.31	2.15	2.32	2.06	1.96	1.91
N-1	2.14	2.33	2.16	2.01	2.15	2.08

Means of Main Effects

Level	N-Means	P-Means	K-Means
0	2.12	2.23	2.13
1	2.14	2.03	2.15
2			2.12
L.S.D. (.05)	N.S.D.	.125	N.S.D.
L.S.D. (.01)	N.S.D.	.177	N.S.D.

Interactive effects not significant

Table 24

Percentage Potassium Content of Size 4 and 5 Beans
(1952, Late Harvest, Frozen After Storage)

Level	Means of Individual Treatments					
	P-0			P-1		
	K-0	K-1	K-2	K-0	K-1	K-2
N-0	2.11	2.12	2.25	2.00	1.95	1.99
N-1	1.95	2.12	2.01	1.93	2.14	1.97

Means of Main Effects

Level	N-Means	P-Means	K-Means
0	2.07	2.09	2.00
1	2.02	1.99	2.08
2			2.05

Means of N x P Combinations

	P-0	P-1
N-0	2.16	1.98
N-1	2.03	2.01

L.S.D. (.05) — .093 L.S.D. (.01) —.125

Table 24 (Cont'd)

Means of N x K Combinations

	K-0	K-1	K-2
N-0	2.06	2.03	2.12
N-1	1.94	2.13	1.99

L.S.D. (.05) — .116 L.S.D. (.01) — .155

Main effects not significant

1953 Crop - The data in Tables 25-27 show that phosphorus fertilization resulted in an increase in the percentage of potassium in two of the three groups studied. These effects were in size 3 beans and in size 4 and 5 beans of the late harvest (Tables 25, 27). However, the tendency of phosphorus to increase the potassium content appeared to depend upon the nitrogen level. In the extra nitrogen treatments (N-2), the use of phosphorus fertilizers significantly reduced the percentage of potassium (Tables 25, 27).

Nitrogen fertilization in the 1953 crop resulted in no other significant changes in the percentage of potassium. The use of potassium fertilizers caused no significant increases or decreases in the percentage of potassium in the bean tissue.

Table 25

Percentage Potassium Content of Size 3 Beans
(1953, Frozen While Fresh)

Level	Means of Individual Treatments			
	P-0		P-1	
	K-0	K-1	K-0	K-1
N-0	1.94	1.92	2.04	1.94
N-1	1.98	1.85	1.96	2.14
N-2	2.11		1.95	
L.S.D. (.05) — .14			L.S.D. (.01) — .20	

	Means of Main Effects (Factorial Treatments)		
Level	N-Means	P-Means	K-Means
0	1.96	1.92	1.98
1	1.98	2.02	1.96
L.S.D. (.05)	N.S.D.	.095	N.S.D.
L.S.D. (.01)	N.S.D.	N.S.D.	N.S.D.

Interactive effects not significant

Table 26

Percentage Potassium Content of Size 4 and 5 Beans
(1953, Early Harvest, Frozen While Fresh)

Level	Means of Individual Treatments			
	P-0		P-1	
	K-0	K-1	K-0	K-1
N-0	1.94	2.01	1.97	1.93
N-1	2.02	1.95	1.91	1.98
N-2	1.88		1.89	

	Means of Main Effects (Factorial Treatments)		
Level	N-Means	P-Means	K-Means
0	1.96	1.96	1.98
1	1.96	1.97	1.95

Individual treatment differences not significant
Main and interactive effects not significant

Table 27

Percentage Potassium Content of Size 4 and 5 Beans
(1953, Late Harvest, Frozen While Fresh)

Level	Means of Individual Treatments			
	P-0		P-1	
	K-0	K-1	K-0	K-1
N-0	1.87	2.01	1.89	1.98
N-1	1.86	1.81	1.99	1.95
N-2	1.98		1.78	
L.S.D. (.05)	— .050		L.S.D. (.01) — .061	

	Means of Main Effects (Factorial Treatments)		
Level	N-Means	P-Means	K-Means
0	1.94	1.88	1.90
1	1.90	1.95	1.94
L.S.D. (.05)	N.S.D.	.066	N.S.D.
L.S.D. (.01)	N.S.D.	N.S.D.	N.S.D.

Interactive effects not significant

The Effects of Nitrogen, Phosphorus, and Potassium Fertilization on the Calcium Content of Pole Beans

1952 Crop - The data in Tables 28, 29, 30, 31, and 33 show that phosphorus fertilization significantly decreased the percentage of calcium in five of the six groups studied. The only exception was the group size 3 beans, late harvest, which were frozen after storage (Table 32). In this group, phosphorus fertilization resulted in a decrease in the percentage of calcium; but, although the decrease was large, statistical analysis indicated that the difference was not significant. Perhaps this may be attributed to the fact that there were only two replications in this group.

Nitrogen fertilization significantly increased the percentage of calcium in three groups (Tables 30, 31, 33). Thus, the calcium percentage of all of the size 4 and 5 beans, regardless of harvest or storage treatment, was significantly affected by the level of nitrogen fertilization. In addition, there was an interactive effect of nitrogen and phosphorus fertilization in the late harvest of size 3 beans, frozen while fresh (Table 29). The data show that the depressive effect of phosphorus was at least partially dependent on the level of nitrogen fertilization.

Potassium fertilization resulted in significantly increased calcium content in only one of the six groups. This was in the size 4 and 5 beans of the late harvest, which were frozen while fresh (Table 31). Potassium chloride (K-1) was associated with the increase. That the kind of potassium fertilizer used has an effect on calcium content is also indicated in the P x K interaction data of Table 29. These data indicate that potassium chloride fertilization had no significant effect on the percentage of calcium regardless of the level of phosphorus fertilization. On the other hand, potassium sulphate usage significantly decreased the percentage of calcium at both levels.

Table 28

Percentage Calcium Content of Size 3 Beans
(1952, Early Harvest, Frozen While Fresh)

Level	Means of Individual Treatments					
	P-0			P-1		
	K-0	K-1	K-2	K-0	K-1	K-2
N-0	.328	.410	.351	.273	.320	.281
N-1	.427	.425	.344	.290	.276	.277

Means of Main Effects

Level	N-Means	P-Means	K-Means
0	.327	.381	.330
1	.340	.286	.358
2			.313
L.S.D. (.05)	N.S.D.	.030	N.S.D.
L.S.D. (.01)	N.S.D.	.045	N.S.D.

Interactive effects not significant

Table 29

Percentage Calcium Content of Size 3 Beans
(1952, Late Harvest, Frozen While Fresh)

Level	Means of Individual Treatments					
	P-0			P-1		
	K-0	K-1	K-2	K-0	K-1	K-2
N-0	.405	.444	.433	.290	.208	.180
N-1	.449	.420	.349	.383	.388	.383

Means of Main Effects

Level	N-Means	P-Means	K-Means
0	.326	.416	.381
1	.395	.305	.361
2			.335
L.S.D. (.05)	N.S.D.	.059	N.S.D.
L.S.D. (.01)	N.S.D.	.084	N.S.D.

Means of N x P Combinations

	P-0	P-1
N-0	.427	.226
N-1	.406	.385
L.S.D. (.05) — .066		L.S.D. (.01) — .093

	K-0	K-1	K-2
P-0	.427	.391	.298
P-1	.432	.336	.281
L.S.D. (.05) — .081		L.S.D. (.01) — .115	

Main effects not significant

Table 30

Percentage Calcium Content of Size 4 and 5 Beans
(1952, Early Harvest, Frozen While Fresh)

Level	Means of Individual Treatments					
	P-0			P-1		
	K-0	K-1	K-2	K-0	K-1	K-2
N-0	.291	.343	.282	.263	.253	.254
N-1	.333	.371	.323	.259	.270	.250

Means of Main Effects

Level	N-Means	P-Means	K-Means
0	.282	.324	.286
1	.301	.258	.309
2			.279
L.S.D. (.05)	.020	.020	N.S.D.
L.S.D. (.01)	N.S.D.	.027	N.S.D.

Interactive effects not significant

Table 31

Percentage Calcium Content of Size 4 and 5 Beans
(1952, Late Harvest, Frozen While Fresh)

Level	Means of Individual Treatments					
	P-0			P-1		
	K-0	K-1	K-2	K-0	K-1	K-2
N-0	.349	.371	.346	.292	.324	.294
N-1	.375	.434	.393	.329	.329	.348

Means of Main Effects

Level	N-Means	P-Means	K-Means
0	.328	.377	.336
1	.368	.319	.365
2			.343
L.S.D. (.05)	.018	.018	.022
L.S.D. (.01)	.024	.024	.030

Interactive effects not significant

Table 32

Percentage Calcium Content of Size 3 Beans
(1952, Late Harvest, Frozen After Storage)

Level	Means of Individual Treatments					
	P-0			P-1		
	K-0	K-1	K-2	K-0	K-1	K-2
N-0	.368	.304	.379	.270	.335	.252
N-1	.408	.315	.348	.349	.312	.339

Means of Main Effects

Level	N-Means	P-Means	K-Means
0	.317	.353	.349
1	.345	.309	.316
2			.328

Main and interactive effects not significant

Table 33

Percentage Calcium Content of Size 4 and 5 Beans
(1952, Late Harvest, Frozen After Storage)

Level	Means of Individual Treatments					
	P-0			P-1		
	K-0	K-1	K-2	K-0	K-1	K-2
N-0	.315	.342	.333	.258	.296	.283
N-1	.345	.374	.328	.315	.322	.310

Means of Main Effects

Level	N-Means	P-Means	K-Means
0	.307	.338	.315
1	.332	.301	.331
2			.313
L.S.D. (.05)	.016	.016	N.S.D.
L.S.D. (.01)	.022	.022	N.S.D.

Interactive effects not significant

1953 Crop - Calcium determinations were made on three groups in 1953, but data are presented on only the two groups in which significant differences are found (Tables 34, 35). Both of these lots were of size 4 and 5 beans. In the early harvested group, there was a significant reduction in the percentage of calcium in the bean tissue as a result of phosphorus fertilization as a main effect (Table 34).

Although the main effect of phosphorus fertilization was not significant in the early harvested beans (Table 34), the effect on the percentage of calcium in the late harvested beans was significantly depressive (Table 35).

The main effect of nitrogen fertilization on the percentage of calcium followed the same pattern as that of phosphorus fertilization.

Table 34

Percentage Calcium Content of Size 4 and 5 Beans
(1953, Early Harvest, Frozen While Fresh)

Level	Means of Individual Treatments			
	P-0		P-1	
	K-0	K-1	K-0	K-1
N-0	.330	.305	.328	.304
N-1	.323	.311	.312	.303
N-2	.347		.289	
L.S.D. (.05) — .01			L.S.D. (.01) — .014	

Table 34 (Cont'd)

	Means of Main Effects (Factorial Treatments)		
Level	N-Means	P-Means	K-Means
0	.316	.317	.323
1	.312	.311	.306
L.S.D. (.05)	N.S.D.	N.S.D.	.014
L.S.D. (.01)	N.S.D.	N.S.D.	N.S.D.

Interactive effects not significant

Table 35

Percentage Calcium Content of 40 Lots of Size 4 and 5
Second Harvest Beans

Level	Means of Individual Treatments			
	P-0		P-1	
	K-0	K-1	K-0	K-1
N-0	.355	.345	.319	.335
N-1	.301	.312	.293	.309
N-2	.321		.321	

	Means of Main Effects (Factorial Treatments)		
Level	N-Means	P-Means	K-Means
0	.339	.334	.317
1	.310	.314	.331
L.S.D. (.05)	.020	.020	N.S.D.
L.S.D. (.01)	.028	N.S.D.	N.S.D.

Individual treatment differences not significant
Interactive effects not significant

The Effects of Nitrogen, Phosphorus, and Potassium Fertilization on the Magnesium Content of Pole Beans

1952 Crop - The data in Tables 36-41 show that phosphorus fertilization significantly depressed the percentage of magnesium in all six groups of beans studied.

Nitrogen fertilization increased the percentage of magnesium in two groups. They had no relationship in size or harvest since one was of the early harvest size 3 bean, frozen while fresh (Table 36) and the other of the late harvest size 4 and 5, frozen after storage (Table 41). Another effect of nitrogen can be seen in the significant N x P interaction found in the size 3 beans of the late harvest, frozen while fresh (Table 37). The depressive effect of phosphorus fertilization on calcium content was very greatly reduced by the use of nitrogen fertilizers in that group.

Potassium fertilization had a significant effect on magnesium percentage in only one of the six groups studied. This response was an increase due to use of potassium chloride, occurring in the early harvest of the size 3 beans which were frozen while fresh (Table 36). Differences due to potassium sulphate were not significant in this or in any other group.

Table 36

Percentage Magnesium Content of Size 3 Beans
(1952, Early Harvest, Frozen While Fresh)

Level	Means of Individual Treatments					
	P-0			P-1		
	K-0	K-1	K-2	K-0	K-1	K-2
N-0	.352	.389	.378	.339	.350	.343
N-1	.395	.407	.404	.334	.360	.345

Means of Main Effects

Level	N-Means	P-Means	K-Means
0	.358	.387	.355
1	.374	.345	.376
2			.367
L.S.D. (.05)	.012	.012	.015
L.S.D. (.01)	.016	.016	.020

Interactive effects not significant

Table 37

Percentage Magnesium Content of Size 3 Beans
(1952, Late Harvest, Frozen While Fresh)

Level	Means of Individual Treatments					
	P-0			P-1		
	K-0	K-1	K-2	K-0	K-1	K-2
N-0	.381	.384	.372	.279	.242	.241
N-1	.380	.363	.360	.317	.385	.374

Means of Main Effects

Level	N-Means	P-Means	K-Means
0	.316	.376	.342
1	.366	.306	.343
2			.336
L.S.D. (.05)	N.S.D.	.060	N.S.D.
L.S.D. (.01)	N.S.D.	N.S.D.	N.S.D.

Means of N x P Combinations

	P-0	P-1
N-0	.379	.254
N-1	.373	.359
L.S.D. (.05) — .033		L.S.D. (.01) — .046

Table 38

Percentage Magnesium Content of Size 4 and 5 Beans
(1952 Early Harvest, Frozen While Fresh)

Level	Means of Individual Treatments					
	P-0			P-1		
	K-0	K-1	K-2	K-0	K-1	K-2
N-0	.350	.363	.348	.323	.323	.311
N-1	.347	.390	.390	.329	.318	.320

	Means of Main Effects		
Level	N-Means	P-Means	K-Means
0	.336	.365	.337
1	.349	.321	.348
2			.342
L.S.D. (.05)	N.S.D.	.006	N.S.D.
L.S.D. (.01)	N.S.D.	.008	N.S.D.

Interactive effects not significant

Table 39

Percentage Magnesium Content of Size 4 and 5 Beans
(1952 Late Harvest, Frozen While Fresh)

Level	Means of Individual Treatments					
	P-0			P-1		
	K-0	K-1	K-2	K-0	K-1	K-2
N-0	.355	.353	.338	.285	.333	.286
N-1	.353	.332	.325	.325	.320	.328

	Means of Main Effects		
Level	N-Means	P-Means	K-Means
0	.325	.347	.329
1	.335	.313	.340
2			.321
L.S.D. (.05)	N.S.D.	.017	N.S.D.
L.S.D. (.01)	N.S.D.	.023	N.S.D.

Interactive effects not significant

Table 40

Percentage Magnesium Content of Size 3 Beans
(1952 Late Harvest, Frozen After Storage)

Level	Means of Individual Treatments					
	P-0			P-1		
	K-0	K-1	K-2	K-0	K-1	K-2
N-0	.341	.350	.304	.266	.283	.283
N-1	.347	.334	.309	.312	.327	.310

Level	N-Means	P-Means	K-Means
	Means of Main Effects		
0	.304	.330	.316
1	.323	.297	.323
2			.301
L.S.D. (.05)	N.S.D.	.020	N.S.D.
L.S.D. (.01)	N.S.D.	.027	N.S.D.

Interactive effects not significant

Table 41

Percentage Magnesium Content of Size 4 and 5 Beans
(1952 Late Harvest, Frozen After Storage)

Level	Means of Individual Treatments					
	P-0			P-1		
	K-0	K-1	K-2	K-0	K-1	K-2
N-0	.323	.337	.323	.287	.282	.281
N-1	.358	.350	.331	.316	.320	.295

Level	N-Means	P-Means	K-Means
	Means of Main Effects		
0	.305	.337	.320
1	.328	.297	.322
2			.307
L.S.D. (.05)	.004	.004	N.S.D.
L.S.D. (.01)	.006	.006	N.S.D.

Interactive effects not significant

1953 Crop - Magnesium determinations were made on three groups, but significant differences due to fertilizer treatments were noted in only one group. This was a main effect of nitrogen fertilization in reducing the percentage of magnesium, occurring in size 4 and 5 beans of the late harvest, frozen while fresh (Table 42).

Table 42

Percentage Magnesium Content of Size 4 and 5 Beans
(1953, Late Harvest, Frozen While Fresh)

Level	Means of Individual Treatments			
	P-0		P-1	
	K-0	K-1	K-0	K-1
N-0	.330	.319	.318	.317
N-1	.292	.322	.292	.291
N-2	.312		.299	

Level	Means of Main Effects (Factorial Treatments) N-Means	P-Means	K-Means
0	.321	.316	.308
1	.299	.304	.312
L.S.D. (.05)	.018	N.S.D.	N.S.D.
L.S.D. (.01)	N.S.D.	N.S.D.	N.S.D.

Interactive effects not significant

The Effects of Nitrogen, Phosphorus, and Potassium Fertilization on the Total Ash Content of Pole Beans

1952 Crop - The effects of the various levels and combinations of fertilizer treatments are shown in Tables 43-48. The data indicate that the total ash content of all the groups was significantly reduced as the result of phosphorus fertilization.

Nitrogen fertilization significantly reduced percentage total ash in only one group, which was the late harvested 4 and 5 size beans, frozen while fresh (Table 46). A significant N x P interaction was also noted in the late harvest of size 3 beans, frozen while fresh (Table 44). In this interaction the depressive effect of phosphorus fertilization was significantly lessened by nitrogen fertilization. These were the only significant effects of nitrogen shown by the data.

Fertilization with potassium chloride (K-1) resulted in significant increase in total ash content in the late harvested 4 and 5 size beans regardless of storage treatment (Tables 46, 48). A similar increase was noted in size 3 beans of the early harvest, frozen while fresh (Table 43).

The effects of potassium sulphate (K-2) were limited to a significant increase in only two groups, and in both cases the increase was of borderline significance. Both groups were of size 4 and 5 beans (Tables 46, 48).

No other significant effects of potassium were indicated by the data.

Table 43

Percentage Total Ash Content of Size 3 Beans
(1952 Early Harvest, Frozen While Fresh)

Level	Means of Individual Treatments					
	P-0			P-1		
	K-0	K-1	K-2	K-0	K-1	K-2
N-0	6.19	6.73	6.35	5.81	5.92	5.91
N-1	6.40	6.59	6.15	5.80	6.02	5.83

Means of Main Effects

Level	N-Means	P-Means	K-Means
0	6.15	6.40	6.05
1	6.13	5.88	6.31
2			6.06
L.S.D. (.05)	N.S.D.	.143	.178
L.S.D. (.01)	N.S.D.	.191	.238

Interactive effects not significant

Table 44

Percentage Total Ash Content of Size 3 Beans
(1952 Late Harvest, Frozen While Fresh)

Level	Means of Individual Treatments					
	P-0			P-1		
	K-0	K-1	K-2	K-0	K-1	K-2
N-0	6.33	6.53	6.58	5.65	5.56	5.88
N-1	6.14	6.35	5.95	5.77	5.98	5.95

Means of Main Effects

Level	N-Means	P-Means	K-Means
0	6.08	6.31	5.97
1	6.02	5.80	6.10
2			6.08
L.S.D. (.05)	N.S.D.	.314	N.S.D.
L.S.D. (.01)	N.S.D.	.465	N.S.D.

Means of N x P Combinations

	P-0	P-1
N-0	6.48	5.69
N-1	6.14	5.90

L.S.D. (.05) — .193 L.S.D. (.01) — .298

Table 45

Percentage Total Ash Content of Size 4 and 5 Beans
(1952 Early Harvest, Frozen While Fresh)

Level	Means of Individual Treatments					
	P-0			P-1		
	K-0	K-1	K-2	K-0	K-1	K-2
N-0	6.11	6.26	6.39	5.58	5.48	5.75
N-1	6.19	6.38	6.06	5.48	5.99	5.73

Level	Means of Main Effects		
	N-Means	P-Means	K-Means
0	5.92	6.23	5.84
1	5.97	5.66	6.02
2			5.98
L.S.D. (.05)	N.S.D.	.154	N.S.D.
L.S.D. (.01)	N.S.D.	.205	N.S.D.

Interactive effects not significant

Table 46

Percentage Total Ash Content of Size 4 and 5 Beans
(1952 Late Harvest, Frozen While Fresh)

Level	Means of Individual Treatments					
	P-0			P-1		
	K-0	K-1	K-2	K-0	K-1	K-2
N-0	5.89	6.18	6.03	5.48	5.65	5.58
N-1	5.56	5.91	5.82	5.30	5.64	5.57

Level	Means of Main Effects		
	N-Means	P-Means	K-Means
0	5.80	5.90	5.55
1	5.63	5.53	5.84
2			5.75
L.S.D. (.05)	.168	.168	.202
L.S.D. (.01)	N.S.D.	.224	.270

Interactive effects not significant

Table 47

Percentage Total Ash Content in 24 Lots of Size 3 Beans
(1952 Late Harvest, Frozen After Storage)

Level	Means of Individual Treatments					
	P-0			P-1		
	K-0	K-1	K-2	K-0	K-1	K-2
N-0	6.56	6.41	6.80	6.02	5.86	5.86
N-1	6.32	6.51	6.02	5.87	6.43	6.08

Means of Main Effects			
Level	N-Means	P-Means	K-Means
0	6.25	6.43	6.19
1	6.20	6.02	6.30
2			6.19
L.S.D. (.05)	N.S.D.	.249	N.S.D.
L.S.D. (.01)	N.S.D.	.351	N.S.D.

Interactive effects not significant

Table 48

Percentage Total Ash Content of Size 4 and 5 Beans
(1952 Late Harvest, Frozen After Storage)

Level	Means of Individual Treatments					
	P-0			P-1		
	K-0	K-1	K-2	K-0	K-1	K-2
N-0	5.92	6.27	6.37	5.69	5.75	5.74
N-1	5.80	6.17	5.85	5.55	5.89	5.72

Means of Main Effects			
Level	N-Means	P-Means	K-Means
0	5.95	6.06	5.74
1	5.83	5.73	6.02
2			5.92
L.S.D. (.05)	N.S.D.	.143	.178
L.S.D. (.01)	N.S.D.	.192	.238

1953 Crop - Total ash determinations were made on three groups, but significant effects from fertilizer treatment were found in only two groups. Both groups of beans were of size 4 and 5 (Tables 49, 50). In beans of the early harvest, phosphorus fertilization significantly depressed the percentage of total ash when used at the 100 pound nitrogen level (Table 49). In the late harvest, nitrogen fertilization significantly decreased total ash content as a main effect (Table 50).

Table 49

Percentage Total Ash Content of Size 4 and 5 Beans
(1953, Early Harvest, Frozen While Fresh)

Level	Means of Individual Treatments			
	P-0		P-1	
	K-0	K-1	K-0	K-1
N-0	5.59	5.68	5.99	5.74
N-1	5.92	5.44	5.82	5.87
N-2	6.01		5.41	
L.S.D. (.05	— .376		L.S.D. (.01)	— .507

Means of Main Effects (Factorial Treatments)

Level	N-Means	P-Means	K-Means
0	5.75	5.67	5.83
1	5.77	5.85	5.69

Main and interactive effects not significant

Table 50

Percentage Total Ash Content of Size 4 and 5 Beans
(1953 Early Harvest, Frozen While Fresh)

Level	Means of Individual Treatments			
	P-0		P-1	
	K-0	K-1	K-0	K-1
N-0	6.09	6.18	5.96	6.27
N-1	5.66	5.95	5.81	6.00
N-2	5.70		5.79	

	Means of Main Effects (Factorial Treatments)		
Level	N-Means	P-Means	K-Means
0	6.13	5.97	5.88
1	5.86	6.01	6.10
L.S.D. (.05)	.253	N.S.D.	N.S.D.
L.S.D. (.01)	N.S.D.	N.S.D.	N.S.D.

Individual treatment differences not significant
Interactive effects not significant

<u>The Effects of Nitrogen, Phosphorus, and Potassium Fertilization on the Seed Content of Pole Beans</u>

<u>1952 Crop</u> - The data in Tables 51-56 show that phosphorus fertilization significantly increased seed content in five of the six groups studied. The exception was size 3 beans, early harvest, canned while fresh (Table 51). However, there was a significant N x P interaction in this group, in which the use of phosphorus significantly increased seed content when nitrogen was not used.

Nitrogen fertilization caused a significant reduction in seed content in two groups. One was size 4 and 5 beans of the early harvest, canned while fresh (Table 53); the other was size 3 beans of the late harvest, also canned while fresh (Table 55). No other significant changes attributable to nitrogen fertilization were indicated by the data in Tables 51, 52, 54, 56.

The use of potassium fertilizers did not significantly affect the seed content of any of the groups studied (Tables 51-56).

Table 51

The Gram Weight of Seeds per 100 Grams Pods of Size 3 Beans (1952 Early Harvest, Canned While Fresh)

Level	Means of Individual Treatments					
	P-0			P-1		
	K-0	K-1	K-2	K-0	K-1	K-2
N-0	2.85	2.75	2.47	3.47	3.14	3.41
N-1	2.71	3.50	3.03	2.91	2.81	2.45

Table 51 (Cont'd)

Level	N-Means	P-Means	K-Means
		Means of Main Effects	
0	3.01	2.88	2.86
1	2.82	2.95	3.05
2			2.84

Means of N x P Combinations

	P-0	P-1
N-0	2.69	3.34
N-1	3.08	2.56
L.S.D. (.05) — .343		L.S.D. (.01) — .459

Means of N x K Combinations

	K-0	K-1	K-2
N-0	3.16	2.95	2.75
N-1	2.57	3.15	2.74
L.S.D. (.05) — .422		L.S.D. (.01) — .565	

Main effects not significant

Table 52

Gram Weight of Seeds per 100 Grams Pods of Size 3 Beans
(1952 Late Harvest, Canned While Fresh)

Level	Means of Individual Treatments					
	P-0			P-1		
	K-0	K-1	K-2	K-0	K-1	K-2
N-0	2.05	2.00	2.08	3.05	2.35	2.79
N-1	2.91	1.88	1.83	2.26	2.27	2.88

Means of Main Effects

Level	N-Means	P-Means	K-Means
0	2.38	2.12	2.56
1	2.34	2.60	2.12
2			2.39
L.S.D. (.05)	N.S.D.	.306	N.S.D.
L.S.D. (.01)	N.S.D.	.431	N.S.D.

Interactive effects not significant

Table 53

Gram Weight of Seeds per 100 Grams Pods of Size 4 and 5 Beans
(1952 Early Harvest, Canned While Fresh)

Level	Means of Individual Treatments					
	P-0			P-1		
	K-0	K-1	K-2	K-0	K-1	K-2
N-0	4.26	5.15	4.86	4.95	5.21	4.67
N-1	4.28	4.25	4.67	3.78	4.52	4.74

Means of Main Effects

Level	N-Means	P-Means	K-Means
0	4.86	4.41	4.32
1	4.20	4.65	4.79
2			4.48
L.S.D. (.05)	.363	N.S.D.	N.S.D.
L.S.D. (.01)	.486	N.S.D.	N.S.D.

Interactive effects not significant

Table 54

Gram Weight of Seeds per 100 Grams Pods of Size 4 and 5 Beans
(1952 Late Harvest, Canned While Fresh)

Level	Means of Individual Treatments					
	P-0			P-1		
	K-0	K-1	K-2	K-0	K-1	K-2
N-0	3.18	3.02	2.70	3.19	3.45	3.21
N-1	2.58	3.17	2.41	3.29	3.13	3.45

Means of Main Effects

Level	N-Means	P-Means	K-Means
0	3.19	2.88	3.06
1	3.01	3.32	3.23
2			3.02
L.S.D. (.05)	N.S.D.	.293	N.S.D.
L.S.D. (.01)	N.S.D.	.392	N.S.D.

Interactive effects not significant

Table 55

Gram Weight of Seeds per 100 Grams Pods of Size 3 Beans
(1952 Late Harvest, Canned While Fresh)

Level	Means of Individual Treatments					
	P-0			P-1		
	K-0	K-1	K-2	K-0	K-1	K-2
N-0	1.93	2.03	1.80	2.63	2.60	2.74
N-1	1.89	1.71	1.70	2.40	1.96	2.31

Level	N-Means	P-Means	K-Means
	Means of Main Effects		
0	2.29	1.84	2.21
1	1.99	2.44	2.07
2			2.13
L.S.D. (.05)	.151	.151	N.S.D.
L.S.D. (.01)	.213	.213	N.S.D.

Interactive effects not significant

Table 56

Gram Weight of Seeds per 100 Grams Pods of Size 4 and 5 Beans
(1952 Late Harvest, Canned After Storage)

Level	Means of Individual Treatments					
	P-0			P-1		
	K-0	K-1	K-2	K-0	K-1	K-2
N-0	3.10	2.91	3.11	3.13	3.27	3.28
N-1	2.32	2.39	2.76	3.58	3.04	3.50

Level	N-Means	P-Means	K-Means
	Means of Main Effects		
0	3.13	2.76	3.03
1	2.92	3.29	2.90
2			3.16
L.S.D. (.05)	N.S.D.	.30	N.S.B.
L.S.D. (.01)	N.S.D.	.39	N.S.D.

Interactive effects not significant

1953 Crop - Nitrogen caused a significant reduction in seed content of size 4 and 5 beans of the early harvest (Table 58). A second effect of nitrogen was shown in late harvested beans of the same size in which the use of 100 pounds of nitrogen resulted in a significant reduction of seed content, when used in the absence of phosphorus (Table 59). Potassium fertilization was followed by a significant reduction in seed content in the same group.

These were the only significant changes in seed content resulting from fertilizer treatment (Tables 57-59).

Table 57

Grams of Seed per 100 Grams Pods of Size 3 Beans
(1953, Canned While Fresh)

Level	Means of Individual Treatments			
	P-0		P-1	
	K-0	K-1	K-0	K-1
N-0	2.47	2.98	2.88	2.96
N-1	2.67	2.35	2.53	2.74
N-2	2.99		2.66	

Means of Main Effects (Factorial Treatments)

Level	N-Means	P-Means	K-Means
0	2.82	2.61	2.64
1	2.57	2.78	2.76

Individual treatment differences not significant; main and interactive effects not significant

Table 58

Grams of Seed per 100 Grams Pods of Size 4 and 5 Beans
(1953 Early Harvest, Canned While Fresh)

Level	Means of Individual Treatments			
	P-0		P-1	
	K-0	K-1	K-0	K-1
N-0	4.05	4.63	4.50	4.23
N-1	4.27	4.09	3.90	4.22
N-2	3.89		3.92	

Means of Main Effects (Factorial Treatments)

Level	N-Means	P-Means	K-Means
0	4.60	4.26	4.18
1	4.12	4.46	4.54
L.S.D. (.05)	0.46	N.S.D.	N.S.D.
L.S.D. (.01)	N.S.D.	N.S.D.	N.S.D.

Interactive effects not significant

Table 59

Grams of Seed per 100 Grams Pods of Size 4 and 5 Beans
(1953 Late Harvest, Canned While Fresh)

Level	Means of Individual Treatments			
	P-0		P-1	
	K-0	K-1	K-0	K-1
N-0	2.71	2.46	2.78	2.59
N-1	2.67	2.55	2.88	2.43
N-2	2.16		2.44	
L.S.D. (.05)	— .453		L.S.D. (.01)	— .613

Means of Main Effects (Factorial Treatments)

Level	N-Means	P-Means	K-Means
0	2.63	2.60	2.76
1	2.64	2.67	2.51
L.S.D. (.05)	N.S.D.	N.S.D.	.218
L.S.D. (.01)	N.S.D.	N.S.D.	N.S.D.

Interactive effects not significant

The Effects of Nitrogen, Phosphorus, and Potassium Fertilization on the Shear Press Readings of Canned Pole Beans

1952 Crop - Significant differences in shear press readings resulting from fertilizer treatments were found in only two of the six groups studied. In both groups phosphorus fertilization resulted in a significant reduction in the force required to shear the beans as measured by the shear press. One group was of size 3 beans of the early harvest, canned while fresh (Table 60); the other was of size 4 and 5 beans, early harvest, canned while fresh (Table 61). In the latter group a significant increase in shear press readings resulted from potassium fertilization. Both salts, chloride (K-1) and sulphate (K-2), were indicated as significantly effective.

1953 Crop - Shear press readings were taken on five groups of canned beans. However, no significant differences from fertilizer treatment were found, so the data are not presented. The readings varied between 22 and 27.5 kilograms (per square inch) shearing force requirement.

Table 60

Shear Press Readings of Size 3 Beans
(1952 Early Harvest, Canned While Fresh)

Level	Means of Individual Treatments*					
	P-0			P-1		
	K-0	K-1	K-2	K-0	K-1	K-2
N-0	73.8	80.0	71.3	66.3	66.3	73.8
N-1	73.8	82.5	80.0	58.8	73.8	72.5

Means of Main Effects*

Level	N-Means	P-Means	K-Means
0	71.5	76.0	68.0
1	72.5	68.0	74.0
2			74.0
L.S.D. (.05)	N.S.D.	6.05	N.S.D.
L.S.D. (.01)	N.S.D.	7.45	N.S.D.

Interactive effects not significant

Table 61

Shear Press Readings of Size 4 and 5 Beans
(1952 Late Harvest Beans, Canned After Storage)

Level	Means of Individual Treatments*					
	P-0			P-1		
	K-0	K-1	K-2	K-0	K-1	K-2
N-0	72.5	82.5	83.8	70.0	72.5	80.0
N-1	73.8	75.8	77.5	70.0	76.3	71.3

Means of Main Effects*

Level	N-Means	P-Means	K-Means
0	77.0	77.5	71.5
1	74.0	73.5	77.0
2			78.0
L.S.D. (.05)	L.S.D.	3.83	4.69
L.S.D. (.01)	L.S.D.	N.S.D.	N.S.D.

Interactive effects not significant

* Shear Press readings are in pounds per square inch

<u>The Effects of Nitrogen, Phosphorus, and Potassium Fertilization on the Shear Press Readings of Frozen Pole Beans</u>

<u>1952 Crop</u> - Shear Press Readings were taken on all six groups of beans, but significant differences in resistance to shear resulting from fertilizer treatments were noted in only three groups. In both sizes of the early harvest beans, frozen while fresh, the use of phosphorus fertilizers significantly reduced shear press readings (Tables 62 and 63). A significant increase from nitrogen fertilization was also noted in size 3 beans (Table 62). A different effect was noted in the size 4 and 5 beans of the late harvest, frozen after storage (Table 64). In that group, phosphorus fertilization resulted in a significant increase in shear press readings.

No other significant effects of nitrogen, phosphorus, or potassium fertilization were indicated by the data.

Table 62

Shear Press Readings of Size 3 Beans
(1952 Early Harvest, Frozen While Fresh)

Level	Means of Individual Treatments*					
	P-0			P-1		
	K-0	K-1	K-2	K-0	K-1	K-2
N-0	62.1	55.8	52.9	49.7	52.1	54.5
N-1	59.5	56.4	69.9	52.8	55.6	61.5

Means of Main Effects*

Level	N-Means	P-Means	K-Means
0	54.7	59.6	56.0
1	59.3	54.5	55.1
2			59.9
L.S.D. (.05)	4.14	4.14	N.S.D.
L.S.D. (.01)	N.S.D.	N.S.D.	N.S.D.

Interactive Effects not significant
* Shear Press readings in kilograms per square inch

Table 63

Shear Press Readings of Size 4 and 5 Beans
(1952 Early Harvest, Frozen While Fresh)

Level	Means of Individual Treatments					
	P-0			P-1		
	K-0	K-1	K-2	K-0	K-1	K-2
N-0	58.9	54.0	51.6	50.3	51.0	49.8
N-1	56.9	62.0	55.6	52.3	51.2	54.4

Means of Main Effects

Level	N-Means	P-Means	K-Means
0	52.6	56.5	54.6
1	55.4	51.5	54.6
2			52.8
L.S.D. (.05)	N.S.D.	3.92	N.S.D.
L.S.D. (.01)	N.S.D.	N.S.D.	N.S.D.

Interactive effects not significant

Table 64

Shear Press Readings of Size 4 and 5 Beans
(1952 Late Harvest, Frozen After Storage)

Level	Means of Individual Treatments					
	P-0			P-1		
	K-0	K-1	K-2	K-0	K-1	K-2
N-0	55.1	65.3	65.0	66.8	69.6	61.1
N-1	61.3	63.3	63.8	68.1	69.1	70.8

	Means of Main Effects		
Level	N-Means	P-Means	K-Means
0	63.8	62.2	62.8
1	66.0	67.6	66.8
2			65.2
L.S.D. (.05)	N.S.D.	4.59	N.S.D.
L.S.D. (.01)	N.S.D.	N.S.D.	N.S.D.

Interactive effects not significant

1953 Crop - Shear press readings were taken on all groups, but significant differences in resistance to shear were indicated in only two groups of beans. Both groups were of size 4 and 5 beans, frozen while fresh; and responses were noted in both harvests.

Significant N x P interactions were indicated in both groups (Tables 65, 66). In both groups, the tendency of nitrogen fertilization to depress the shear press readings was affected by the phosphorus fertilization level since this depression did not occur when phosphorus fertilizers were used. A similar P x K interaction is shown in the early harvest group (Table 65). The tendency of potassium fertilization to significantly depress shear press readings was shown to be dependent on the phosphorus fertilization level.

Table 65

Shear Press Readings of 40 of Size 4 and 5 Beans
(1953 Early Harvest, Frozen While Fresh)

Level	Means of Individual Treatments			
	P-0		P-1	
	K-0	K-1	K-0	K-1
N-0	52.1	42.6	44.3	42.5
N-1	40.1	33.8	45.3	48.4
N-2	48.0		47.1	

Means of Main Effects (Factorial Treatments)

Level	N-Means	P-Means	K-Means
0	45.31	42.09	45.44
1	41.88	45.09	41.75

Table of N x P Combinations

	P-0	P-1
N-0	47.25	43.38
N-1	36.94	46.81

L.S.D. (.05) — 5.43   L.S.D. (.01) — 7.39

Table of P x K Combinations

	P-0	P-1
K-0	46.13	44.75
K-1	38.06	45.44

L.S.D. (.05) — 5.43   L.S.D. (.01) — 7.39

Individual treatment differences and main effect differences not significant

Table 66

Shear Press Readings of Size 4 and 5 Beans
(1953 Late Harvest, Frozen While Fresh)

Level	Means of Individual Treatments			
	P-0		P-1	
	K-0	K-1	K-0	K-1
N-0	50.4	43.4	43.4	42.4
N-1	43.0	43.8	49.4	49.4
N-2	52.1		47.1	
L.S.D. (.05) — 4.95			L.S.D. (.01) — 6.74	

Means of Main Effects (Factorial Treatments)

Level	N-Means	P-Means	K-Means
0	47.38	47.63	46.53
1	45.13	44.88	45.97

Table of N x P Combinations

	P-0	P-1
N-0	51.88	42.88
N-1	43.38	46.88
L.S.D. (.05) — 3.49		L.S.D. (.01) — 4.76

Main effects not significant

<u>The Effect of Nitrogen, Phosphorus, and Potassium Fertilization on the Hunter "Rd", "a", and "b" Readings of Canned Pole Beans</u>

<u>1952 Crop</u> - Objective evaluations of color were made on all groups of canned beans, using the Hunter Color and Color Difference Meter; but significant differences in readings due to fertilization were found in only four groups. The use of potassium fertilizers resulted in significantly lower "a" readings in size 3 beans of the early harvest, canned while fresh (Table 68). This was true of both forms of potassium fertilizers used. In the case of the "b" readings, only potassium chloride (K-1) was associated with a significant reduction (Table 69). In the absence of significant change in "Rd" (Table 67), this would indicate that the use of potassium chloride fertilizer had resulted in beans of more yellow and of less green hue. Less chroma (lesser degree of saturation of color) is also indicated. Potassium sulphate fertilization resulted in beans of more yellow (and less green) hue while the degree of saturation remained about the same.

In the size 4 and 5 beans of the late harvest, also canned fresh, the effect of potassium was again evident (Tables 71, 72). The use of both forms of fertilizer was associated with a significant reduction in both "a" and "b" readings. In the absence of significant change in "Rd" (Table 70), this indicates that the beans were more yellow (and less green) and that there was a lesser degree of chroma.

A third color response resulting from potassium fertilization was noted in the size 4 and 5 beans of the late harvest, canned after storage (Tables 73, 74). Use of potassium chloride significantly increased "Rd" and "a", which indicates an increase in reflection and a change in hue toward green (from yellow). Use of potassium sulphate, on the other hand, was associated with a significant increase in "a" only (Table 74). In this same group, phosphorus fertilization significantly decreased "a", which in the absence of significant change in "Rd" or "b", indicates a shift toward yellow, from green.

Nitrogen fertilization significantly increased "Rd" readings in the size 3 beans of the late harvest, canned after storage (Table 76). Use of phosphorus had the same effect. In the absence of changes in "a" and "b" readings, this indicates an increase in reflection.

Table 67

Hunter "Rd" Readings of Size 3 Beans
(1952 Early Harvest, Canned While Fresh)

Level	Means of Individual Treatments					
	P-0			P-1		
	K-0	K-1	K-2	K-0	K-1	K-2
N-0	9.31	9.14	9.73	9.10	8.96	9.32
N-1	9.37	9.01	9.41	10.08	8.72	9.18

Level	Means of Main Effects		
	N-Means	P-Means	K-Means
0	9.26	9.33	9.47
1	9.30	9.23	8.96
2			9.41

Main and interactive effects not significant

Table 68

Hunter "a" Readings of Size 3 Beans*
(1952 Early Harvest, Canned While Fresh)

Level	Means of Individual Treatments					
	P-0			P-1		
	K-0	K-1	K-2	K-0	K-1	K-2
N-0	5.17	5.14	4.57	5.12	4.81	5.00
N-1	4.97	4.90	4.70	5.45	4.88	5.10

Means of Main Effects

Level	N-Means	P-Means	K-Means
0	4.97	4.91	5.18
1	5.00	5.06	4.93
2			4.84
L.S.D. (.05)	N.S.D.	N.S.D.	.181
L.S.D. (.01)	N.S.D.	N.S.D.	.243

Interactive effects not significant
* All Hunter "a" readings are minus

Table 69

Hunter "b" Readings of Size 3 Beans
(1952 Early Harvest, Canned While Fresh)

Level	Means of Individual Treatments					
	P-0			P-1		
	K-0	K-1	K-2	K-0	K-1	K-2
N-0	19.30	15.15	14.75	15.10	14.52	15.01
N-1	14.83	14.28	14.74	15.58	14.45	14.97

Means of Main Effects

Level	N-Means	P-Means	K-Means
0	14.97	14.84	15.20
1	14.81	14.94	14.60
2			14.87
L.S.D. (.05)	N.S.D.	N.S.D.	.464
L.S.D. (.01)	N.S.D.	N.S.D.	.622

Interactive effects not significant

Table 70

Hunter "Rd" Readings of Size 4 and 5 Beans
(1952 Early Harvest, Canned While Fresh)

Level	Means of Individual Treatments					
	P-0			P-1		
	K-0	K-1	K-2	K-0	K-1	K-2
N-0	10.71	10.62	9.85	10.20	10.06	10.09
N-1	10.48	9.90	10.15	10.68	10.27	10.04

Means of Main Effects

Level	N-Means	P-Means	K-Means
0	10.26	10.29	10.52
1	10.25	10.23	10.21
2			10.03

Main and interactive effects not significant

Table 71

Hunter "a" Readings of Size 4 and 5 Beans
(1952 Early Harvest, Canned While Fresh)

Level	Means of Individual Treatments					
	P-0			P-1		
	K-0	K-1	K-2	K-0	K-1	K-2
N-0	5.56	5.27	4.92	5.18	5.06	5.09
N-1	5.39	5.04	5.10	5.32	5.03	4.93

Means of Main Effects

Level	N-Means	P-Means	K-Means
0	5.18	5.22	5.36
1	5.13	5.10	5.11
2			5.01
L.S.D. (.05)	N.S.D.	N.S.D.	.179
L.S.D. (.01)	N.S.D.	N.S.D.	.241

Interactive effects not significant

Table 72

Hunter "b" Readings of Size 4 and 5 Beans
(1952 Early Harvest, Canned While Fresh)

Level	Means of Individual Treatments					
	P-0			P-1		
	K-0	K-1	K-2	K-0	K-1	K-2
N-0	16.46	15.70	15.17	15.58	15.60	14.68
N-1	15.75	15.11	15.41	15.82	15.61	15.48

Means of Main Effects

Level	N-Means	P-Means	K-Means
0	15.53	15.60	15.90
1	15.53	15.46	15.51
2			15.19
L.S.D. (.05)	N.S.D.	N.S.D.	.364
L.S.D. (.01)	N.S.D.	N.S.D.	N.S.D.

Interactive effects not significant

Table 73

Hunter "Rd" Readings of Size 4 and 5 Beans
(1952 Late Harvest, Canned After Storage)

Level	Means of Individual Treatments					
	P-0			P-1		
	K-0	K-1	K-2	K-0	K-1	K-2
N-0	9.45	9.72	9.70	9.38	9.55	9.26
N-1	8.96	9.72	9.62	9.07	10.24	9.40

Means of Main Effects

Level	N-Means	P-Means	K-Means
0	9.51	9.51	9.22
1	9.50	9.48	9.81
2			9.49
L.S.D. (.05)	N.S.D.	N.S.D.	.323
L.S.D. (.01)	N.S.D.	N.S.D.	.433

Interactive effects not significant

Table 74

Hunter "a" Readings of Size 4 and 5 Beans
(1952 Late Harvest, Canned After Storage)

Level	Means of Individual Treatments					
	P-0			P-1		
	K-0	K-1	K-2	K-0	K-1	K-2
N-0	5.20	5.35	5.42	4.67	5.19	5.13
N-1	4.82	5.25	5.15	4.37	5.50	4.56

Means of Main Effects

Level	N-Means	P-Means	K-Means
0	5.16	5.20	4.76
1	4.94	4.90	5.32
2			5.06
L.S.D. (.05)	N.S.D.	.228	.281
L.S.D. (.01)	N.S.D.	.306	.376

Interactive effects not significant

Table 75

Hunter "b" Readings of Size 4 and 5 Beans
(1952 Late Harvest, Canned After Storage)

Level	Means of Individual Treatments					
	P-0			P-1		
	K-0	K-1	K-2	K-0	K-1	K-2
N-0	14.97	15.00	14.78	15.05	15.22	14.95
N-1	14.55	15.09	15.35	14.59	15.58	14.75

Means of Main Effects

Level	N-Means	P-Means	K-Means
0	14.99	14.96	14.79
1	14.99	15.02	15.22
2			14.96

Main and interactive effects not significant

Table 76

Hunter "Rd" Readings of Size 3 Beans
(1952 Late Harvest, Canned After Storage)

Level	Means of Individual Treatments					
	P-0			P-1		
	K-0	K-1	K-2	K-0	K-1	K-2
N-0	8.98	8.57	8.51	8.55	8.67	8.57
N-1	8.60	8.98	8.63	9.15	9.87	9.45

Means of Main Effects

Level	N-Means	P-Means	K-Means
0	8.64	8.71	8.82
1	9.11	9.04	9.02
2			8.79
L.S.D. (.05)	.293	.293	N.S.D.
L.S.D. (.01)	.392	N.S.D.	N.S.D.

Interactive effects not significant

1953 Crop - Objective color readings were taken on all groups, using the Hunter Color and Color Difference Meter; but significant differences due to fertilizer treatments were found in only three groups.

Phosphorus fertilization affected color readings only in the size 4 and 5 beans of the early harvest, canned while fresh. In that group, it significantly reduced the "Rd" and "a" readings (Tables 77, 78). The fact that the "b" readings were not significantly changed (Table 79) indicates that the effect was a reduction in reflection and a shift in hue from green toward yellow.

Nitrogen fertilization was associated with significant changes in the color of both size groups of beans canned after storage. In the size 4 and 5 beans, the use of Nitrogen fertilizer significantly increased "Rd" and "a" readings (Tables 83, 84). In the absence of a significant change in "b" readings, this indicates an increase in reflection and a shift in hue from green toward yellow. In the size 3 beans, the use of nitrogen resulted in a significant increase in "b" readings (Table 82). The differences in "Rd" and "a" attributable to the main effects of nitrogen fertilization were not quite large enough to be significant (Tables 80, 81). The "b" change (Table 82) indicates an increase in chroma; also, an increase in reflection would probably be observed.

Table 77

Hunter "Rd" Readings of Size 4 and 5 Beans
(1953 Early Harvest, Canned While Fresh)

Level	Means of Individual Treatments			
	P-0		P-1	
	K-0	K-1	K-0	K-1
N-0	8.51	8.67	8.19	7.88
N-1	9.13	8.71	8.36	8.21
N-2	8.59		8.87	
L.S.D. (.05) — .937			L.S.D. (.01) — 1.268	

Level	Means of Main Effects (Factorial Treatments)		
	N-Means	P-Means	K-Means
0	8.31	8.75	8.55
1	8.60	8.16	8.36
L.S.D. (.05)	N.S.D.	.327	N.S.D.
L.S.D. (.01)	N.S.D.	.443	N.S.D.

Interactive effects not significant

Table 78

Hunter "a" Readings of Size 4 and 5 Beans
(1953 First Harvest, Canned While Fresh)

Level	Means of Individual Treatments			
	P-0		P-1	
	K-0	K-1	K-0	K-1
N-0	5.28	5.30	4.74	4.71
N-1	5.47	5.02	5.21	4.99
N-2	5.25		5.46	
L.S.D. (.05)	— .295		L.S.D. (.01) — .399	

Level	Means of Main Effects (Factorial Treatments)		
	N-Means	P-Means	K-Means
0	5.01	5.27	5.17
1	5.17	4.91	5.01
L.S.D. (.05)	N.S.D.	.226	N.S.D.
L.S.D. (.01)	N.S.D.	.306	N.S.D.

Interactive effects not significant

Table 79

Hunter "b" Readings of Size 4 and 5 Beans
(1953 Early Harvest, Canned While Fresh)

Level	Means of Individual Treatments			
	P-0		P-1	
	K-0	K-1	K-0	K-1
N-0	13.44	13.90	12.93	12.46
N-1	13.82	12.66	13.03	12.59
N-2	13.13		13.78	
L.S.D. (.05)	— .726		L.S.D. (.01) — .981	

Level	Means of Main Effects (Factorial Treatments)		
	N-Means	P-Means	K-Means
0	13.18	13.45	13.30
1	13.02	12.75	12.90

Main and interactive effects not significant

Table 80

Hunter "Rd" Readings of Size 3 Beans
(1953, Canned After Storage)

Level	Means of Individual Treatments			
	P-0		P-1	
	K-0	K-1	K-0	K-1
N-0	6.26	6.98	6.39	6.76
N-1	6.80	6.78	7.19	7.05
N-2	6.95		7.25	

Means of Main Effects (Factorial Treatments)

Level	N-Means	P-Means	K-Means
0	6.59	6.71	6.66
1	6.96	6.84	6.88

Individual Treatment differences not significant
Main and interactive effects not significant

Table 81

Hunter "a" Readings of Size 3 Beans
(1953, Canned After Storage)

Level	Means of Individual Treatments			
	P-0		P-1	
	K-0	K-1	K-0	K-1
N-0	4.06	4.36	4.05	4.26
N-1	4.42	4.33	4.43	4.25
N-2	4.30		4.57	

Means of Main Effects (Factorial Treatments)

Level	N-Means	P-Means	K-Means
0	4.19	4.30	4.24
1	4.36	4.25	4.30

Individual Treatment differences not significant
Main and interactive differences not significant

Table 82

Hunter "b" Readings of Size 3 Beans
(1953, Canned After Storage)

Level	Means of Individual Treatments			
	P-0		P-1	
	K-0	K-1	K-0	K-1
N-0	11.65	12.36	11.45	12.15
N-1	12.33	12.18	12.73	12.55
N-2	12.33		12.55	

Level	Means of Main Effects (Factorial Treatments) N-Means	P-Means	K-Means
0	11.90	12.13	12.04
1	12.45	12.22	12.31
L.S.D. (.05)	.500	N.S.D.	N.S.D.
L.S.D. (.01)	N.S.D.	N.S.D.	N.S.D.

Interactive effects not significant

Table 83

Hunter "Rd" Readings of Size 4 and 5 Beans
(1953 Early Harvest, Canned After Storage)

Level	Means of Individual Treatments			
	P-0		P-1	
	K-0	K-1	K-0	K-1
N-0	7.67	7.77	7.74	7.39
N-1	8.02	7.88	8.16	8.35
N-2	8.39		7.48	

Level	Means of Main Effects (Factorial Treatments) N-Means	P-Means	K-Means
0	7.64	7.83	7.90
1	8.10	7.91	7.85
L.S.D. (.05)	.451	N.S.D.	N.S.D.
L.S.D. (.01)	N.S.D.	N.S.D.	N.S.D.

Interactive effects not significant

Table 84

Hunter "a" Readings of Size 4 and 5 Beans
(1953 Early Harvest, Canned After Storage)

Level	Means of Individual Treatments			
	P-0		P-1	
	K-0	K-1	K-0	K-1
N-0	4.59	4.91	4.55	4.56
N-1	4.89	5.10	5.00	5.02
N-2	5.06		4.57	

Level	N-Means	P-Means	K-Means
	Means of Main Effects (Factorial Treatments)		
0	4.65	4.87	4.76
1	5.00	4.78	4.90
L.S.D. (.05)	.272	N.S.D.	N.S.D.
L.S.D. (.01)	N.S.D.	N.S.D.	N.S.D.

Interactive effects not significant

The Effects of Nitrogen, Phosphorus, and Potassium Fertilization on the Hunter "Rd", "a", and "b" Readings of Frozen Pole Beans

1952 Crop - Objective evaluations of color were made on all groups of frozen beans, using the Hunter Color and Color Difference Meter; but significant differences due to fertilizer treatments were noted in only two groups. In the size 3 beans of the late harvest, frozen while fresh, phosphorus fertilization significantly decreased Hunter "b" readings (Table 88). In the absence of significant change in "Rd" and "a" (Tables 86, 87), this would indicate a decrease in chroma and a small change in hue, toward green from yellow.

In the size 4 and 5 beans of the late harvest, frozen after storage, phosphorus fertilization resulted in significantly lowered "a" readings (Table 90). The reduction in "Rd" readings was not quite large enough to be significant (Table 89). In the absence of significant change in "b" (Table 91), this indicates a shift in hue from green toward yellow and, perhaps, some reduction in reflection.

Table 86

Hunter "Rd" Readings of Size 3 Beans
(1952 Late Harvest, Frozen While Fresh)

Level	Means of Individual Treatments					
	P-0			P-1		
	K-0	K-1	K-2	K-0	K-1	K-2
N-0	6.85	7.00	6.78	6.54	7.32	6.14
N-1	6.80	6.62	6.80	6.79	6.54	6.62

Means of Main Effects

Level	N-Means	P-Means	K-Means
0	6.77	6.81	6.75
1	6.69	6.66	6.86
2			6.58

Main and interactive effects not significant

Table 87

Hunter "a" Readings of Size 3 Beans
(1952 Late Harvest, Frozen While Fresh)

Level	Means of Individual Treatments					
	P-0			P-1		
	K-0	K-1	K-2	K-0	K-1	K-2
N-0	6.51	7.07	6.48	5.74	7.14	5.68
N-1	6.61	6.37	6.12	6.35	6.48	6.98

Means of Main Effects

Level	N-Means	P-Means	K-Means
0	6.43	6.52	6.30
1	6.48	6.39	6.76
2			6.31

Main and interactive effects not significant

Table 88

Hunter "b" Readings of Size 3 Beans
(1952 Late Harvest, Frozen While Fresh)

Level	Means of Individual Treatments					
	P-0			P-1		
	K-0	K-1	K-2	K-0	K-1	K-2
N-0	10.38	10.98	10.44	10.27	10.67	9.34
N-1	10.48	10.43	10.33	10.38	9.89	10.13

Means of Main Effects

Level	N-Means	P-Means	K-Means
0	10.35	10.51	10.38
1	10.27	10.11	10.49
2			10.06
L.S.D. (.05)	N.S.D.	.262	N.S.D.
L.S.D. (.01)	N.S.D.	.352	N.S.D.

Interactive effects not significant

Table 89

Hunter "Rd" Readings of Size 4 and 5 Beans
(1952 Late Harvest, Frozen After Storage)

Level	Means of Individual Treatments					
	P-0			P-1		
	K-0	K-1	K-2	K-0	K-1	K-2
N-0	6.70	6.70	6.52	6.68	6.62	6.42
N-1	6.71	7.20	6.68	6.45	6.59	6.48

Means of Main Effects

Level	N-Means	P-Means	K-Means
0	6.61	6.75	6.64
1	6.68	6.54	6.78
2			6.52

Main and interactive effects not significant

Table 90

Hunter "a" Readings of Size 4 and 5 Beans
(1952 Late Harvest, Frozen After Storage)

Level	Means of Individual Treatments					
	P-0			P-1		
	K-0	K-1	K-2	K-0	K-1	K-2
N-0	6.59	6.88	6.56	6.42	6.31	6.07
N-1	6.87	6.64	6.62	6.15	6.18	6.58

Means of Main Effects

Level	N-Means	P-Means	K-Means
0	6.46	6.68	6.51
1	6.50	6.28	6.49
2			6.46
L.S.D. (.05)	N.S.D.	.258	N.S.D.
L.S.D. (.01)	N.S.D.	.346	N.S.D.

Interactive effects not significant

Table 91

Hunter "b" Readings of Size 4 and 5 Beans
(1952 Late Harvest, Frozen After Storage)

Level	Means of Individual Treatments					
	P-0			P-1		
	K-0	K-1	K-2	K-0	K-1	K-2
N-0	10.54	10.32	10.02	10.52	10.06	10.10
N-1	9.74	10.68	10.25	10.15	10.40	10.26

Means of Main Effects

Level	N-Means	P-Means	K-Means
0	10.26	10.26	10.23
1	10.25	10.25	10.36
2			10.16

Main and interactive effects not significant

1953 Crop - Nitrogen fertilization was the only factor which significantly changed color. In size 3 beans, frozen while fresh, nitrogen fertilization significantly increased "b" readings (Table 94). In the absence of significant changes in "Rd" and "a" (Tables 92, 93), this indicates an increase in chroma and a slight shift in hue from green toward yellow, as a result of nitrogen fertilization.

In two groups of size 4 and 5 beans, the use of nitrogen was associated with a significant increase in "a" readings (Tables 96, 99). In the first group (late harvest, frozen while fresh), there were no significant changes in the other readings, although the differences between "b" readings approached significance (Table 97). A shift in hue toward green and a possible increase in chroma is thus indicated.

In the second group (early harvest, frozen after storage), the use of nitrogen resulted in increase of both "a" and "b" readings (Tables 99, 100). Differences in "Rd" were not great enough to be significant (Table 98). These shifts indicate a greater degree of saturation (chroma), with little change in hue. The color of the nitrogen fertilized beans would thus appear lighter.

Significant N x P interactions affecting "Rd" and "a" readings occurred in the size 4 and 5 beans of the early harvest, canned while fresh (Tables 101, 102).

In these interactions, the tendency of nitrogen fertilization to increase "Rd" and "a" is shown to be dependent on the level of phosphorus fertilization, since the increase occurred only in the presence of phosphorus (P-1).

The color change indicated by increase in "Rd" and "a", without change in "b" is an increase in reflection and a shift in hue toward green.

Table 92

Hunter "Rd" Readings of Size 3 Beans
(1953, Frozen While Fresh)

Level	Means of Individual Treatments			
	P-0		P-1	
	K-0	K-1	K-0	K-1
N-0	6.96	6.70	7.00	6.95
N-1	7.36	6.70	7.13	6.83
N-2	7.42		7.41	

	Means of Main Effects (Factorial Treatments)		
Level	N-Means	P-Means	K-Means
0	6.91	6.93	7.11
1	7.00	6.98	6.80

Individual Treatment differences not significant
Main and interactive effects not significant

Table 93

Hunter "a" Readings of Size 3 Beans
(1953, Frozen While Fresh)

Level	Means of Individual Treatments			
	P-0		P-1	
	K-0	K-1	K-0	K-1
N-0	8.99	8.99	9.30	8.86
N-1	8.77	9.10	9.17	9.02
N-2	8.94		9.44	

Means of Main Effects (Factorial Treatments)

Level	N-Means	P-Means	K-Means
0	9.03	8.96	9.06
1	9.01	9.09	8.99

Individual treatment differences not significant
Main and interactive effects not significant

Table 94

Hunter "b" Readings of Size 3 Beans
(1953, Frozen While Fresh)

Level	Means of Individual Treatments			
	P-0		P-1	
	K-0	K-1	K-0	K-1
N-0	11.05	11.22	11.53	11.38
N-1	12.04	11.56	11.74	11.49
N-2	11.52		11.78	

Means of Main Effects (Factorial Treatments)

Level	N-Means	P-Means	K-Means
0	11.29	11.47	11.59
1	11.71	11.53	11.41
L.S.D. (.05)	.329	N.S.D.	N.S.D.
L.S.D. (.01)	N.S.D.	N.S.D.	N.S.D.

Interactive effects not significant

Table 95

Hunter "Rd" Readings of Size 4 and 5 Beans
(1953 Late Harvest, Frozen While Fresh)

Level	Means of Individual Treatments			
	P-0		P-1	
	K-0	K-1	K-0	K-1
N-0	7.33	7.67	7.34	7.26
N-1	7.53	7.35	7.72	7.87
N-2	7.59		7.98	

Level	Means of Main Effects (Factorial Treatments)		
	N-Means	P-Means	K-Means
0	7.40	7.47	7.48
1	7.37	7.40	7.29

Individual treatment differences not significant
Main and interactive effects not significant

Table 96

Hunter "a" Readings of Size 4 and 5 Beans
(1953 Late Harvest, Frozen While Fresh)

Level	Means of Individual Treatments			
	P-0		P-1	
	K-0	K-1	K-0	K-1
N-0	8.47	8.41	8.17	8.21
N-1	8.96	8.54	9.31	8.47
N-2	8.76		8.19	
L.S.D. (.05) — .628			L.S.D. (.01) — .848	

Level	Means of Main Effects (Factorial Treatments)		
	N-Means	P-Means	K-Means
0	8.31	8.59	8.73
1	8.82	8.54	8.40
L.S.D. (.05)	.260	N.S.D.	.260
L.S.D. (.01)	.352	N.S.D.	.352

Interactive effects not significant

Table 97

Hunter "b" Readings of Size 4 and 5 Beans
(1953 Late Harvest, Frozen While Fresh)

Level	Means of Individual Treatments			
	P-0		P-1	
	K-0	K-1	K-0	K-1
N-0	11.94	11.52	11.76	11.23
N-1	11.99	12.11	12.34	11.62
N-2	12.04		11.51	

Means of Main Effects (Factorial Treatments)

Level	N-Means	P-Means	K-Means
0	11.61	11.89	12.00
1	12.01	11.74	11.62

Individual treatment differences not significant
Main and interactive effects not significant

Table 98

Hunter "Rd" Readings of Size 4 and 5 Beans
(1953 Early Harvest, Frozen After Storage)

Level	Means of Individual Treatments			
	P-0		P-1	
	K-0	K-1	K-0	K-1
N-0	6.62	6.33	6.69	6.40
N-1	6.60	7.05	6.73	6.81
N-2	7.14		6.66	

Means of Main Effects (Factorial Treatments)

Level	N-Means	P-Means	K-Means
0	6.51	6.60	6.61
1	6.80	6.71	6.70

Individual treatment differences not significant
Main and interactive effects not significant

Table 99

Hunter "a" Readings of Size 4 and 5 Beans
(1953 Early Harvest, Frozen After Storage)

Level	Means of Individual Treatments			
	P-0		P-1	
	K-0	K-1	K-0	K-1
N-0	8.71	8.33	8.66	7.98
N-1	9.01	8.79	8.68	8.61
N-2	9.13		9.18	
L.S.D. (.05) — .611			L.S.D. (.01) — .826	

Level	Means of Main Effects (Factorial Treatments)		
	N-Means	P-Means	K-Means
0	8.43	8.71	8.77
1	8.77	8.49	8.43
L.S.D. (.05)	.377	N.S.D.	N.S.D.
L.S.D. (.01)	.510	N.S.D.	N.S.D.

Interactive effects not significant

Table 100

Hunter "b" Readings of Size 4 and 5 Beans
(1953 Early Harvest, Frozen After Storage)

Level	Means of Individual Treatments			
	P-0		P-1	
	K-0	K-1	K-0	K-1
N-0	10.74	10.42	10.70	10.84
N-1	11.22	11.22	10.83	11.21
N-2	11.18		11.07	

Level	Means of Main Effects (Factorial Treatments)		
	N-Means	P-Means	K-Means
0	10.68	10.90	10.87
1	11.12	10.90	10.93
L.S.D. (.05)	.307	N.S.D.	N.S.D.
L.S.D. (.01)	.415	N.S.D.	N.S.D.

Individual treatment differences not significant
Interactive effects not significant

Table 101

Hunter "Rd" Readings of Size 4 and 5 Beans
(1953 Early Harvest, Frozen While Fresh)

Level	Means of Individual Treatments			
	P-0		P-1	
	K-0	K-1	K-0	K-1
N-0	7.44	8.12	7.37	7.22
N-1	7.93	7.29	7.67	7.89
N-2	7.60		7.34	

Means of Main Effects (Factorial Treatments)

Level	N-Means	P-Means	K-Means
0	7.61	7.77	7.67
1	7.69	7.54	7.63

Table of N x P Combinations

	P-0	P-1
N-0	7.93	7.29
N-1	7.55	7.78

L.S.D. (.05) — .459 L.S.D. (.01) — .622

Table 102

Hunter "a" Readings of Size 4 and 5 Beans
(1953 Early Harvest, Frozen While Fresh)

Level	Means of Individual Treatments			
	P-0		P-1	
	K-0	K-1	K-0	K-1
N-0	9.14	9.42	9.12	8.56
N-1	9.03	8.91	9.72	9.54
N-2	9.18		8.89	

Means of Main Effects (Factorial Treatments)

Level	N-Means	P-Means	K-Means
0	9.05	9.12	9.25
1	9.30	9.23	9.10

Table 102 (Cont'd)

Table of N x P Combinations

	P-0	P-1
N-0	9.28	8.83
N-1	8.97	9.63
L.S.D. (.05) — .516	L.S.D. (.01) — .702	

Individual treatment differences not significant
Main effects not significant

Table 103

Hunter "b" Readings of Size 4 and 5 Beans
(1953, Frozen While Fresh)

Level	Means of Individual Treatments			
	P-0		P-1	
	K-0	K-1	K-0	K-1
N-0	12.39	12.46	12.30	11.75
N-1	12.55	12.10	12.31	12.82
N-2	12.36		11.64	

Means of Main Effects (Factorial Treatments)

Level	N-Means	P-Means	K-Means
0	12.23	12.37	12.39
1	12.44	12.29	12.28

Individual treatment differences not significant
Main and interactive effects not significant

The Effects of Nitrogen, Phosphorus, and Potassium Fertilization on the Agricultural Marketing Service Score for Texture and Maturity of Canned Pole Beans

1952 Crop - Four groups of beans were graded by the A.M.S., but significant differences due to fertilization were noted only in the size 4 and 5 beans which were canned after storage. In that group, the use of nitrogen significantly decreased the score for texture and maturity, whereas the use of potassium chloride (K-1) was associated with a significant increase (Table 104).

The scores for texture and maturity of all beans were in the medium grade A range. Average scores for all groups are listed in Table 105.

Table 104

A.M.S. Scores for Texture and Maturity of Size 4 and 5 Beans
(1952 Late Harvest, Canned After Storage)

Level	Means of Individual Treatments					
	P-0			P-1		
	K-0	K-1	K-2	K-0	K-1	K-2
N-0	37.5	38.5	38.0	37.0	38.0	37.0
N-1	34.5	37.5	37.0	35.5	37.0	38.0

Means of Main Effects

Level	N-Means	P-Means	K-Means
0	37.67	37.17	36.13
1	36.58	37.08	37.75
2			37.50
L.S.D. (.05)	.473	N.S.D.	.579
L.S.D. (.01)	.668	N.S.D.	.817

Interactive effects not significant

Table 105

Average A.M.S. Scores for Texture and Maturity of Four Groups of Canned Pole Beans

Canned Fresh		Canned After Storage	
Size 3	Size 4 and 5	Size 3	Size 4 and 5
37.42	37.42	37.21	37.12

<u>1953 Crop</u> - Four groups of beans were graded, but significant differences were found in only two groups. In the size 3 beans which were canned while fresh, phosphorus fertilization significantly reduced the score for texture and maturity (Table 106). Phosphorus fertilization was associated with the same significant effect in the 4 and 5 size beans of the late harvest, which were canned after storage (Table 107).

Analysis of the variance of individual treatments showed that the use of 100 pounds of nitrogen (N-2) resulted in a significant increase in score for texture and maturity when used in the absence of phosphorus. In the factorial analysis, nitrogen fertilization caused increase in this score, on the main effect basis (Table 107).

Since these scores are very important in grade evaluation, the average scores for all groups which were graded have been presented (Table 108).

Table 106

A.M.S. Scores for Texture and Maturity of Size 3 Beans
(1953, Canned While Fresh)

Level	Means of Individual Treatments			
	P-0		P-1	
	K-0	K-1	K-0	K-1
N-0	38.00	37.50	37.50	37.50
N-1	37.75	37.75	37.25	37.00
N-2	37.25		37.75	

Means of Main Effects (Factorial Treatments)

Level	N-Means	P-Means	K-Means
0	37.63	37.75	37.63
1	37.43	37.31	37.43
L.S.D. (.05)	N.S.D.	.37	N.S.D.
L.S.D. (.01)	N.S.D.	.50	N.S.D.

Individual treatment differences not significant
Interactive effects not significant

Table 107

A.M.S. Scores for Texture and Maturity of Size 4 and 5 Beans
(1952 Early Harvest, Canned After Storage)

Level	Means of Individual Treatments			
	P-0		P-1	
	K-0	K-1	K-0	K-1
N-0	36.00	36.25	35.75	35.75
N-1	36.75	37.00	36.25	36.25
N-2	37.25		36.25	
L.S.D. (.05) — .96			L.S.D. (.01) — 1.30	

Means of Main Effects (Factorial Treatments)

Level	N-Means	P-Means	K-Means
0	35.94	36.50	36.19
1	36.56	36.00	36.31
L.S.D. (.05)	.44	.44	N.S.D.
L.S.D. (.01)	.60	N.S.D.	N.S.D.

Interactive effects not significant

Table 108

Average A.M.S. Scores for Texture and Maturity
of Five Groups of Canned Pole Beans

Frozen While Fresh			Frozen After Storage	
Size 3	Size 4 and 5		Size 3	Size 4 and 5
	First Harv.	Second Harv.		Second Harv.
37.53	34.60	36.20	37.40	36.35

The Effects of Nitrogen, Phosphorus, and Potassium Fertilization on the Agricultural Marketing Service Score for Texture and Maturity of Frozen Pole Beans

1952 Crop - Four groups of beans were graded, but significant differences due to fertilization were found in only one group. This difference was a reduction in score for texture and maturity, as the result of phosphorus fertilization, and occurred in 4 and 5 size beans, stored before being frozen (Table 109).

The scores of the 1952 beans which were frozen while fresh were in the medium grade A range. However, the scores of the stored product were either border-line between A and B (36), or in grade B (32-35). Average scores for all groups graded are listed in Table 110.

Table 109

A.M.S. Scores for Texture and Maturity of Size 4 and 5 Beans
(1952 Late Harvest, Frozen After Storage)

Level	Means of Individual Treatments					
	P-0			P-1		
	K-0	K-1	K-2	K-0	K-1	K-2
N-0	35.5	36.0	34.5	33.5	35.5	34.5
N-1	37.0	37.0	36.5	34.0	35.0	33.0

Means of Main Effects

Level	N-Means	P-Means	K-Means
0	34.92	36.08	33.50
1	35.42	34.25	35.87
2			34.83
L.S.D. (.05)	N.S.D.	1.70	N.S.D.
L.S.D. (.01)	N.S.D.	N.S.D.	N.S.D.

Interactive effects not significant

Table 110

Average A.M.S. Scores for Texture and Maturity of Four Groups of Frozen Pole Beans

Frozen While Fresh		Frozen After Storage	
Size 3	Size 4 and 5	Size 3	Size 4 and 5
37.08	37.50	36.42	34.83

1953 Crop - Five groups were graded. There were no significant differences due to fertilization found in any of the groups. The average scores were in the grade A range, which is 36-40 in the A.M.S. system. The average scores for the five groups are presented in Table 111.

Table 111

Average A.M.S. Scores for Texture and Maturity of Five Groups of Frozen Pole Beans

Frozen While Fresh			Frozen After Storage	
Size 3	Size 4 and 5		Size 3	Size 4 and 5
	First Harv.	Second Harv.		Second Harv.
38.19	36.95	36.90	37.83	37.15

<u>The Effects of Nitrogen, Phosphorus, and Potassium Fertilization on the Agricultural Market Service Score for Color of Canned Pole Beans</u>

<u>1952 Crop</u> - Four groups were graded. Significant differences due to fertilizers were found in two of these groups. In them, phosphorus fertilization significantly reduced the scores for color in size 4 and 5 beans, of both fresh and stored lots (Tables 112, 113). Potassium fertilization resulted in a change in scores for color in these same groups, with the form used showing slightly different effects. In the stored group, both the chloride and sulphate of potassium were associated with increased scores for color (Table 113). In the fresh group, potassium chloride was associated with a slightly decreased color score, as compared to the plots receiving either potassium sulphate or no potassium treatment (Table 112).

The average scores for color of the other groups were: 13.96 for "Size 3 Beans, Frozen while Fresh", and 14.04 for "Size 3 Beans, Frozen after Storage".

Table 112

A.M.S. Scores for Color of Size 4 and 5 Beans
(1952 Late Harvest, Canned While Fresh)

Level	Means of Individual Treatments					
	P-0			P-1		
	K-0	K-1	K-2	K-0	K-1	K-2
N-0	14.0	14.0	15.0	15.0	14.5	14.0
N-1	15.0	14.0	15.0	14.0	14.0	14.0

Means of Main Effects

Level	N-Means	P-Means	K-Means
0	14.42	14.50	14.50
1	14.41	14.25	14.12
2			14.50
L.S.D. (.05)	N.S.D.	.12	.16
L.S.D. (.01)	N.S.D.	.18	.23

Table 113

A.M.S. Scores for Color of Size 4 and 5 Beans
(1952 Late Harvest, Canned After Storage)

Level	Means of Individual Treatments					
	P-0			P-1		
	K-0	K-1	K-2	K-0	K-1	K-2
N-0	13.5	14.0	15.0	12.5	14.5	14.0
N-1	14.5	14.0	14.5	13.0	14.5	13.5

Means of Main Effects

Level	N-Means	P-Means	K-Means
0	13.92	14.25	13.37
1	14.00	13.67	14.25
2			14.25
L.S.D. (.05)	N.S.D.	.425	.526
L.S.D. (.01)	N.S.D.	.601	.736

	K-0	K-1	K-2
P-0	14.00	14.00	14.75
P-1	12.75	14.50	13.75

L.S.D. (.05) — .726 L.S.D. (.01) — 1.025

1953 Crop - Five groups were graded, and significant differences due to fertilizer usage were noted in three of them. In the size 4 and 5 beans which were canned while fresh, the combination of 100 pounds of nitrogen (N-2) with phosphorus resulted in a significant decrease in the score for color (Table 114). In the same group, the potassium fertilization also significantly lowered score for color. Scores for color in both stored lots of 4 and 5 size beans were increased by nitrogen fertilization (Tables 115, 116). The increase in color score represents a change from grade B to grade A, according to the A.M.S. system.

Table 114

A.M.S. Scores for Color of Size 4 and 5 Beans
(1953 Late Harvest, Canned While Fresh)

Level	Means of Individual Treatments			
	P-0		P-1	
	K-0	K-1	K-0	K-1
N-0	14.25	14.00	14.75	14.00
N-1	14.50	14.25	14.50	14.25
N-2	14.50		14.00	
L.S.D. (.05) — .45			L.S.D. (.01) — .61	

Means of Main Effects

Level	N-Means	P-Means	K-Means
0	14.25	14.25	14.50
1	14.38	14.38	14.13
L.S.D. (.05)	N.S.D.	N.S.D.	.30
L.S.D. (.01)	N.S.D.	N.S.D.	N.S.D.

Interactive effects not significant

Table 115

A.M.S. Scores for Color of Size 3 Beans
(1953, Canned After Storage)

Level	Means of Individual Treatments			
	P-0		P-1	
	K-0	K-1	K-0	K-1
N-0	13.50	13.75	13.75	13.50
N-1	14.50	14.00	14.25	14.25
N-2	14.00		14.25	

	Means of Main Effects (Factorial Treatments)		
Level	N-Means	P-Means	K-Means
0	13.63	13.94	14.00
1	14.25	13.94	13.87
L.S.D. (.05)	.60	N.S.D.	N.S.D.
L.S.D. (.01)	N.S.D.	N.S.D.	N.S.D.

Individual treatment differences not significant
Interactive effects not significant

Table 116

A.M.S. Scores for Color of Size 4 and 5 Beans
(1953 Early Harvest, Canned After Storage)

Level	Means of Individual Treatments			
	P-0		P-1	
	K-0	K-1	K-0	K-1
N-0	14.00	13.75	13.25	13.75
N-1	14.25	14.50	14.50	14.50
N-2	14.75		14.25	
L.S.D. (.05) — 1.07			L.S.D. (.01) — 1.44	

	Means of Main Effects (Factorial Treatments)		
Level	N-Means	P-Means	K-Means
0	13.69	14.13	14.13
1	14.44	14.00	14.00
L.S.D. (.05)	.48	N.S.D.	N.S.D.
L.S.D. (.01)	.65	N.S.D.	N.S.D.

Interactive effects were not significant

The Effects of Nitrogen, Phosphorus, and Potassium Fertilization on the Agricultural Marketing Service Scores for Color of Frozen Pole Beans

1952 Crop - Fertilization had a significant effect on scores for color in only one of the four groups graded. This was an effect of phosphorus fertilization in reducing score for color, which occurred in the stored 4 and 5 size beans (Table 117).

The A.M.S. scores for color were in the A range (18-20) for the groups of beans which were frozen while fresh. However, the scores of beans which were frozen after storage were in the B range (16-18). Average scores for color for the four groups which were graded are tabulated (Table 118).

Table 117

A.M.S. Scores for Color of Size 4 and 5 Beans
(1952 Late Harvest, Frozen After Storage)

Level	Means of Individual Treatments					
	P-0			P-1		
	K-0	K-1	K-2	K-0	K-1	K-2
N-0	16.5	18.0	18.5	16.0	15.5	15.0
N-1	17.0	17.5	17.0	17.0	17.5	16.5

Means of Main Effects

Level	N-Means	P-Means	K-Means
0	16.58	17.42	16.62
1	17.08	16.25	17.12
2			16.75
L.S.D. (.05)	N.S.D.	.929	N.S.D.
L.S.D. (.01)	N.S.D.	N.S.D.	N.S.D.

Interactive effects not significant

Table 118

Average A.M.S. Scores for Color of
Four Groups of Frozen Pole Beans

Frozen While Fresh		Frozen After Storage	
Size 3	Size 4 and 5	Size 3	Size 4 and 5
18.46	18.00	16.92	16.83

<u>1953 Crop</u> - Five groups were graded. No significant differences due to fertilization were found in any of the groups. Because of the importance of these scores in grade evaluation, the averages are presented in the following table.

Table 119

Average A.M.S. Scores for Color of
Five Groups of Pole Beans

Frozen While Fresh			Frozen After Storage	
Size 3	Size 4 and 5		Size 3	Size 4 and 5
	First Harv.	Second Harv.		Second Harv.
18.85	17.98	18.40	17.38	18.05

The Effects of Nitrogen, Phosphorus, and Potassium Fertilization on the Agricultural Marketing Service Score for Absence of Defects in Frozen Pole Beans

1952 Crop - Four groups of beans were graded. Significant differences due to fertilization were found in only one group. Phosphorus fertilization significantly decreased scores for "absence of defects" in size 3 beans of the late harvest, frozen after storage (Table 120). This was the only significant effect indicated by the data.

Although significant differences from fertilizer treatments were found in only this group, it was noted that storing the beans before freezing resulted in their receiving a lower score for "absence of defects". This was very noticeable in size 4 and 5 beans (Table 121).

Table 120

A.M.S. Scores for Absence of Defects in Size 3 Beans
(1952 Late Harvest, Frozen After Storage)

Level	Means of Individual Treatments					
	P-0			P-1		
	K-0	K-1	K-2	K-0	K-1	K-2
N-0	28.0	34.0	36.5	28.0	32.5	30.5
N-1	36.5	32.0	33.5	30.0	25.0	32.0

Level	N-Means	P-Means	K-Means
	Means of Main Effects		
0	31.58	33.42	30.63
1	31.50	29.67	30.88
2			33.12
L.S.D. (.05)	N.S.D.	3.61	N.S.D.
L.S.D. (.01)	N.S.D.	N.S.D.	N.S.D.

Interactive effects not significant

Table 121

Average A.M.S. Scores for Absence of Defects
in Four Groups of Frozen Pole Beans

Frozen While Fresh		Frozen After Storage	
Size 3	Size 4 and 5	Size 3	Size 4 and 5
37.08	36.22	36.22	27.96

The Effects of Sulphur on the Chemical Composition and Quality of Canned and Frozen Pole Beans

1952 Crop - As was discussed in the introduction, there was an extra treatment added to check the effect of sulphur on yield. Since the phosphate fertilizers used contained sulphur, the extra treatment was fertilized with sulphur-free diammonium phosphate. This treatment supplied the same amount of nitrogen, phosphorus, and potassium (100-120-0) and was comparable to the regular (100-120-0) treatment. The latter is designated as the "sulphur" treatment in this dissertation; whereas, the extra (100-120-0) treatment, fertilized with C. P. diammonium phosphate, is designated as the "sulphur-free" treatment.

Beans from this extra "sulphur-free" treatment were evaluated for quality and chemical composition as were those in the regular 2 x 2 x 3 factorial system, except that they were not graded by the Agricultural Marketing Service. The data from the "sulphur" and "sulphur-free" treatments were tabulated and differences evaluated for statistical significance.

A significantly higher percentage of phosphorus was found in the sulphur-free treatment of three groups of beans (Table 122), two groups of which were of late harvest, frozen after storage. They included both sizes of beans. The third group was size 3 of the early harvest, frozen while fresh. In addition, the means of the phosphorus percentage of the sulphur-free treatments in the fresh-frozen beans of both harvests were higher; although the difference was not great enough to meet requirements for significance (Table 122).

Table 122

Effect of Sulphur on Percentage of Phosphorus in Frozen Pole Beans (1952)

	Means of Individual Treatments					
	Frozen While Fresh				Frozen After Storage	
	Size 3		Size 4 and 5		Size 3	Size 4 and 5
	Har.1	Har.2	Har.1	Har.2	All 2nd Harvest	
Sulphur	.368	.394	.385	.376	.366	.360
Sulphur-free	.356	.443	.391	.395	.415	.421
L.S.D. (.05)	N.S.D.	.020	N.S.D.	N.S.D.	.033	.036
L.S.D. (.01)	N.S.D.	.038	N.S.D.	N.S.D.	.046	.049

The Effects of Nitrogen, Phosphorus, and Potassium Fertilization on the Percentage of Crooked and Misshapen Pods in Pole Beans

1953 Crop - Percentages, by weight, of misshapen and crooked beans were determined for the 1953 crop only. The data showed that potassium fertilization as a main effect significantly increased the percentage of crooked and misshapen pods in the size 3 beans (Table 124).

In the size 4 and 5 beans the main and interactive effects of fertilizers were not significant, but some of the differences between individual treatments were significant (Table 123). Fertilization with nitrogen, when used with potassium and phosphorus fertilizers (note combination N-0, P-1, K-1 vs. N-1, P-1, K-1), resulted in significantly increased percentage of crooked and misshapen beans. It was also indicated that the association of nitrogen fertilization with increased percentage of crooked and misshapen beans was dependent on the phosphorus fertilization level in the N-2 series (100 pounds nitrogen). Percentage of crooked and misshapen beans was significantly increased by phosphorus fertilization in the N-2 series (Table 123).

The main effects of nitrogen fertilization in the size 4 and 5 beans were not great enough to be significant, although inspection of the means of individual treatments showed that there was a consistent increase in percentage of crooked and misshapen beans in all groups in which nitrogen was used (Table 123). The variation among determinations was relatively high, making proof of significance more difficult.

Table 123

Percentage of Crooked and Misshapen Pods in Size 4 and 5 Beans

Level	Means of Individual Treatments			
	P-0		P-1	
	K-0	K-1	K-0	K-1
N-0	6.35	5.55	5.55	6.15
N-1	6.50	5.80	6.22	7.68
N-2	5.28		6.60	
L.S.D. (.05) — 1.28		L.S.D. (.01) — 1.74		

Level	N-Means	P-Means	K-Means
	Means of Main Effects (Factorial Treatments)		
0	5.90	6.05	6.16
1	6.55	6.40	6.29

Main and interactive effects not significant

Table 124

Percentage of Crooked and Misshapen Pods in Size 3 Beans

Level	Means of Individual Treatments			
	P-0		P-1	
	K-0	K-1	K-0	K-1
N-0	6.08	6.02	6.45	7.03
N-1	5.80	6.08	5.35	7.62
N-2	5.90		7.30	

Level	N-Means	P-Means	K-Means
	Means of Main Effects (Factorial Treatments)		
0	6.39	5.92	5.92
1	6.21	6.61	6.69
L.S.D. (.05)	N.S.D.	N.S.D.	.77
L.S.D. (.01)	N.S.D.	N.S.D.	N.S.D.

Individual treatment differences not significant
Main and interactive effects not significant

The Effects of Nitrogen, Phosphorus, and Potassium Fertilization on the Crude Fiber Content of Canned Pole Beans

1952 Crop - Crude fiber determinations were made on all canned lots of the 1952 crop. The data indicated no significant differences had resulted from fertilizer treatments in any of the groups studied.

Since crude fiber content is a very important quality factor, the average percentages of crude fiber found in the various groups have been presented in Table 125.

Table 125

Average Percentage Crude Fiber in Six Groups of Canned Pole Beans

Early Harvest		Late Harvest			
Canned Fresh		Canned Fresh		Canned After Storage	
Size 3	Size 4 and 5	Size 3	Size 4 and 5	Size 3	Size 4, 5
.0171	.0177	.0146	.0198	.0149	.0253

The Effects of Nitrogen, Phosphorus, and Potassium Fertilization on Panel Preference Scores for Flavor of Canned and Frozen Size 4 and 5 Pole Beans

1953 Crop - No significant differences in preference scores for flavor of canned beans were indicated by statistical analysis of the data. However, in frozen beans a significant interaction of P x K was found, in which it was shown that the use of potassium fertilizer significantly depressed scores for flavor preference when phosphorus fertilizers were not used (Table 126).

Table 126

Panel Preference Scores for Flavor of Frozen Pole Beans

Level	Means of Individual Treatments			
	P-0		P-1	
	K-0	K-1	K-0	K-1
N-0	.000	-.636	-.363	.545
N-1	.363	-.363	.182	-.273
N-2	.273		.363	
L.S.D. (.05) — .698			L.S.D. (.01) — .924	

Level	N-Means	P-Means	K-Means
	Means of Main Effects (Factorial Treatments)		
0	-.114	-.159	.045
1	-.023	+.023	-.182

Means of P x K Combinations	P-0	P-1
K-0	.181	.091
K-1	-.500	.136
L.S.D. (.05) — .566		L.S.D. (.01) — .752

Individual treatment differences not significant.
Main effects not significant

The Effects of Nitrogen, Phosphorus, and Potassium Fertilization on Preference Scores for Appearance of Canned and Frozen Size 4 and 5 Pole Beans

1953 Crop - The data in Tables 127 and 128 show that significant differences in panel preference scores for appearance occurred as a result of fertilizer treatments.

Potassium fertilization significantly depressed the preference scores for appearance of canned beans, on the main effect basis (Table 127). This was the only significant result of fertilizer treatment indicated by the data in that group.

Potassium fertilization also appeared as a significant factor affecting the preference scores for appearance of frozen beans (Table 128). In a P x K interaction, a tendency of phosphorus fertilization to increase the panel preference score in the absence of potassium, was significantly counteracted by potassium fertilization.

Table 127

Panel Preference Scores for Appearance of Canned Pole Beans

Level	Means of Individual Treatments			
	P-0		P-1	
	K-0	K-1	K-0	K-1
N-0	.000	-.727	.182	-.091
N-1	.182	-.273	⁄.363	.091
N-2	.363		-.091	

Means of Main Effects (Factorial Treatments)

Level	N-Means	P-Means	K-Means
0	-.159	-.204	.181
1	.091	.136	-.250
L.S.D. (.05)	N.S.D.	N.S.D.	.306
L.S.D. (.01)	N.S.D.	N.S.D.	.404

Individual treatment differences not significant
Interactive effects not significant

Table 128

Panel Preference Score for Appearance of Frozen Pole Beans

Level	Means of Individual Treatments			
	P-0		P-1	
	K-0	K-1	K-0	K-1
N-0	.000	.454	.182	-.182
N-1	.454	.454	1.272	.182
N-2	.818		.636	
L.S.D. (.05	— .686		L.S.D. (.01)	— .908

Means of Main Effects (Factorial Treatments)

Level	N-Means	P-Means	K-Means
0	.114	.341	.477
1	.591	.364	.227

Means of P x K Combinations

	P-0	P-1
K-0	.223	.727
K-1	.454	.000
L.S.D. (.05) — .468		L.S.D. (.01) — .621

Main effects not significant

The Effects of Nitrogen, Phosphorus, and Potassium Fertilization on the Total Solids Content of Frozen Pole Beans

1952 and 1953 Crops - The percentage of total solids was determined on all groups of frozen beans prior to chemical analysis. No significant differences in total solids content were found to have resulted from fertilizer treatments.

However, the average percentages of the several groups are presented for use in conversion of chemical data from the dry weight to the frozen weight basis (Table 129).

Table 129

Percentage Total Solids Content of Frozen Pole Beans (1952 and 1953 Crops)

1952				1953		
Early Harvest		Late Harvest			Early Harvest	Late Harvest
Size 3	Size 4-5	Size 3	Size 4-5	Size 3	Size 4-5	
8.62	8.92	7.93	7.96	7.33	7.56	6.69

DISCUSSION

The Effects of Nitrogen, Phosphorus, and Potassium Fertilization on the Chemical Composition of Pole Beans

In general, the effects of fertilization with the elements nitrogen, phosphorus, and potassium on their own individual percentage compositions were relatively small. The effects of fertilization with one specific nutrient element on the percentage composition of other elements were much more noticeable.

Nitrogen - Fertilization with nitrogen resulted in an increase in nitrogen content of all of the size 4 and 5 beans except one group. The exception was the late harvest of 1953. Storage treatment did not affect this general condition.

Nitrogen fertilization resulted in an increase in nitrogen content in only one group of size 3 beans. In three other groups, phosphorus fertilization either depressed nitrogen percentage or conditioned the response from nitrogen fertilization.

The increase of nitrogen content of the beans, which was brought about by nitrogen fertilization, was less than five percent. However, the fact that the nitrogen content of the larger-sized beans was maintained at a higher level by nitrogen fertilization may have implications concerning other findings reported later in this dissertation.

<u>Phosphorus</u> - The percentage composition of phosphorus was increased by phosphorus fertilization in only one of nine groups studied. This does not at first seem compatible with the large yield response obtained from phosphorus fertilization during 1952 (Appendix Table 2). However, these determinations were made on the bean pods, late in the growth cycle. Dean and Fried (19, p.45) state that the effects of phosphorus fertilization on absorption of phosphorus by the plant are much more noticeable early in the growth cycle. This generality applies to many crop species. An increased phosphorus content from phosphorus fertilization, therefore, should not necessarily be expected in tissues collected late in the growing season.

Nitrogen fertilization resulted in significantly decreased phosphorus content in beans of the 1952 crop. This year was characterized by a positive yield response to phosphorus fertilization with no significant change in yield from nitrogen fertilization. In 1953, although nitrogen fertilization resulted in no significant effects on the phosphorus content of the harvested beans, the effect on yield was a small but significant increase. The possible relationship of these two effects is of interest.

Cullinan and Batjer (18, p.54) noted a sharp decrease in phosphorus in peach whips receiving liberal quantities of nitrogen. Boynton and Compton (11, p.15) after finding a reduction in phosphorus content of apple leaves as a result of fertilization with nitrogen, considered dilution to be at least in part responsible.

Increase in dry weight of leaves induced by nitrogen fertilization caused a decrease in percentage composition of phosphorus, according to this theory. This explanation seems applicable to Cullinan and Batjer's results also, but if such an explanation were applied to the 1952 results reported in this study, one would need to presuppose that an increase in dry weight had occurred as the result of nitrogen fertilization. If this actually did occur, it did not contribute to yield of beans. Although dilution is a possibility, the dilution effect would have to be considerable since the reduction in phosphorus percentage averaged about ten percent.

Significant effects of potassium fertilization on the phosphorus content of the beans occurred only in 1952 and were limited to a single group of beans. The effect was a depression of the phosphorus percentage, which was apparent only in the absence of nitrogen fertilization. As was pointed out earlier, the effects of nitrogen fertilization on phosphorus content were conditioned by the crop year, this being an example of an effect found only in the 1952 beans.

Phosphorus percentage was the only factor of chemical composition or quality showing significant effects from sulphur fertilization (Table 122). A higher percentage of phosphorus was generally found in beans fertilized with sulphur-free diammonium phosphate. This condition is comparable to that found by Ergle and Eaton (21, p.648). Their data indicated that cotton plants grown in sulphur-deficient nutrient solutions had higher quantities of phosphorus, magnesium, and calcium in their tissues. These were called "extra" accumulations by these writers but no explanations for the effects were offered.

Potassium - Potassium fertilization had very little effect on the percentage composition of that element in the beans. The significant effects found were limited to interactions with phosphorus or nitrogen in two groups of size 4 and 5 beans. Potassium levels were approximately two percent of the dry weight, in both the 1952 and 1953 crops.

The effects of phosphorus fertilization on potassium content of the beans appeared to be conditioned by size of the beans, the crop year, and by interactions with nitrogen. These interactions occurred frequently in both sizes of beans and in both crop years. In such interactions, the tendency for phosphorus fertilization to reduce the potassium content depended on the level of nitrogen applied. In general, although not without exception, the effect of phosphorus in reducing the potassium level was greatest when no nitrogen fertilizer was applied.

Main effect reductions of the potassium percentage by phosphorus fertilization were limited to size 3 beans of the 1952 crop. Such inverse relationships have been reported before, although the effect has usually been that of depressed phosphorus content resulting from potassium application. Mulder (38, p.116) relates this to a depressive effect of potassium on magnesium, which he believes to be more directly related to the absorption of phosphorus. Others, such as Carolus (16, p.358) have noted this effect, but the reverse condition appears to be more rare.

The effects of nitrogen fertilization on the potassium content of the beans were limited to the interactive effects with phosphorus already described. Perhaps this may be explained on the basis of the reduction of phosphorus content by nitrogen fertilization.

Calcium - Phosphorus fertilization was associated with a marked decrease in calcium content of the beans, particularly in the 1952 crop. This association is of considerable interest since in the course of the investigations reported here it was found that phosphate ions would cause depression in the apparent calcium readings of the flame photometer. This condition had not been reported previously, but Baker and Johnson (2, pp.465-468) made such a report in March, 1954, approximately the time that the same finding was made independently in these experiments.

Since phosphate was present in all solutions, this means that all of the calcium values were depressed by this condition. Baker and Johnson's data (2, p.466) indicate that this depression was perhaps as much as 25%. This also creates the possibility that the reduction in calcium content associated with phosphorus fertilization could be a technical artifact. However, phosphorus fertilization increased the percentage of phosphorus found in the beans in only one of nine groups; thus, the possibility of a technical artifact is practically eliminated. It is concluded, therefore, that phosphorus fertilization actually did result in a marked decrease in calcium content of the beans.

This condition is not commonly mentioned in the literature. However there have been a few instances in which phosphorus has been found to affect calcium absorption adversely. In some greenhouse tests with low calcium soils, Bishop (6, p.243) found that when super-phosphate was used in rates up to 2000 pounds per acre, the calcium content of plants usually showed a decrease until the highest applications were reached. Beeson (5, p.46) cites Stale (48) in a discussion of this same condition. In his work on high potash soils, it was found that phosphorus fertilization resulted in a decrease in the calcium content of hay.

A possible explanation for this reduction in calcium, induced by phosphorus fertilization, is found in the fact that calcium and phosphorus can form many compounds with a wide range in Ca to P ratios. The treble super-phosphate used in these experiments contained 21% calcium oxide and 45% phosphorus anhydride (Appendix Tables 1 and 3). In the soil, the addition of treble super-phosphate could result in the formation of compounds containing a higher Ca to P ratio than originally present in the super-phosphate itself. The source of this calcium would be the soil, which would result in less calcium being available to the plant. Reduced calcium absorption could then be expected. A similar reaction forms the basis of the commercial use of sequestering agents.

A high concentration of phosphorus has been shown to retard the uptake of iron by beans. Rediske and Biddulph (43, pp.584-586) determined the quantitative aspects of this retardation.

The effects of nitrogen fertilization on the percentage of calcium were almost entirely limited to size 4 and 5 beans and were conditioned by the crop year. In 1952, nitrogen fertilization significantly increased the calcium content of all of the size 4 and 5 groups, but in 1953 the only significant effect was a depression in the calcium content of one of the groups. Some of the increases may be technical artifacts since the phosphorus content was generally reduced by nitrogen fertilization during 1952. Thus, phosphorus interference in the flame photometric determinations of calcium may have been reduced by nitrogen fertilization.

The effects of potassium fertilization on calcium content were few, and they were conditioned by the year. Although potassium fertilization has been noted to cause significant depression of calcium in many experiments (54, p.486), such effects were limited to one group in these experiments.

<u>Magnesium</u> - The results from magnesium determinations were very similar to those of calcium, including the observation that apparent magnesium readings can be depressed by phosphate interference. However, the observation that phosphorus fertilization

significantly decreased the percentage magnesium in all groups of the 1952 crop is believed to be substantiated on the same basis as calcium. No depressive effects of phosphorus fertilization on magnesium were found in the 1953 beans. Perhaps this has some relationship to the observation that yield effects of phosphorus fertilization were limited to the 1952 crop.

Nitrogen fertilization resulted in an increased magnesium percentage in three groups during 1952, while in 1953 a decrease was found to have resulted from nitrogen fertilization in one group. Results were thus dependent on one year, and are possibly related to the fact that a yield response to nitrogen occurred in 1953 but not in 1952 (Appendix Tables 2 and 4).

Total Ash - Phosphorus fertilization reduced the percentage of total ash in all groups of beans in 1952. This effect is believed to be related to the reduction of calcium and magnesium percentages by phosphorus fertilization. In the 1953 crop the effect was not so noticeable, again showing relationship to the calcium and magnesium contents.

The effects of nitrogen fertilization on the percentage of total ash were limited to three of the nine groups studied. Reduction in total ash occurred in two of those groups, both of which were size 4 and 5 beans. This may be a dilution effect.

In general, fertilization with potassium chloride increased the total ash content during 1952. This type of effect from potassium is well-known. York, Bradfield, and Peech (54, pp.53-63) demonstrated an increase in cationic content from potassium fertilization in alfalfa and corn. Although the increase in cationic content is often related to excess absorption of potassium, this condition does not appear to be applicable to the results obtained in these experiments since potassium fertilization did not increase the potassium content of the beans to any appreciable degree.

The yield data from the 1952 crop showed that potassium affected yield adversely (Appendix Table 2). This response is similar to the one found in Sericea by York, Bradfield, and Peech (54, p.60). Their analyses indicated an inverse relationship between yields and the sum of the cations.

Potassium sulphate fertilization did not appear to have as great an effect on total ash as did fertilization with potassium chloride. These two forms were noted to have dissimilar effects on other factors.

The potassium effects noted were limited to the 1952 crop; no significant differences in total ash attributable to potassium were found in the 1953 beans. Thus, the conditions described were related to the crop season.

The Effects of Nitrogen, Phosphorus, and Potassium Fertilization on the Quality of Pole Beans

Seed content - Phosphorus fertilization resulted in an increase in seed content in almost all of the beans of the 1952 crop and, also, significantly increased the yield. In 1953, there were no significant phosphorus fertilization effects on seed content, and no significant increase in yield occurred. Apparently, there is a strong positive relationship between yield and seed content.

Nitrogen fertilization often resulted in a reduction in seed content, usually in size 4 and 5 beans. These have been shown to have had a higher nitrogen content. It would thus appear that nitrogen fertilization often resulted in a delay in maturity, as expressed by the degree of development of the seeds and the higher nitrogen content of the tissues. Also during 1952, nitrogen fertilization had the effect of decreasing phosphorus percentage, which could be related to seed development as noted above.

Potassium fertilization effects on seed content were limited to one group of the 1953 beans, in which a reduction in seed content was observed.

The seed contents of all groups of beans were below the limits Gould (24, p.68) suggests for grade A beans, and most groups received maturity scores in the A range (35-40), when graded by the Agricultural Marketing Service. However, there were some groups which were border-line between A and B in maturity score, suggesting that phosphorus fertilization could increase seed content sufficiently to be limiting in score for maturity.

Shear press readings - No consistent relationship of the data from shear press readings and quality of the beans could be observed. Readings often appeared to be inversely related to seed content, as shown by the effect of phosphorus fertilization in significantly depressing shear press readings. This would indicate that processed beans of higher seed content may have less resistance to shear than those of lower seed content. However, this relationship was not consistent, indicating the possible existence of other complicating factors.

Color of canned beans - The effects of potassium on color were quite prominent in the beans canned in 1952, but not in those canned in 1953. In the 1952 crop the effects were conditioned by the storage treatment. Significant reductions in "a" and/or "b" readings were noted to result from potassium fertilization in beans processed while fresh, whereas significantly increased "Rd" and "a" readings were obtained from beans processed after storage. These latter effects were limited to the larger sized beans. Significant effects on grade were limited to the stored beans, with potassium fertilization significantly increasing the A.M.S. score for color of size 4 and 5 beans, canned after storage.

Although potassium fertilization significantly altered objective color readings in freshly processed beans as noted above, these changes were not reflected in changes in A.M.S. color scores.

The effects of phosphorus fertilization on color in 1952 were limited to beans which were canned after storage. In size 4 and 5 beans, the effect was a decrease in "a" only, which was associated with a decreased A.M.S. color score. In size 3 beans, phosphorus fertilization resulted in beans of higher "Rd" readings, but this had no significant effect on the A.M.S. color score. In the 1953 crop, phosphorus fertilization resulted in decreased "Rd" and "a" readings in freshly canned beans of the early harvest, but A.M.S. color score reductions were noted only when the 100 pounds of nitrogen treatment was combined with phosphorus.

Nitrogen fertilization was observed to affect objective color readings of three of the four groups which were canned after storage. The effect was an increase in one or more of the color readings, usually indicating an increase in reflection or in color concentration resulting from nitrogen fertilization. In 1953, these reading increases were associated with an increased color score for both groups of beans canned after storage.

In the range of "Rd", "a", and "b" of these samples significant reduction of any one, or a combination of these readings usually was associated with a significant reduction in A.M.S. color score. Conversely, an increase in color readings usually was associated with an increase in color score. There were some exceptions, which are believed to be cases in which the difference in color as determined by the Hunter Color and Color Difference Meter were not great enough to have commercial significance.

The effects of nitrogen fertilization toward maintaining a higher color score in beans stored before canning are particularly emphasized. The effects of phosphorus fertilization were often the opposite to those of nitrogen fertilization. The effects of potassium fertilization on color of stored beans, when significant, were similar to those of nitrogen fertilization.

Color of frozen beans - There were numerous cases in which the color, as determined by objective measurement, was significantly affected by fertilizer treatments, but these color differences were reflected in A.M.S. color scores in only one group. This lack of association may be due to the fact that the A.M.S. grading system permits a wider tolerance in color of frozen beans than it permits in the color of canned beans.

The only significant changes in color of frozen beans noted in the 1952 crop resulted from phosphorus fertilization. Only two groups were involved, and in them phosphorus fertilization resulted in lowered "a" readings in one group and in lowered "b" readings in the other. Lowered A.M.S. scores were associated with the lowered "a" readings, which occurred in size 4 and 5 beans, frozen after storage. Storage was shown to have some relationship in respect to which the "a" coordinate was lowered, since significant lowering of "b" occurred in freshly frozen beans. Storage was also related to sensitivity of the A.M.S. color score, since significant change in this score occurred only in the beans which were frozen after storage.

The only significant changes in color of frozen beans noted in the 1953 crop resulted from nitrogen fertilization. Readings of one or more of the three objective measurements were increased in four of the five groups studied in 1953. These color changes were not reflected in the A.M.S. color scores. Again this may be due to the fact that the A.M.S. grading system permits a wider tolerance in color of frozen beans than it permits in the color of canned beans.

The color effects of nitrogen and phosphorus fertilization were shown to be opposing effects in frozen beans, with nitrogen fertilization resulting in increased objective color readings and phosphorus fertilization resulting in decreased objective color readings. Increased readings, indicating increased reflectance and/or more green hue and/or higher degree of color saturation, are thought to indicate greater chlorophyll content. The effect of nitrogen is perhaps related to the fact that nitrogen is a constituent of chlorophyll. Its effect in significantly reducing phosphorus content of the beans may also contribute to the differences in color resulting from nitrogen versus phosphorus fertilization.

The effects of phosphorus fertilization on color may be related to depression in magnesium content, causing limitation in the amount of chlorophyll. A second effect of phosphorus fertilization may be that of reducing iron uptake and translocation as pointed out by Rediske and Biddulph (43, pp.584,586). This can go so far as to cause chlorosis.

Potassium fertilization did not result in any significant changes in color readings or color scores of frozen beans, although it was quite prominent in affecting color readings of canned beans. This might merit further investigation.

Texture and maturity - Effects of fertilization on texture and maturity were limited to the size 4 and 5 beans processed after storage, with one exception. Phosphorus fertilization was the strongest influencing factor in these scores, causing their significant reduction in both canned and frozen beans. The effects of nitrogen were indecisive, and those of potassium were limited to only one group.

Some explanations of these findings may be related to Parker and Stuart's work on changes in chemical composition of beans after harvest (41, pp.301,309,311-313). Changes which would be likely to affect texture and maturity scores were (1) continuation of the seed ripening process (2) synthesis of protein in the beans, accompanied by hydrolysis of the pods, and (3) changes in pectins to water soluble forms, reducing crispness. If seed ripening occurred at a faster rate in phosphorus fertilized beans, this could contribute to a lowered texture and maturity score. In addition to a higher seed content, faster deterioration of the pod would be very likely to occur since this metabolism would be occurring from materials translocated from the pods.

Absence of defects - A.M.S. scoring for this factor was limited to the 1952 pack. Phosphorus fertilization was associated with a significantly lowered score in one group of stored beans. This is another example of reduction in a quality factor in stored beans, resulting from phosphorus fertilization.

Crooked and misshapen pods - These determinations were limited to the 1953 crop. Potassium fertilization significantly increased the percentage of crooked and misshapen pods in size 4 and 5 beans. Nitrogen fertilization appeared to increase the percentage of such beans in the size 3 group. These effects are thought to be related to seed fill. Crooked pods often result from this condition.

Preference scores for appearance and flavor - These determinations were limited to the 1953 crop. Canned beans from potassium fertilized plots received significantly lower preference scores for appearance. Potassium fertilization was also a factor in the frozen bean appearance scores, in which a tendency of phosphorus fertilization to increase the panel score was significantly counteracted by potassium.

Potassium fertilization resulted in depressed scores for flavor preference, when phosphorus fertilizers were not used.

The bases for these effects are not known, nor is the commercial significance of these panel scores known. They are different from A.M.S. scores, which are accepted by the trade to the extent that they can form the basis for private loans and sales transactions.

However, these results do point out the advisability of supplementing A.M.S. grades with panel scoring, since by this means other effects may be uncovered.

SUMMARY AND CONCLUSIONS

A study of the effects of nitrogen, phosphorus and potassium fertilization on the quality and chemical composition of pole beans was made over a two year period. Quality factors included (a) objective measurements of seed content, color, crude fiber and shear press readings (b) subjective scoring for color, texture and maturity, and absence of defects by the Agricultural Marketing Service, and (c) subjective scoring of appearance and flavor by a staff panel.

The conclusions reached were as follows:

1. Nitrogen fertilization significantly increased the percentage of nitrogen in the larger sized beans. The amount of increase was less than five percent.

2. The effect of nitrogen fertilization on the nitrogen content of the smaller beans was either not significant or was conditioned by phosphorus fertilization.

3. Nitrogen fertilization significantly depressed the phosphorus content of the 1952 crop, but not of the 1953 crop.

4. Nitrogen fertilization often resulted in reduced seed content, particularly in larger sized beans.

5. Canned and frozen beans from nitrogen fertilized plots usually had color of greater reflectance and/or often were more green in hue and higher in chroma.

6. Nitrogen fertilization resulted in higher A.M.S. color scores of the 1953 beans canned after storage.

7. Phosphorus fertilization did not significantly affect the phosphorus content of the beans.

8. A tendency of phosphorus fertilization to reduce the potassium content of the beans was often conditioned by the level of nitrogen fertilization.

9. Phosphorus fertilization significantly reduced the percentage of calcium in the beans.

10. Similar effects were noted on magnesium, but these were limited to the 1952 crop.

11. Phosphorus fertilization resulted in a significantly lower total ash content in beans of the 1952 crop, but not of the 1953 crop.

12. Phosphorus fertilization significantly increased the seed content of the beans of the 1952 crop.

13. Frozen beans from phosphorus fertilized plots usually had color showing lower reflectance and/or often were more yellow in hue and lower in chroma, but the differences in objective readings were associated with lower color scores in only one group.

14. Phosphorus fertilization often resulted in reduced texture and maturity scores of beans stored before processing.

15. Potassium fertilization did not increase the potassium content of the beans.

16. Potassium fertilization often increased total ash content of beans of the 1952 crop, with the chloride form showing the greatest effect.

17. Potassium fertilization resulted in some change in color of canned beans measured objectively, but these resulted in changed A.M.S. color scores in only one group.

18. The flavor of frozen beans grown on potassium fertilized plots was less preferred by a panel of staff members, but the effect was conditioned by the level of phosphorus fertilization.

19. Potassium fertilization resulted in processed beans which were less preferred for appearance, as indicated by a panel of staff members.

20. Potassium fertilization significantly increased the percentage of crooked and misshapen beans of 4 and 5 size in the 1953 crop. In size 3 beans nitrogen appeared to have the same effect.

21. The crude fiber content of the beans was found to be very low and to be unaffected by fertilization treatments in 1952.

22. Sulphur treatment in 1952 was shown to have resulted in decreased phosphorus content of the beans. No other chemical or quality effects were indicated by the data.

23. Phosphate was found to cause marked interference with the determination of calcium and magnesium by flame photometry.

In general, nitrogen fertilization contributed to improved quality in the beans, especially toward improvement of color and lowering of seed content. Phosphorus fertilization often reduced quality from higher seed content, less desirable texture, and through the development of a color of less reflectance and more yellow hue. The desirable effects of nitrogen fertilization and the undesirable effects of phosphorus fertilization were accentuated by storing the beans before processing.

Significant effects from potassium fertilization were few, with the most important being lowered preference scores for appearance of canned and frozen beans, and lowered preference for flavor of frozen beans. The latter effect was conditioned by the level of phosphorus fertilization.

These conclusions are limited to the conditions of these experiments.

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APPENDIX

Appendix Table 1

Effect of Various Rates, Kinds, and Amount of Fertilizer on the Yield of Pole Beans (1952)

Treatment (lbs. per acre of N-P_2O_5-K_2O)*	Yield in Tons per acre	Sieve Sizes - Percentage 1-2-3	#4	#5	#6 & over
Check-No fertilizer	9.62	39	28	22	11
0-120-0	11.91	34	27	23	16
0-240-0	11.79	35	28	22	15
0-0-100	8.89	42	27	23	8
0-120-100	11.04	34	29	22	15
0-240-100	11.04	29	26	25	20
50-0-0	9.00	35	26	23	16
100-0-0	8.33	45	28	19	8
50-120-0	12.17	35	27	22	16
50-240-0	12.33	36	26	21	17
50-120-100	12.05	33	26	22	19
50-240-100	11.70	31	26	23	20
100-120-0	11.83	34	28	24	14
100-240-0	12.21	36	26	21	17
100-120-100	11.21	37	28	23	12
100-240-100	10.96	33	25	23	19
50-0-100	8.31	34	26	21	19
100-0-100	7.97	45	28	21	6
Sidedress 100# N	9.87	35	25	22	18
Sidedress 100-120-0	10.00	35	27	22	16
100# N (NH_4NO_3 + $(NH_4)_2SO_4$)**	8.45	39	27	18	16
50-120-0 plus 2-25# N sidedresses	12.05	37	25	19	19
100-120-0 as diammonium phosphate + NH_4NO_3***	12.89	39	27	20	14
100-120-100 plus minor elements****	10.39	37	27	21	15
100-120-100) K_2SO_4	12.32	36	29	24	11
100-0-100) as a	8.24	41	28	20	11
0-0-100) source of	9.12	42	29	19	10
0-120-100) potash	11.66	34	26	21	19
L.S.D. (.05 level)	1.17				
L.S.D. (.01 level)	1.56				

*Unless otherwise stated, ammonium nitrate, treble-superphosphate, and muriate of potash are sources of nutrient. All banded at planting time, unless otherwise stated.

**Sufficient $(NH_4)_2SO_4$ to supply double the amount of sulphur found in treble-superphosphate used to supply 120# P_2O_5 per acre.

***Di-ammonium phosphate contained 0.001% sulphur as (SO_4).

****Minor elements were 50# $MgSO_4$, 25# each of $MnSO_4$, $ZnSO_4$, and $CuSO_4$, and 10# borax per acre.

Appendix Table 2

The Effects of Nitrogen, Phosphorus, and Potassium Fertilization on Yields of Pole Beans (1952)

Level	Means of Individual Treatments					
	K-0			K-1		
	P-0	P-1	P-2	P-0	P-1	P-2
N-0	9.62	11.91	11.79	8.89	11.04	11.04
N-1	9.00	12.17	12.33	8.31	12.05	11.70
N-2	8.33	11.83	12.21	7.97	11.21	10.96

Means of Main Effects

Level	N-Means	P-Means	K-Means
0	10.70	8.68	11.01
1	10.92	11.70	10.34
2	10.41	11.67	
L.S.D. (.05)	0.48	0.48	0.39
L.S.D. (.01)	0.64	0.64	0.52

Interactive effects not significant

Appendix Table 3

The Effects of Rate and Time of Application of Fertilizers on Pole Bean Yields (1953)

Treatment (lbs. per acre of $N-P_2O_5-K_2O$)*	Yield in Tons per acre	Sieve Sizes - Percentage 1-2-3	#4	#5	#6 & over
Check-No fertilizer	10.33	29	24	24	23
0-60-0	9.65	33	23	21	23
0-120-0	10.66	31	25	24	20
0-60-60	10.42	30	23	23	24
0-120-60	9.78	30	23	23	24
0-0-60	9.97	33	25	23	19
50-0-0	10.53	35	25	23	17
50-60-0	11.38	30	22	23	25
50-120-0	11.39	33	24	23	20
50-0-60	10.44	30	25	24	21
50-60-60	10.83	30	23	22	25
50-120-60	10.39	37	25	21	17
50-120-0 plus 2-25# N sidedresses	10.96	31	24	22	23
50-120-0 as diammonium phosphate	10.85	31	22	21	26
100-0-0 from NH_4NO_3	10.87	36	26	21	17
100-0-0 from $(NH_4)_2SO_4$	10.12	34	25	21	20
100-120-0	11.08	33	25	23	19
50-60-0 plus 60# P_2O_5 deep placed	10.96	29	23	22	26
43-88-60 plus 4-15# N sidedresses	10.57	31	23	20	26
50-120-0 sidedressed 45 days after planting	10.25	35	24	21	20
L.S.D. (.05)	0.95				
L.S.D. (.01)	1.26				

*All plots received in addition a uniform application of 50 pounds N/acre (as calcium cyanamid) prior to turning under cover crop.

Unless stated otherwise, ammonium nitrate, treble-superphosphate, and muriate of potash were the nutrient sources. All banded at planting time unless otherwise stated.

Appendix Table 4

The Effects of Nitrogen, Phosphorus, and Potassium Fertilization on Yields of Pole Beans (1953)

Level	Means of Individual Treatments					
	K-0			K-1		
	P-0	P-1	P-2	P-0	P-1	P-2
N-0	10.33	9.65	10.66	9.97	10.42	9.78
N-1	10.53	11.38	11.39	10.44	10.83	10.39

	Means of Main Effects		
Level	N-Means	P-Means	K-Means
0	10.14	10.32	10.66
1	10.83	10.58	10.31
2		10.56	
L.S.D. (.05)	0.39	N.S.D.	N.S.D.
L.S.D. (.01)	0.52	N.S.D.	N.S.D.

Interactive effects not significant