A STUDY OF FACTORS AFFECTING THE QUALITY OF SNAP BEANS

(*Phaseolus vulgaris* L.)

by
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INTRODUCTION

Snap beans (Phaseolus vulgaris L.) are the fourth largest truck crop for processing in the United States with a value in 1949 of over 26 millon dollars. Maryland has a ten year average acreage of 11,390 acres, second highest in the country. However, during the past few years the acreage grown in this state has declined, and in 1949 was 6,800 acres (48). Despite this drop, snap beans remain a million dollar business in Maryland.

During the past several years, there has been an increasing emphasis on quality of fresh and processed snap beans, as well as other crops. This increasing emphasis on quality has stimulated this and other research on factors affecting quality in snap beans. It was the purpose of this work therefore, to investigate thoroughly these factors and to develop, evaluate, and apply various objective and organoleptic methods for determining quality in snap beans.

One of the first factors to be taken into consideration in any experiment where quality is involved, is the growth and maturation of the particular crop being studied. A study of growth and maturation in snap beans involves a study of seed and fiber development, color, size and shape, and maturation rates. It is also important to know the effect of harvesting at different stages of maturity on yield as well as quality, since both must be considered from an economic standpoint.

In recent years interest in control of the maturation process has been stimulated by the appearance of several new chemical growth regulators. To date, this interest has been centered primarily around control of maturation in tree fruits, with little being reported on vegetable crops.

Yet the problem of maturation is an important one to the processor of vegetable crops, since over-all production and quality are in part dependent upon getting the raw material to the plant at the right time and in the proper amounts. In the normal course of events the planting and harvesting schedule provides for raw material of a high quality. There are environmental conditions, however, over which the processor or grower has no control which may cause changes in the harvesting schedule and ultimate loss in quality. Investigations are herein reported on the effect of these growth regulators on the rate of maturation of snap beans.

Snap beans produced for the fresh market and for processing are often subjected to storage periods either in transit from grower to market or to the processor, or after arrival at the market or processing plant. The effect of this delay as well as the effect of the temperature of storage on the quality of snap beans has not been investigated thoroughly and therefore was included in this experiment.

All of the factors mentioned above, affect in one way or another the quality of the snap beans to be used by the consumer. Since there is no generally accepted rapid objective method of measuring the quality of the raw snap beans, one of the main purposes of this experiment was to develop, evaluate, and apply various methods for determining the quality of the raw and processed green and wax beans. In order to test the methods developed, the above-mentioned factors which are known to affect quality were introduced experimentally.

REVIEW OF LITERATURE

Aside from development of new varieties and the improvement of cultural practices, research on snap beans has been concerned primarily with studies of factors affecting their composition and use as a food product.

Chemical Composition. Several early investigations concerned primarily with the composition of the snap bean, were summarized by Chatfield and Adams (5) who found on the average that snap beans contain 88.9 per cent water, 2.4 per cent protein, .2 per cent fat, 2.2 per cent starch, and .37 per cent sugar. In more recent studies on canned beans summarized by the National Canners Association, (41) snap beans were reported as containing on the average 6.5 per cent total solids, 1.2 per cent ash, .1 per cent fat, 1.1 per cent protein, .7 per cent crude fiber, 3.4 per cent carbohydrates and 90 calories per pound. Parker and Stuart (42) made a thorough investigation of the changes that occur in the chemical composition of green beans after harvest. They state that the principal after harvest changes involve carbohydrates; starch is hydrolyzed and sugar accumulates. Cold temperatures were found to accerlerate this accumulation of total sugars. Platenius and coworkers (43) have reported that 40° F is the optimum temperature for storing snap beans.

Williams and coworkers (60) studied the changes in sugar content during storage. They found that when beans were picked commercially and stored at room temperature for 7 days the reducing sugars had dropped 50 per cent while the sucrose remained unchanged. When stored in cracked ice for 7 days no change was found in reducing sugars while the sucrose content increased.

Culpepper (7) found that the maturity of the beans greatly affected their composition. He found that since the major part of the growth of the hull or pod occurs before that of the seed, changes in chemical composition during the early stages of growth are determined largely by the changes in the pod or hull, while variations in later stages are determined largely by changes in the seed. Resistance to pressure, as measured by a pressure tester equipped with a needle of .050" diameter, developed by Culpepper and Magoon (8), increased from 332 gm. when the beans were tested five days after tagging of blossoms, to 490 gm., 30 days after tagging. The seed was found to increase from 4 per cent 15 days after blossoming to 53.8 per cent 40 days after blossoming. As maturity advanced the pod size and seed size increased directly.

Vitamin Content. During the period 1940-1945 several papers were presented on the vitamin content of snap beans, including studies by Farrell and Fellers (13), and Jones (25). A group of papers by Heinze, Wade, Hayden, and co-workers (21, 22, 51, 52) show that ascorbic acid content which is a heritable character may also vary between pods because of the size of the pod and its position on the plant. These authors analyzed over 200 strains and varieties grown during six growing seasons. Upon averaging the results of these varieties, they found that snap beans contain 22.8 mg. of ascorbic acid, 79 mcg. of thiamin, 100 mcg. of riboflavin, and 348 mcg. of carotene per hundred grams. In work summarized by the National Canners Association (41) canned snap beans were reported to contain an average .18 mg. of carotene, 3.3 mg. of ascorbic acid, .029 mg. of thiamine, .035 mg. of riboflavin, and .32 mg. of niacin per 100 gm. of fresh material. Studies by other investigators indicate that the smallest pods may not be the most nutritious when the vitamin content is considered. Mack et al. (32) and Caldwell et al. (4) have shown that the vitamin content of green beans increases with maturity of the pods. The concentration in the pods decreases slightly while there is a rapid increase in the seeds. Other workers, however, (Tressler et al. (51)) have reported either no change in maturity or a slight decrease. Zscheile et al (63) found that the younger, shorter beans are higher in provitamin A or carotene than those longer and more mature.

In an attempt to explain the apparent disagreement, Hibbard and Flynn (23) found that green beans harvested in the most immature stage are highest in carotene and riboflavin, but lower in thiamin and niacin than those harvested when more mature. The pods were found to have more carotene than the seeds, but the reverse was true for riboflavin, ascorbic acid, thiamin, and niacin. Carotene, riboflavin, and thiamin decreased as the beans matured and ascorbic acid, and niacin increased. These workers suggest that green beans should be harvested as soon as pods have reached full length to obtain maximum production and the best balance of vitamins.

Kramer (26) found a correlation between nutrient contents, maturity, size, and fibrousness of snap beans. As the beans matured total solids, carbohydrates, phosphorus, and ascorbic acid contents increased while calcium and carotene contents decreased.

Quality Factors. Several investigators (9, 11, 12) have reported on the nature of the pod cell structure and its relationship to the edible quality of the fruit. Rowe and Bonney (44) presented a tentative method for determining quality in snap beans based upon the measurement of the total content of fibrous material in the side wall of the pods. Stark and Mahoney (48) made a thorough study of the time of development of the fibrous sheath in the side wall of edible snap bean pods with respect to quality. They found that fiber consists mainly of inner mesocarp. Increase in the width of the inner mesocarp occurs at a constant rate until the large sieve sizes are reached. External factors such as climatic conditions appear responsible for the amount of thickening in the cell wall of the varieties studied.

Kramer and Smith (29) have investigated various objective methods for determining quality in snap beans. Correlations between the per cent seed and per cent strings ranged from .372 in cut wax beans to .502 in cut green and whole green beans. The per cent seed was found to be more closely correlated to organoleptic ratings than was the per cent strings. Other objective tests were tried and discarded for various reasons. The refractometer was of little use since the composition of the liquor influenced the values obtained. No difference in pH was found between samples of decidedly different maturities. A blendor flotation method did not differentiate between fancy, extra standard, and standard grades. However, a blendor fiber method was developed which showed promise. This method was used in the present study. An iodine method for determining reducing substances showed large differences in varietal response and was therefore discarded.

In a series of recent papers, Gould (16, 17, 18, 19, 20)[1] discussed quality in snap beans. A new instrument was presented, based on the principle used in the asparagus fiberometer, which determines resistance to shearing on individual pods; a review of the U. S. grades and standards were presented; the use of heat summation was suggested for spacing planting dates and for predicting time of harvest. Seed length was suggested as a method of determining maturity.

<u>Growth Regulators</u>. Work by Wittwer and Murneek (61), Murneek, Wittwer, and Hemphill (40) and later by Stark (48) and Fisher (14, 15) has shown that hormone sprays can be used to increase the yield and to prevent blossom drop during hot, dry periods. They report that para-chlorophenoxyacetic acid

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[1]Recently summarized by Gould, W. A. Quality evaluation of fresh, frozen, and canned snap beans. Ohio Agr. Exp. Sta. Res. Bul. 701. 1951.

(ClPA) and similar materials at concentrations approaching 2 ppm. will do this quite effectively.

The use of chemical growth regulators to control certain growth phenonema which occur in fruit crops has been studied extensively by various workers. Mitchell and Cullinan (36) and later Marth, Havis, and Batjer (33), found that the use of sodium and potassium salts of naphthalene acetic acid applied in the preceeding summer delayed blossoming at best two days and caused severe damage to peach trees at higher concentrations. Retardation of blossoming was not obtained without injury to the leaves. On the other hand, Hitchcock and Zimmerman (24) found that summer sprays with potassium naphthalene acetic acid delayed opening of flower buds of peaches up to 14 days and up to 19 days for vegetative buds when applied the preceeding summer. Work has also been carried on by Mitchell and Marth (37) and others on the effect of several of these growth regulators on the ripening of detached fruit, 2,4-di chlorophenoxyacetic acid was found to ripen detached fruits of bananas, pears and apples but did not affect tomato, pepper, or persimmon.

Mitchell and coworkers (34) in greenhouse studies have found that the application of para-chlorophenoxyacetic acid to the pods of snap beans before picking resulted in a higher retention of Vitamin C. Subsequent work (38) showed that application of 4-chlorophenoxyacetic acid as a dip or a spray retarded maturation of attached fruits. This treatment significantly reduced the yield especially when used at high concentrations (1000 ppm.). Spray applications of 4-Cl (4 chlorophenoxyacetic acetic acid) at concentrations ranging from 50 ppm. to 1000 ppm. to attached fruits increased their water retaining capacity when they were harvested and stored.

Clark and Wittwer (6) showed that certain growth regulators, especially chlorophenoxyproprionic acid, hastened the elongation of 8 to 12 week old seed stalks of celery and lettuce.

Recently, Schoene and Hoffman (45) have reported that maleic hydrazide has a pronounced but temporary inhibiting effect on plant growth. Currier and Crafts (10) noted that maleic hydrazide killed barley and had no effect on cotton. They suggested that it might be used as a selective herbicide. White (57) found that maleic hydrazide delayed flowering of raspberries and strawberries without injury or loss in quality. Moore (39) listed several effects of maleic hydrazide on plants. Wittwer et al. (62) have found that sprouting and root growth of onions held at 55° F for five months was completely inhibited by the application of a water spray containing 2500 ppm. of maleic hydrazide to the foliage of intact plants two months before harvesting the bulbs.

MATERIALS AND METHODS

1948 Quality and Storage Studies

On July, 20, 1948, two varieties, Stringless Green Pod and Pencil Pod Black Wax were planted at the Plant Research Farm of the University of Maryland. Each plot consisted of one 90 foot row. Each treatment was replicated 4 times. The beans were harvested in the following manner:

Starting September 3, or 45 days after planting, one plot was harvested twice a week for the harvest period which ended on September 26, 68 days from time of planting. A second plot was harvested at one week intervals and other plots were harvested twice, 10 days apart, and still others were harvested once at various times throughout the harvest period. The samples thus obtained represented a complete range of maturity for both varieties.

Yield records were obtained and the beans were brought to the horticulture processing laboratories where each sample was thoroughly mixed and divided into four parts. One portion was retained for immediate study, and the remaining three portions were placed in storage chambers at three temperatures, namely 35, 50 and 70° F. Lots of beans were removed from each storage chamber for analysis in the raw state, and for canning and freezing, at 1, 4, 7, and 10day storage durations. The canned samples were used for further objective tests and the frozen beans were used for organoleptic tests.

The beans to be canned and frozen were washed, snipped, and blanched for 2 to 3 minutes, the length of time depending on the maturity of the beans. The beans to be frozen were placed in frozen food containers and held overnight at -20° F, and stored until used at 0° F. For canning, the beans were placed in #1 picnic cans, and hot brine was added. They were then closed and processed at 240° F for 20 minutes.

The following determinations were carried out on all of the raw and some of the canned andfrozen samples:

Per cent seed in the raw and canned material was determined by the official method proposed by the Food and Drug Administration (44).

Pressure fiber recordings were made on the raw beans with the use of a modified fruit pressure tester in which the plunger was replaced with a piece of stainless steel having a straight, blunt cutting edge of .030" thickness. A minimum of 10 pods was cut through at their widest points for each sample test. The pods were placed in such a position that the cutting edge was across the pod at right angles to the sutures.

Fiber was determined by the official method proposed by the Food and Drug Administration (44), as well as by a rapid modification of this method which is described as follows (29): One hundred grams of pods and seeds were weighed and transferred to the cup of a Waring Blendor. Two hundred ml. of water were added and the contents were blended for 5 minutes poured through a 30 mesh monel metal or stainless steel screen, and washed thoroughly with liberal quantities of water. The fibrous residue retained on the screen was dried in an oven at 100° C for 2 hours, weighed, and calculated as per cent fiber.

Color was determined by an extraction method as follows: One hundred grams of beans were blended with an equal weight of water in a Waring Blendor to a uniform pulp. Twenty grams of the above mixture were weighed and transferred to a Blendor cup with 70 ml. of acetone and blended for exactly 5 minutes. The blended material was transferred to a 100 ml. graduated cylinder, the cup was then rinsed several times with acetone and the washings added to the cylinder, which was made to volume and mixed thoroughly. A portion of the solution was then transferred to a centrifuge tube and centrifuged for 10 minutes at 2000 RPM or until clear. A portion of the clarified solution was transferred to the 10 mm. cuvette of a Beckman spectrophotometer and the per cent transmittance was read at 665 mu and 450 mu. The readings obtained at 665 mu were converted to ppm. chlorophyll, and those at 450 mu to ppm. carotene. Although the results obtained are recorded as chlorophyll and carotene respectively, they include total green and yellow pigment fractions, respectively, and are undoubtedly higher than actual chlorophyll and carotene contents of these samples, since the instrument was calibrated by the use of pure solutions of chlorophyll a and b and carotene b, respectively.

Ascorbic acid content was determined by a method described by Bessey and King (2).

Moisture was determined by the official A.O.A.C. method (1).

Organoleptic ratings were provided by a panel of 6 judges who graded the frozen product for maturity, fibrousness, color, flavor and over-all grade separately on a scale of 10. In each case a score of 1 indicated the poorest quality, and a score of 10 the highest.

1949-1950 Quality Yield Studies

The succeeding experiments were designed for further studies of factors associated with maturity and objective methods for measuring them. In 1949 plantings of the varieties, Tendergreen, Bountiful, and Black Valentine were made on May 11, June 23, and August 2. In 1950 the varieties Tendergreen, Topcrop, and Ranger were planted on May 10, June 28, and August 2. Commercial planting and growing practices were followed for all six crops. Five treatments or harvest dates based on per cent seed, were included in each experiment. These were 4, 8, 12, 16, and 24 per cent seed. Each plot, which consisted of one 50 foot row in 1949 and one 25 foot row in 1950 was harvested at each respective seed level as often as required. In this way comparative yield data were obtained for each stage of maturity. Thus, each planting consisted of three varieties, harvested at five stages of maturity, and replicated four times. There were 60 plots per planting and six plantings which gave a total of 360 plots for the experiment.

After harvest, the beans were weighed and brought to the processing laboratories where per cent seed and fiber-pressure readings were obtained on the raw beans. Samples were then canned and frozen following procedures described above. Both the FDA and the Blendor fiber methods as well as per cent seed determinations were carried out on the canned samples. The frozen samples, as before, were used for organoleptic grading by a panel of judges who rated them on a basis of 1 to 10 for appearance, maturity, flavor, fiber and over-all grade.

1949-1950 Growth Regulating Substances

The following experiments were designed in order to study the effect of certain growth regulating substances on maturation in snap beans. In 1949 experiments were carried out using Para-chlorophenoxyacetic acid (CLPA) on the varieties Bountiful, Black Valentine, and Tendergreen. The first crop, or that planted May 11, was used for preliminary studies to determine the most effective levels of CLPA.

The second crop, planted June 23, was sprayed with .1, .3, and .9 per cent solutions of CLPA when the beans reached the 4 per cent seed stage of maturity. The CLPA was applied as an aerosol at the rate of 18 lbs. to the acre. Plots were harvested 4, 7, and 10 days after application. Each experiment was replicated 3 times so that with the check plots the experiment included 120 plots. After harvesting, the beans were weighed to obtain yield data and taken to the horticultural processing laboratories where they were subjected to the same procedures as mentioned for the 1949 and 1950 maturity study crops.

A similar experiment was carried out on the third crop which was harvested in late September and early October. It differed from the second crop in that the time of spraying was the variable. Plots were sprayed at 2, 4, and 8 per cent seed stages of maturity, and all plots were harvested ten days after application of CLPA.

In 1950 experiments with maleic hydrazide were carried out using the varieties Tendergreen, Topcrop, and Ranger. Each plot consisted of a 15 foot row which was replicated twice in the first planting (May 11), and three times in the second planting (June 28). The beans were sprayed at full blossom, early pod, four per cent seed, and eight per cent seed stages of maturity. The concentrations used were .04, .2 and 1.0 per cent. A "Sure Shot" one-quart pressure sprayer, manufactured by the Milwaukee Sprayer Company, was used to apply the solutions to run off.

All plots were harvested when the check plots reached approximately 16 per cent seed. It was necessary to delay slightly the harvest of the second crop due to unforeseen circumstances. Yield data were obtained and the beans were taken to the horticultural processing laboratories where the samples were canned and frozen. The same objective and organoleptic tests were used as were used in the previous work with CLPA with the exception of the FDA fiber and per cent seed determinations on the canned beans.

The data obtained from these experiments were subjected to statistical analysis in order to arrive at statistically sound conclusions.

DISCUSSION OF RESULTS

Growth and Maturation

Any study of factors affecting or correlated with maturation of snap beans, or a study of objective methods of measuring maturation should be based on a knowledge of the growth and maturation of the snap bean, as well as on a knowledge of factors affecting growth and maturation. These include rate of growth, size and shape of pod, development of seed in relation to pod, color, chemical composition, as well as other factors.

Seed-Pod Ratio. In 1948 data were obtained on the per cent by weight of the various sieve sizes at four stages of maturity. These data, on two varieties, Burpee's Stringless Green Pod, and Pencil Pod Black Wax are presented in Table 1. As might be expected relatively larger percentages of the smaller sieve sizes were obtained when the beans were young and immature. When the beans had reached 8 per cent seed, 70 to 80 per cent of the pods fell in sieve size five or larger. This is in agreement with Culpepper (7) who noted that the major part of the growth of the hull and seed occurred at different times. He noted that the pod attained its full length between 10 and 15 days after flowering, and that the greatest rate of growth of the seed, as measured by increase in diameter was 25 to 30 days after flowering. Mitchell and Marth (35) have studied the growth in length of pods and seeds of the variety Black Valentine. They found that the pods increased in length most rapidly during the first eight days after anthesis, and that a rapid increase in seed size did not occur until after the pod had nearly reached full length, which was the 12th or 13th day. This information indicates that seed development succeeds, and is not concomitant with pod development as far as growth or size is concerned. Thus per cent seed can be useful as an index of growth, after the pod has reached full length.

The effect of delaying the harvest on the increase in per cent seed is shown in Tables 2, 3, and 4. In 1948, per cent seed was found to be a good index of maturity; consequently, during 1949 and 1950, maturity levels established on the basis of seed content were used. This was accomplished by taking samples for pretests at random throughout each plot. On the average the increase from 4 per cent to 24 per cent seed was found to take a little over 2 weeks. Since the per cent seed was fixed experimentally any variation obtained in 1949 and 1950 data in respect to per cent seed merely indicated absence of absolute control over the time of harvest rather than actual varietal or seasonal effects.

Table 1. The Relationship of Time of Harvest to the Per Cent Yield of Different Sieve Sizes.

Sieve Size	Sept. 3		Sept. 7		Sept. 10		Sept. 15	
	Per Cent Weight	Per Cent Seed	Per Cent Weight	Per Cent Seed	Per Cent Weight	Per Cent Seed	Per Cent Weight	Per Cent Seed
Burpee's Stringless Green Pod								
1 & 2	12.9	—	1.9	—	1.6	—	1.0	—
3	21.9	—	2.8	2.8	4.2	3.4	1.5	—
4	35.6	2.9	8.2	3.4	8.6	6.8	3.0	—
5	29.6	4.8	86.7	9.2	85.6	14.0	94.5	30.5
Field Run		4.2		8.5		11.7		25.7
Pencil Pod Black Wax								
1 & 2	23.3	—	4.3	—	2.1	—	1.0	—
3	24.5	2.3	6.3	2.1	3.9	2.3	2.0	—
4	27.0	9.0	18.4	4.8	4.0	6.1	3.3	—
5	24.9	5.6	71.0	9.5	90.0	14.7	93.7	31.7
Field Run		4.0		8.7		12.2		25.8

Table 2. The Effect of Date of Harvest and Varieties on the Maturity, Fibrousness, Moisture Content, Ascorbic Acid Content, and Color of Snap Beans (1948).

	Maturity			Fiber			
	Per cent Seed Raw	Per cent Seed Canned	Organ. Maturity	Fiber Pressure Test/lbs.	F.D.A. Fiber Mg./100	Blendor Fiber Mg./100	Organ. Fiber
Date of Harvest							
1st	3.7	4.0	8.1	6.43	19.8	16.8	9.3
2nd	8.6	8.4	6.8	8.32	29.4	39.8	8.7
3rd	13.2	13.3	5.5	8.85	62.4	86.5	7.7
4th	28.2	25.1	4.5	10.18	161.1	222.3	6.6
L.S.D. 5%	1.1	1.1	.3	.3	16.0	---	.3
F value	786.5**	292.5**	157.0**	172.9**	128.7**	---	98.4**
Varieties							
Stringless Green Pod	14.4	14.3	6.3	9.09	93.9	131.2	8.1
Pencil Pod Wax	12.5	11.2	6.2	7.8	42.4	76.4	8.1
L.S.D. 5%	.7	.8	.2	.2	11.4	---	.2
F value	25.2**	35.6**	.3	117.8**	81.7**	---	---

	Per cent Moisture	Mg./100 Ascorbic Acid	Green Pigment Raw	Yellow Pigment Raw	Green Pigment Canned	Yellow Pigment Canned	Organ. Color
Date of Harvest							
1st	90.7	11.1	114.3	8.8	74.8	9.7	7.6
2nd	89.4	13.0	89.9	7.4	55.8	7.1	6.5
3rd	88.3	15.6	103.8	7.5	44.4	6.4	5.9
4th	82.7	22.2	85.0	6.4	47.2	6.3	4.7
L.S.D. 5%	1.6	1.3	9.6	.5	---	---	.4
F value	269.7**	106.1**	14.9**	29.2**	---	---	84.1**
Varieties							
Stringless Green Pod	87.0	16.9	160.8	12.0	98.0	11.4	7.4
Pencil Pod Wax	88.5	14.7	35.2	3.1	14.4	3.6	4.9
L.S.D. 5%	.4	.9	6.8	.4	---	---	.3
F value	51.2**	36.1**	1371.0**	2276.0**	---	---	350.0**

**Significant at 1% level

Table 3. The Effect of Time of Harvest, Variety, and Growing Season on the Maturity of Snap Beans as Measured by Objective and Organoleptic Tests (1949).

	Per cent Seed Raw	Per cent Seed Canned	Organoleptic Grades Maturity	Color	Flavor
Harvested at					
4% seed	4.6	4.6	7.6	7.2	6.0
8% seed	7.7	7.7	6.2	6.7	6.2
12% seed	12.3	13.0	5.4	6.7	5.7
16% seed	16.7	16.3	4.2	6.6	6.9
24% seed	24.7	25.1	3.3	6.1	6.9
L.S.D. 5% level	1.2	1.0	.4	.3	.3
F value	341.0**	472.9**	173.1**	11.7**	12.6**
Variety					
Bountiful	13.2	13.9	4.9	5.5	6.1
Tendergreen	12.7	12.3	5.5	7.4	7.1
Black Valentine	13.8	13.8	5.7	7.0	6.4
L.S.D. 5% level	.9	.8	.3	.3	.2
F value	2.7	10.2**	20.1**	114.3**	38.5**
Season					
Spring	12.2	12.2	5.4	7.0	6.6
Summer	13.4	13.7	5.2	6.2	6.0
Fall	14.0	14.1	5.4	6.9	6.4
L.S.D. 5% level	.9	.8	.3	.3	.3
F value	7.3**	12.5**	1.0	21.4**	1.9**
Replications					
1	13.0	12.9	5.3	6.6	6.6
2	13.6	13.5	5.1	6.8	6.5
3	12.9	13.3	5.5	6.5	6.5
4	13.2	13.6	5.5	6.8	6.5
L.S.D. 5% level	1.1	.9	.4	.3	.3
F value	.6	.8	2.7	1.5	.2

**Significant at 1% level

Table 3. (Cont.) The Effect of Time of Harvest, Variety, and Growing Season on the Maturity of Snap Beans as Measured by Objective and Organoleptic Tests (1949).

	FDA Method mg./100 gms.	Blendor Method mg./100 gms.	Fiber Pressure Test lbs.	Organoleptic	
				Fiber	Overall Grade
Harvested at					
4% seed	35	17	6.3	7.9	6.4
8% seed	85	51	7.2	7.0	6.0
12% seed	180	157	8.6	6.0	5.7
16% seed	282	264	9.7	5.1	5.1
24% seed	451	470	10.0	4.0	4.6
L.S.D. 5% level	44*	36	.3	.4	.4
F value	116.8**	208.9**	219.7**	113.6**	35.5**
Variety					
Bountiful	163	173	8.4	5.3	4.9
Tendergreen	64	78	7.8	7.4	6.6
Black Valentine	393	324	8.9	5.3	5.3
L.S.D. 5% level	34	28	.2	.3	.3
F value	200.5**	160.3**	4.8**	113.7**	93.1**
Season					
Spring	173	177	8.0	6.1	5.6
Summer	271	240	8.9	5.7	5.5
Fall	175	158	8.2	6.2	5.6
L.S.D. 5% level	34	28	.2	.3	.3
F value	22.1**	18.9**	3.1*	7.3**	1.3
Replications					
1	200	194	8.2	6.0	5.8
2	201	203	8.3	5.9	5.5
3	221	174	8.4	5.9	5.6
4	205	196	8.5	6.0	5.5
L.S.D. 5% level	39	32	.3	.4	.4
F value	.5	1.1	1.1	.1	1.6

* Significant at 5% level
**Significant at 1% level

Table 4. The Effect of Time of Harvest, Variety, and Growing Season on the Maturity of Snap Beans as Measured by Objective and Organoleptic Tests (1950).

	Per Cent Seed Raw	Per Cent Seed Canned	Organoleptic Grades		
			Maturity	Color	Flavor
Harvested at					
4% seed	4.1	3.9	7.7	6.5	5.9
8% seed	8.1	8.1	6.4	6.1	6.8
12% seed	11.8	12.5	5.1	5.8	6.4
16% seed	16.2	16.6	4.6	5.5	6.4
24% seed	24.2	23.4	3.1	4.7	6.2
L.S.D. 5% level	1.2	1.1	.4	.3	.4
F value	321.3**	362.7**	182.6**	36.8**	6.0**
Variety					
Tendergreen	12.9	12.7	5.2	6.0	6.5
Top Crop	13.7	13.7	4.9	6.1	6.4
Ranger	11.9	12.5	5.9	5.1	6.1
L.S.D. 5% level	.9	.9	.3	.2	.3
F value	7.2**	4.3*	27.0**	42.0**	4.7*
Season					
Spring	13.4	13.0	5.3	5.5	6.0
Summer	13.4	13.6	5.3	5.7	6.6
Fall	11.7	12.2	5.6	6.0	6.4
L.S.D. 5% level	.9	.9	.3	.2	.3
F value	8.5**	5.0**	2.6	70.2**	8.5**
Replications					
1	13.0	12.3	5.5	5.7	6.4
2	13.0	13.3	5.4	5.5	6.1
3	13.0	13.3	5.3	5.9	6.4
4	12.4	12.9	5.4	5.8	6.4
L.S.D. 5% level	1.1	1.0	.4	.3	.4
F value	.6	1.6	.8	2.7	1.2

* Significant at 5% level
**Significant at 1% level

Table 4. (Cont.) The Effect of Time of Harvest, Variety, and Growing Season on the Maturity of Snap Beans as Measured by Objective and Organoleptic Tests (1950).

	Fiber		Fiber	Organoleptic	
	FDA Method	Blendor Method	Pressure Test		Overall
	mg./100 gms.		lbs.	Fiber	Grade
Harvested at					
4% seed	9	4	4.5	9.0	6.5
8% seed	14	10	5.6	8.1	6.3
12% seed	30	25	6.0	7.0	5.7
16% seed	60	31	6.6	6.2	5.2
24% seed	118	189	6.9	5.5	4.4
L.S.D. 5% level	8	16	.2	.3	.3
F value	242.6**	188.6**	194.9**	157.9**	67.2**
Variety					
Tendergreen	45	51	6.2	7.1	5.8
Top Crop	46	50	6.1	6.9	5.7
Ranger	48	54	5.4	7.6	5.3
L.S.D. 5% level	.6	12	.2	.2	.2
F value	.3	.3	76.4**	17.0**	9.7**
Season					
Spring	42	55	5.8	7.1	5.3
Summer	55	54	6.3	7.0	5.6
Fall	41	46	5.7	7.4	5.9
L.S.D. 5% level	6	12	.2	.2	.2
F value	12.7**	1.41	40.6**	3.91*	11.8**
Replications					
1	46	50	5.9	7.1	5.6
2	47	45	6.0	7.1	5.5
3	45	59	5.9	7.1	5.7
4	47	53	5.9	7.3	5.7
L.S.D. 5% level	7	14	.2	.3	.3
F value	.3	1.3	.3	.7	1.3

* Significant at 5% level
**Significant at 1% level

Fiber. Another factor to be considered in growth and maturation of snap beans is the development of the fibrous sheath in the wall of the pod. Stark and Mahoney (49) have investigated extensively fiber development in snap beans.

The effect of delaying the harvest on the fiber content is presented in Tables 2, 3, and 4. In general for all varieties there was an increase in fiber content as the harvest was delayed. The fiber content of the beans in 1949 was much higher than for 1948 or 1950. This was a varietal difference and is shown in Fig. 1. It is obvious that Black Valentine and Bountiful have fibrous layers which develop at a much faster rate and to a much greater extent than do Tendergreen, Top Crop or Ranger. The blocked in portion on the figure represents the standards set up by the Food and Drug Administration. Both Black Valentine and Bountiful exceed these limits for fiber content when they have reached the 10 and 14 per seed stage respectively. This is well within the range where most beans are picked commercially. On the other hand the other varieties did not exceed the fiber limits until the 25 per cent seed stage was reached.

Table 5. The Relationship of Season and Variety to the Fiber Development of Snap Beans (mg./100 gms.).

	Bountiful	Tendergreen	Black Valentine
Spring	143	53	325
Summer	204	77	533
Fall	141	62	322

In 1949 and 1950 there was a tendency for beans grown in the summer to develop more fiber than those grown in the fall when beans of both seasons were measured at the same stage of maturity. This is best shown in Table 5, where the 1949 data are presented including the high fiber producing varie-

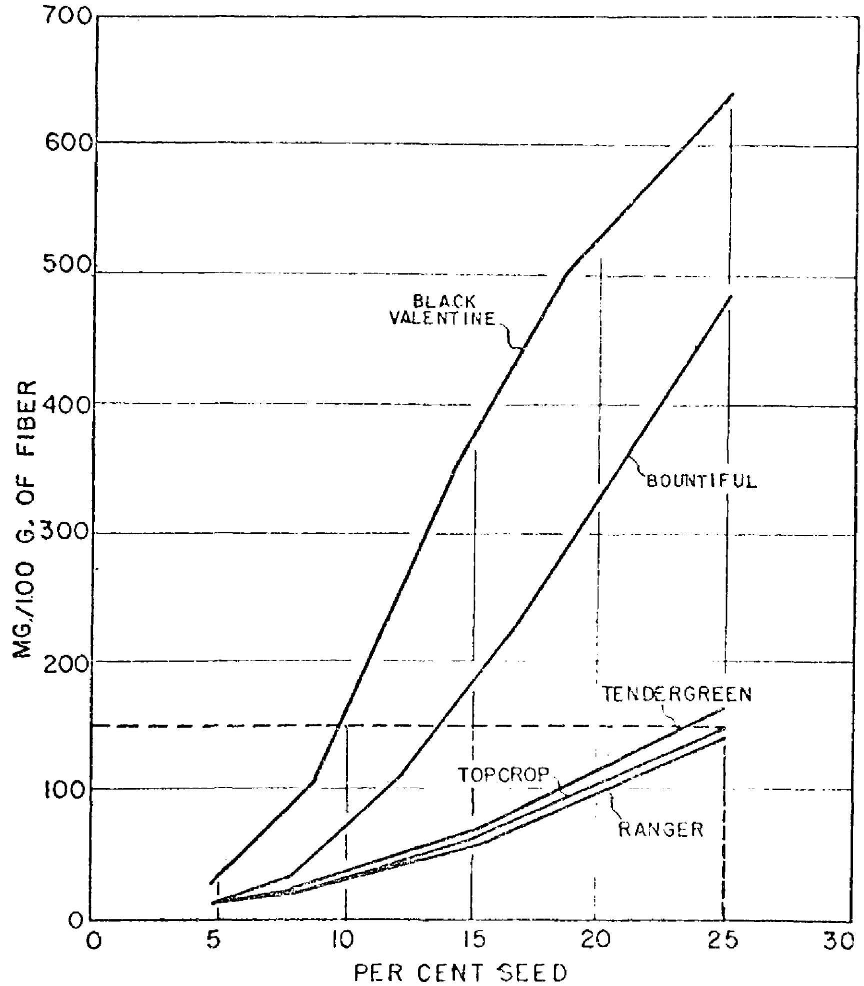


Figure 1. The Relationship of Seed to Fiber Development in Five Varieties of Snap Beans. The dotted lines indicate substandard limits as promulgated by The Food and Drug Administration for canned beans. (Fiber reported as mg./100 g. of fresh material)

ties Bountiful and Black Valentine along with Tendergreen. At first glance it would appear that Black Valentine was affected to a greater extent than the other varieties, but actually the percentage increase in fiber of summer over spring is nearly the same for all varieties. Thus although Tendergreen increased from 53 to 77, Bountiful from 143 to 204, and Black Valentine from 325 to 533, still the ratio of fiber increase was 1.5, 1.4 and 1.6 respectively.

Moisture. The effect of delaying the harvest on the moisture content of the two varieties Burpee's Stringless Green Pod and Pencil Pod Black Wax, was determined during the 1948 growing season. As the per cent seed increased from 4 to 24 per cent, there was a corresponding decrease in the moisture content from 90.7 per cent to 82.7 per cent. In terms of total solids this difference appears more important since it is an increase from 9.3 to 17.3 per cent. Pencil Pod Wax had a higher moisture content than did Burpee's Stringless Green Pod, this was probably a result of harvesting the Pencil Pod Wax at an earlier stage of maturity as is shown by the varietal differences in per cent seed.

Ascorbic Acid. Ascorbic acid was found to increase 100 per cent as the harvest was delayed from the 4 per cent to the 24 per cent seed stage of maturity, from 11.1 mg./100 gms. at 4 per cent seed to 22.2 mg./100 gms. of fresh material when the beans reached the 24 per cent seed stage of maturity. Thus ascorbic acid content increased much in the same manner as total solids, so that on a dry weight basis, there was little change in ascorbic acid. This is in agreement with the results of Hibbard and Flynn (23). The amounts present in the most edible stages (up to 15 mg.) was considerably less than the 22.0 mg./100 gms. of fresh material found by Heinze and coworkers (22) to be the average of 200 varieties grown in

South Carolina. This might indicate that the stage of maturity used by Heinze and coworkers (22) was considerably advanced.

Pigmentation. Pigmentation was determined both organoleptically and objectively for the beans grown in 1948. In 1949 and 1950 the color determinations were limited to organoleptic grades. In general, pigmentation was found to decrease as the beans matured regardless of the method of measurement used.

It is interesting to note the varietal differences in pigment concerntration. As might be expected the green beans had more green pigment than the wax beans (Table 2); the green variety also had a greater concentration of yellow pigments than the yellow variety. This indicates that the yellow pigments were partially masked by the presence of the green pigments.

The panel results in 1949 showed that Tendergreen had the best color, Black Valentine was rated next, followed by Bountiful. In 1950, Tendergreen and Topcrop were graded similarly for color and were both found to have a more desirable appearance than Ranger. These data indicate a panel preference for a dark green over a light type.

The season was found to affect the color grade given by a panel of judges. In 1949 the beans harvested from the summer crop were found to be less desirable than the beans harvested from the spring or fall crops.

In 1950 there was an increase in desirability as the seasons progressed with the beans having the best appearance produced in the fall.

Over-all Grade. The over-all grade, which takes into consideration maturity, fiber, flavor, and color decreased as the delay in harvesting increased. In 1949, Tendergreen was graded higher than Black Valentine which in turn was graded higher than Bountiful. In 1950 there was less difference in the over-all grades; however, Topcrop and Tendergreen were graded slightly higher than Ranger. No effect of season was noted for the over-all grade in 1949 but in 1950 those beans grown in the fall were graded highest with those grown in summer and spring following in that order.

Flavor. Flavor in snap beans in 1949 was found to increase as the maturity increased, those with 16 and 24 per cent seed having the best flavor; however, in 1950 the panel selected those beans at the 8 per cent stage of maturity as having the best flavor. In both cases the presence of seed added considerably to the flavor. In 1949 Tendergreen was found to have a better flavor than either Bountiful or Black Valentine. In 1950 both Tendergreen and Topcrop were graded higher in flavor than Ranger. In 1949 the panel graded the spring and fall crops as having better flavor than the summer crop. In 1950 the reverse was true, with those beans grown in the summer having better flavor than those grown in the spring or fall.

Effect of Season and Variety. By using the increase in per cent seed as an index of growth, it was found that there are both seasonal and varietal effects on growth and maturation rates. As is shown in Fig. 2, the five varieties studied react differently to various seasonal and climatic conditions. In 1949 Bountiful reached the four per cent seed stage in 49 days when planted on May 11. It took 41 days when planted on June 23, and 62 days when planted on August 2. A similar pattern holds for the other varieties. This difference in time is probably due to temperature differences for the most part.

The variety Tendergreen was included in the experiments both in 1949 and 1950 and its reactions to season and yearly climatic changes are shown in Fig. 2. The spring crop reacted similarly for both years when only several days' difference was noted in time required to reach the 4 per cent seed stage. However, the summer crop reached the 4 per cent seed stage 4 days earlier than in 1950, but took nearly twice as long to reach the 24 per cent seed stage. In this case perhaps rainfall and not temperature was the environmental factor which controlled the growth and maturation rate. The fall crop in 1949 required 13 days longer to reach the 4 per cent seed stage than in 1950. In spite of this fact the temperature summation for the fall crop in 1949 was greater (27,864) than in 1950 (24,600). This was perhaps due to unfavorable pod set conditions.

Different varietal responses to the same growing conditions may also be pointed out in Fig. 2; for example in 1950 Topcrop and Tendergreen followed the same pattern. Ranger on the other hand was several days to a week slower in each season to reach the 4 per cent seed stage. Ranger also required a longer period to develop from the 4 per cent to the 24 per cent seed stage. This was probably due to the peculiar growth habits of this variety which continues to set pods over a period of nearly 2 weeks, where other varieties tend to be more concentrated in time of setting.

Temperature Summations. The indications from these data are that environmental factors greatly influence the length of time necessary for snap beans to reach any given stage of maturity. Temperature is only one of the factors involved. A great deal of work has been done on a large number of crops on the use of temperature summations for planning of planting schedules and predicting harvest dates. This work is summarized by Walls (53). To date little has been done with snap beans in this connection. Stark and Mahoney (49) suggested a base line of 50° F. This base line was used by Gould (18) who reported the use of temperature summations for 47 varieties of snap beans. He found that most snap bean varieties require

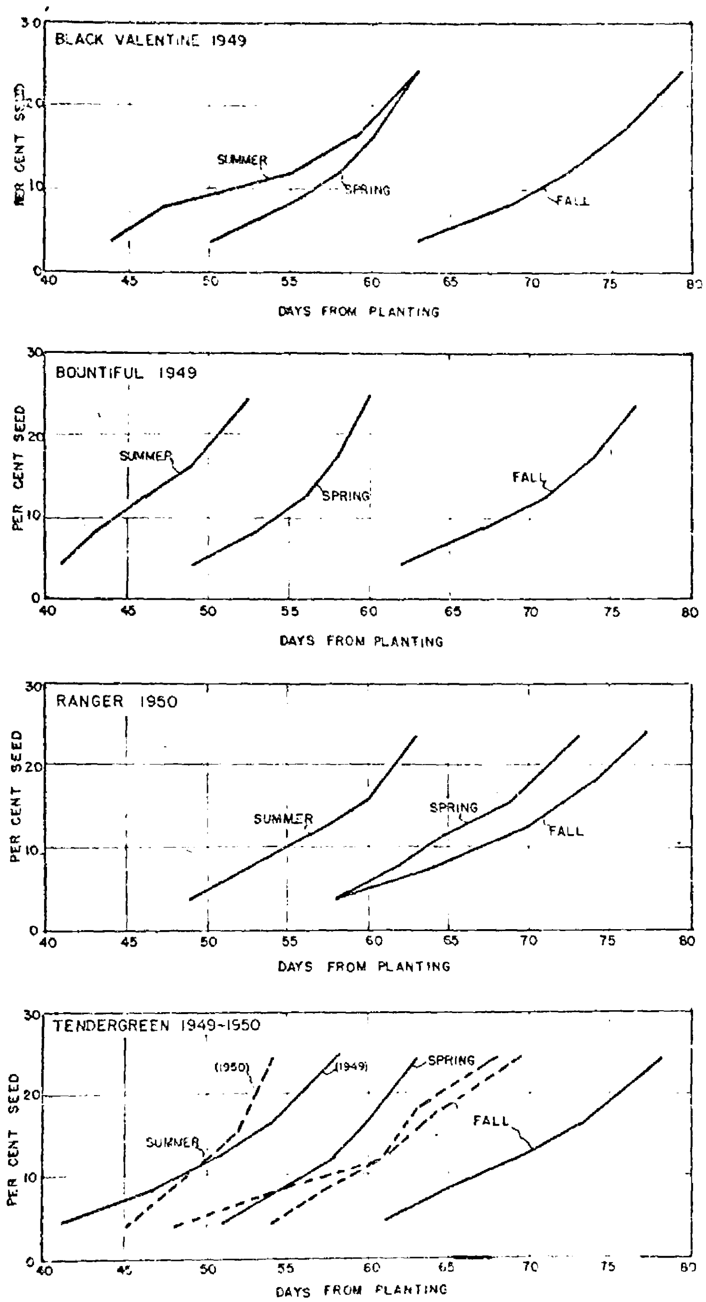


Figure 2. The Number of Days Required for Snap Beans Grown in Spring, Summer, and Fall to Reach Various Stages of Maturity as Determined by Per Cent Seed.

27,000 heat units to reach the optimum stage of maturity and suggested planting at every 600 degree hours for smoothness of picking operations.

Temperature data were obtained for the months of May through October for both 1949 and 1950. The results of the number of degree hours above a 50 degree base line necessary to bring any of the varieties tested to the 8 per cent seed stage of maturity in any season are presented in Table 6. These data show that in 1949, 29,333 degree hours were required to bring snap beans to a commercial stage of maturity, but in 1950 only 24,470 degree hours were required. Thus nearly 5000 degree hours, or in terms of average days, approximately 8 days difference must be explained by factors other than temperature. Seasonal differences were also noted. It was found that crops planted in the spring required a lower number of heat units than those maturing in midsummer and fall. Varieties were found to have different heat requirements as has been reported by Gould (18). However, varietal differences were found to be not as great as year and season differences. On the basis of these data the use of temperature summations alone would be of limited value for planning planting dates and of even less value for predicting harvesting dates, since there seems to be no exact number of degree hours necessary to bring the pods to a commercial picking stage of maturity.

It is thus apparent that other environmental factors such as rainfall can be limiting regardless of temperature. For example, in the summer of 1949 the crop matured during an extended dry period which lasted several weeks. The daily mean temperature during this period was between 80 and 90° F, but regardless of this high temperature the maturation of the pods was slow as compared to 1950. This effect is shown in Fig. 2.

Table 6. The Effect of Seasons, Varieties, and Years on the Degree Hours Necessary to Bring Snap Beans to the Eight Per Cent Stage of Maturity.

		Number of Degree Hours			
Year	Variety	Spring Crop	Summer Crop	Fall Crop	Variety Average
1949	Tendergreen	27,624	31,272	27,864	28,920
	Bountiful	27,624	29,750	28,704	28,692
	Black Valentine	29,232	31,212	30,720	30,388
					29,333 (1949)
1950	Tendergreen	22,272	24,144	24,600	23,672
	Topcrop	22,272	24,144	24,600	23,672
	Ranger	24,768	26,688	26,750	26,068
					24,470 (1950)
Season Average		25,632	27,868	27,206	

	F value	L.S.D. 5%
Varieties	3.4*	1,403
Years	174.1**	807
Seasons	12.9*	992

* Significant at 5% level
**Significant at 1% level

It is interesting to note that Went (56) working with tomatoes found that night temperatures control the rate of stem growth, and that the optimal night temperature is not constant but decreases as the plants become older. Night temperatures also completely regulate the fruit set, with the optimum gradually shifting lower as the plant grows taller and older. It is very possible that a similar condition exists for snap beans especially for those varieties which do not concentrate their pod set. Thus, if this is true and if night temperatures are not suitable for pod setting, the pods will not begin their growth until the combination of blossom presence and suitable night temperatures are attained.

Relationship of Yield to Quality

Although the yield of snap beans is of great importance, its relationship to quality cannot be ignored. As in other crops quality suffers if harvesting is delayed to the point of obtaining maximum yields at any one picking. Consequently, it is necessary to find the proper stage of maturity and the number of pickings necessary and practical to maintain quality and still obtain high yields. Tables 7, 8 and 9 show varietal differences as well as effects of harvesting at various stages of maturity.

Number and Time of Harvests. Considering the first harvest only or the first picking at the five stages of maturity (Table 8) it can be seen that yield increases progressively as the harvest is delayed until the 16 per cent seed stage is reached. The point of maximum yield varies for different varieties, some reaching their peak yields closer to the 24 per cent seed stage. If a second harvest is made when the beans reach their respective maturity stages, those being harvested at the 4 and 8 per cent seed stages will show yields comparable to the first picking, but those beans harvested at the 12 per cent seed stage would yield considerably less than the first picking. Harvesting twice at the 16 and 24 per cent seed stage was found to be impractical because of the very small additional yields.

It was found that when four pickings were made at the 4 per cent seed stage, three at the 8, and two at the 12, that the accumulated yields for each treatment were nearly the same and in some cases were higher at the younger stages of maturity. It may be impractical to harvest at the four per cent seed stage since the yield per picking was so low.

Perhaps the most profitable method would be to harvest two or perhaps three times for some varieties, when the beans have matured to the 8 to 12 per cent seed stage. By this method quality would be substantially maintained and yields would also be high. The actual harvesting practice for any given field would of course depend on the relation of expected price to quality so that if a sufficiently high premium could be obtained for very immature beans, it might be profitable to harvest at a stage of maturity younger than 8 per cent and harvest more frequently, or sacrifice a greater part of the potential yield (Fig. 3).

Varietal Differences. The varieties grown in 1948, namely, Stringless Green Pod and Pencil Pod Black Wax, yielded less than the varieties grown in subsequent experiments. In 1949 Black Valentine and Bountiful, and in 1950 Topcrop and Ranger, were found to produce higher yields than Tendergreen. Zaumeyer (64) who introduced Topcrop, found that the average yield in all states tested was 10,576 lbs. per acre, as compared to Tendergreen which yielded 6,339 lbs. per acre. These results agree with the relative yields obtained in this experiment. The somewhat higher yields reported by Zaumeyer may be due to yields from irrigated crops included in his

Table 7. The Effect of Date and Frequency of Harvesting on the Yield and Quality of Green and Wax Beans (1948).

	Stringless Green Pod			Pencil Pod Wax		
Method of Harvesting	Yield lbs/acre	Seed per cent	Per cent of total 4 sieve or less	Yield lbs/acre	Seed per cent	Per cent of total 4 sieve or less
Harvested once:						
44 days from planting	2421	4.2	70.4	1495	4.0	75.0
48 " " "	2148	8.5	13.0	3092	8.7	28.9
49 " " "	2530	9.5	11.6	3473	9.0	17.9
51 " " "	2806	11.7	14.9	3804	12.2	10.0
55 " " "	3274	30.5	5.5	3692	25.8	5.0
Harvested twice:						
44 days from planting	2421	4.2	70.4	1495	4.0	75.0
47 " " "	773	2.8	54.6	589	3.0	61.9
Total	3194	3.9	66.6	2084	3.7	71.3
48 days from planting	2148	8.5	13.0	3092	8.7	28.9
58 " " "	1198	6.0	—	1210	5.0	—
Total	3346	7.6		4302	7.7	
49 days from planting	2530	9.5	11.6	3473	9.0	17.9
56 " " "	955	4.2	24.0	1032	3.6	—
Total	3485	8.0	15.0	4505	7.8	
51 days from planting	2806	11.7	14.9	3804	12.2	10.0
62 " " "	661	11.6	—	799	9.5	—
Total	3467	11.7		4603	11.7	
Harvested three times:						
44 days from planting	2421	4.2	70.4	1495	4.0	75.0
47 " " "	773	2.8	54.6	589	3.0	61.9
50 " " "	396	3.3	67.9	362	2.1	82.8
Total	3590	3.8	66.7	2446	3.5	73.0
Harvested four times:						
44 days from planting	2421	4.2	70.4	1495	4.0	75.0
47 " " "	773	2.8	54.6	589	3.0	61.9
50 " " "	396	3.3	67.9	362	2.1	82.8
53 " " "	381	3.2	51.1	382	2.4	54.5
Total	3971	3.7	65.2	2828	3.3	70.5
L.S.D. 5% level	654			654		

Table 8. The Effect of Maturity and Frequency of Harvesting on the Yield of Snap Beans (1949).

Method of Harvesting	Tendergreen lbs./acre Each Picking	Tendergreen lbs./acre Accum. Total	Per Cent of Max. Yield	Bountiful lbs./acre Each Picking	Bountiful lbs./acre Accum. Total	Per Cent of Max. Yield	Black Valentine lbs./acre Each Picking	Black Valentine lbs./acre Accum. Total	Per Cent of Max. Yield	Average Per Cent of Max. Yield
Harvested at 4% seed										
1st picking	1189	1189	19.9	2465	2465	29.9	2030	2030	24.2	24.6
2nd picking	1392	2581	43.2	3219	5684	69.0	3103	5133	61.2	57.8
3rd picking	1972	4553	76.2	1653	7337	89.1	1943	7076	54.4	83.2
4th picking	580	5133	85.9	580	7917	96.1	957	8033	95.8	92.6
Harvested at 8% seed										
1st picking	3074	3074	51.5	4437	4437	53.9	4350	4350	51.9	52.4
2nd picking	2059	5133	85.9	2059	6496	78.9	3045	7395	88.2	84.3
3rd picking	841	5974	100.0	1131	7627	92.6	986	8381	100.0	97.5
Harvested at 12% seed										
1st picking	4611	4611	77.2	6438	6438	78.2	5974	5974	71.2	75.5
2nd picking	1247	5858	98.1	1798	8236	100.0	2001	7975	95.1	97.7
Harvested at 16% seed	5220	5220	89.1	6293	6293	76.4	7047	7047	84.0	83.1
Harvested at 24% seed	5104	5104	85.4	6612	6612	80.2	6844	6844	81.6	82.4
L.S.D. 5% level	855			855			855			

Table 9. The Effect of Maturity and Frequency of Harvesting on the Yield of Snap Beans (1950).

Method of Harvesting	Tendergreen lbs./acre		Per Cent of Max. Yield	Topcrop lbs./acre		Per Cent of Max. Yield	Ranger lbs./acre		Per Cent of Max. Yield	Average Per Cent of Max. Yield
	Each Picking	Accum. Total		Each Picking	Accum. Total		Each Picking	Accum. Total		
Harvested at 4% seed										
1st picking	1943	1943	24.2	2732	2732	28.7	1972	1972	19.7	24.2
2nd picking	1943	3886	48.5	2558	5290	55.6	2320	4292	43.0	49.0
3rd picking	2030	5916	73.9	2076	7366	77.4	2146	6438	64.5	71.9
4th picking	812	6728	84.0	1624	8990	94.5	2088	8526	85.3	81.9
Harvested at 8% seed										
1st picking	4217	4217	52.6	5290	5290	55.6	4826	4826	48.3	52.1
2nd picking	1873	6090	76.0	2250	7540	79.3	2946	7772	77.8	77.7
3rd picking	812	6902	86.2	1467	9007	94.6	2204	9976	100.0	93.6
Harvested at 12% seed										
1st picking	5452	5452	68.1	6844	6844	71.9	6293	6293	63.0	67.6
2nd picking	2552	8004	100.0	2668	9512	100.0	2581	8874	88.9	96.3
Harvested at 16% seed	5429	5429	67.8	7134	7134	75.0	7389	7389	74.0	72.2
Harvested at 24% seed	6073	6073	75.8	7575	7575	79.6	7702	7702	77.2	77.5
L.S.D. 5%	1017			1017			1017			

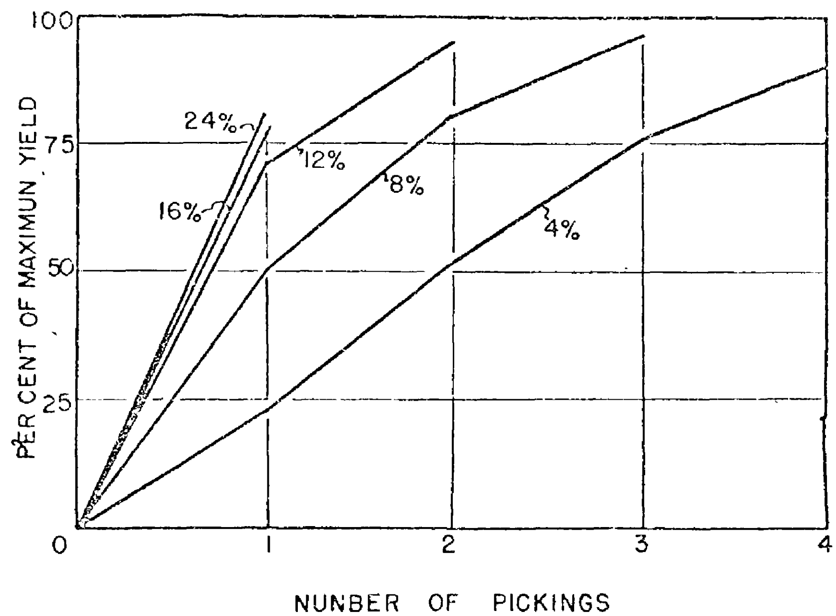


Figure 3. The Relationship of Number of Pickings to the Per Cent of the Total Yield of Snap Beans Harvested at Five Stages of Maturity.

reports. Zaumeyer also reports that when Topcrop is picked 4 times the yields per picking are nearly equal. This was also found to be true in this experiment. On the other hand the yield of varieties Tendergreen, Bountiful, and Black Valentine tended to decrease at the last picking. The variety Ranger, because of its growth habits, tends to continue in production and may be picked 5 and possibly 6 times.

Season Differences. Table 10 shows the effect of season on yield of five different varieties. The variety Tendergreen which was grown both years, gave lower yields when grown in the spring than when grown in the summer or fall. A possible explanation for the low yield during the summer of 1949 is the hot and dry period which resulted in a poor pod set. The fall growing season in 1949 was favorable for high yields of all varieties.

Table 10. The Effect of Variety, Season, and Year on the Yield of Snap Beans.

Year	Variety		Yield in lbs./Acre		
			Spring Crop	Summer Crop	Fall Crop
1949	Tendergreen		3335	3422	6467
	Bountiful		4379	6061	8526
	Black Valentine		4640	5191	9209
	L.S.D. 5% level	440			
1950	Tendergreen		3816	6612	6090
	Topcrop		6264	7714	7018
	Ranger		6272	6612	7308
	L.S.D. 5% level	534			

In 1950 there was less difference between seasons as far as yields were concerned. This may in part have been due to an adequate supply of soil moisture throughout the entire summer. Both Tendergreen and Topcrop produced the highest yields during the summer season, while Ranger produced its highest yield in the fall. The period during which the beans were maturing in the fall of 1950 was cold and very wet, possibly explaining the lower yield for that crop.

Growth Regulators

Recently two growth regulating substances, para-chlorophenoxyacetic acid and maleic hydrazide, have been shown to partially control maturation of some crops (34, 38, 45, 61). These materials were therefore selected for a study of the practicability of using growth regulating substances to retard maturation in snap beans.

Para-Chlorophenoxyacetic Acid. The results of the application of para-chlorophenoxyacetic acid (CLPA) to snap beans are presented in Tables 11 and 12 and Figures 4 and 5. It was found that the three concentrations .1, .3, and .9 per cent affected the beans in a similar manner; therefore, for ease of presentation these were averaged and are hereafter referred to as the treated plots.

The application of CLPA had a retarding effect upon fiber development, as is shown in Figure 4. Four days after spraying, the fiber content of the check plots was 117 mg. of fiber per 100 gms. of fresh material while the treated plots increased only to 85 mg. of fiber. After 7 days the check plots had reached 254 mg. of fiber and the treated plots had increased to 231 mg. of fiber. Ten days after spraying the check plots had increased to 481 mg. and the treated plots to 312 mg. However, when a panel graded samples of these beans organoleptically, no differences were detected between the fiber content of the treated beans and those not treated.

Table 11. The Effect of Snap Beans of Three Levels of Para-Chlorophenoxyacetic Acid Where Harvests Were Made 4, 7, and 10 Days After Application (August, 1949).

Concentration of CLPA Spray	Per Cent Seed		Fiber mg./100gms.		Fiber Pressure Tester (lbs.)	Organoleptic Grades - 0 poor - 10 good					Yield in lbs. per 30 ft. Row
	Canned	Raw	Blendor Method	F.D.A. Method		Color	Maturity	Fiber	Flavor	Overall Grade	
0	13.4	13.0	284	223	8.9	6.0	5.1	5.4	6.7	5.4	10.1
.1%	9.5	9.7	192	162	8.4	5.5	5.0	5.6	6.3	5.0	9.7
.3%	9.4	9.7	225	181	8.6	5.3	5.1	5.9	6.3	5.1	9.3
.9%	9.0	8.5	210	168	8.2	5.3	5.1	5.6	5.7	4.7	9.5
L.S.D. 5% level	1.9	1.7	39	46	.5	.4	.5	.6	.4	.4	4.0
F value	9.60**	10.78**	8.41**	2.84**	3.06*	5.96**	.4	.65	6.98**	6.50**	.5

* Significant 5% level
**Significant 1% level

Table 12. The Effect on Snap Beans of Three Levels of Para-Chlorophenoxyacetic Acid Applied at Three Stages of Maturity (September, 1949).

Concentration of ClPA Spray	Per Cent Seed Canned	Per Cent Seed Raw	Fiber mg./100gms. Blendor Method	Fiber mg./100gms. F.D.A. Method	Fiber Pressure Tester (lbs.)	Organoleptic Grades - 0 poor - 10 good: Color	Maturity	Fiber	Flavor	Overall Grade	Yield in lbs. per 30 ft. Row
0	10.5	10.4	73	120	8.0	7.1	6.3	6.5	7.0	6.5	10.1
.1%	8.9	8.5	77	120	7.5	6.5	6.1	6.6	6.4	5.8	10.8
.3%	8.2	8.4	68	121	7.5	6.6	6.2	6.8	6.6	6.1	10.1
.9%	7.4	8.3	65	109	7.3	6.6	6.1	6.7	6.4	5.9	10.9
L.S.D. 5% level	1.1	1.0	14	14	.4	.4	.4	.4	.3	.2	.9
F value	11.66**	7.91**	1.11	.29	3.87*	4.05**	.20	.93	5.67**	10.26**	1.93

* Significant 5% level
**Significant 1% level

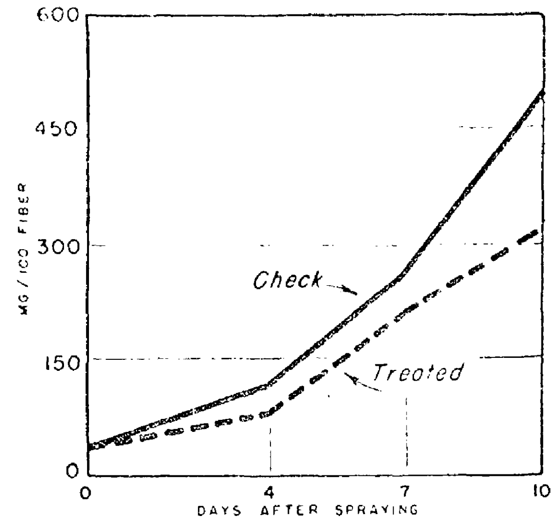
The increase in the per cent seed, which normally occurs as the snap beans mature, was significantly affected by applications of CLPA. Seven days after the application the treated plots showed an increase from 4.9 to 7.8 per cent, while the check had increased from 4.9 to 13.8. After ten days the check plot contained 18.1 per cent while the treated plots were significantly lower at 12.1 per cent (Figure 4).

When the beans were judged organoleptically for maturity no significant difference was noted in the maturity of the treated beans and those not treated. This was perhaps due to the fact that the treated beans appeared upon casual observation to be of the same maturity as the checks, i.e., their pods were as large as the checks and appeared to have large seeds. However, in many cases the seeds were in reality small and the pods were blistered and punky. When the pods were graded for shape according to U. S. standards, it was found that the treated beans had a much higher percentage of misshapen pods than those not treated. This was particularly true of the variety Bountiful (Figure 8).

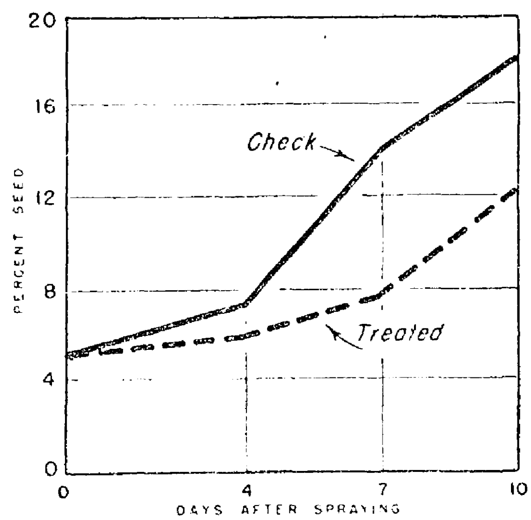
The fiber pressure tester showed a decrease in resistance to shearing for the treated beans over the untreated ones. This was probably due to the retardation of the seed and fiber development.

The panel scores showed a significant decrease in the color, flavor and over-all grade (Figure 5) of the beans treated with CLPA over those not treated.

Data presented in Table 2 show the results obtained with .1, .3, and .9 per cent applications of CLPA at three stages of maturity. As in the previous experiment, it was found that the increase in per cent seed was significantly retarded by these applications. However, no significant retardation of the fiber content was accomplished in this experiment. The

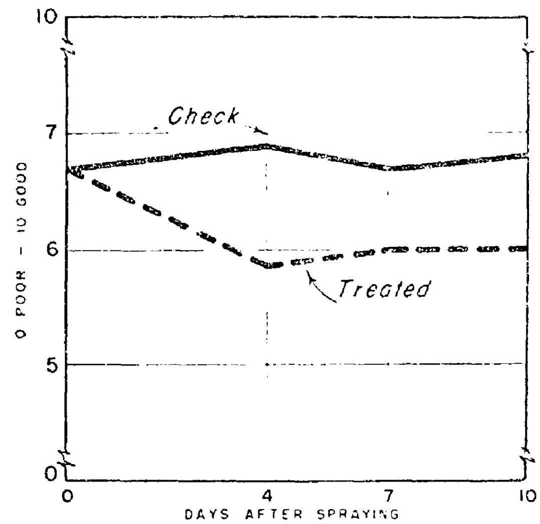


Effect of CLPA on the Fiber Content of Snap Beans

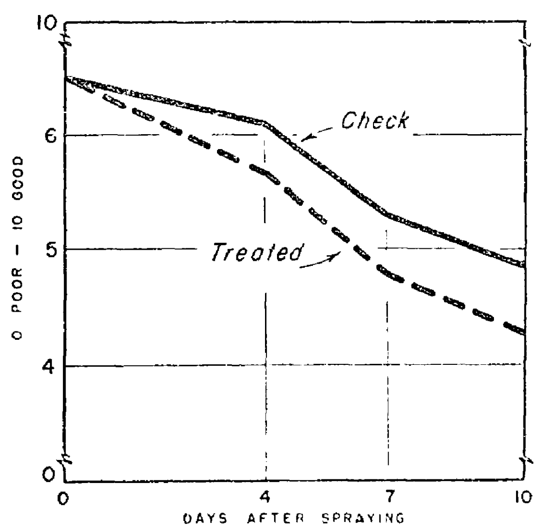


Effect of CLPA on the Percent Seed of Snap Beans

Figure 4. The Effect of Para-chlorophenoxyacetic Acid on the Per Cent Seed and Fiber Development in Snap Beans.



Effect of CLPA on the Flavor as determined by a Panel of Judges



Effect of CLPA on the Overall Grade as determined by a Panel of Judges

Figure 5. The Effect of Para-chlorophenoxyacetic Acid on the Flavor and Over-all Grade of Snap Beans.

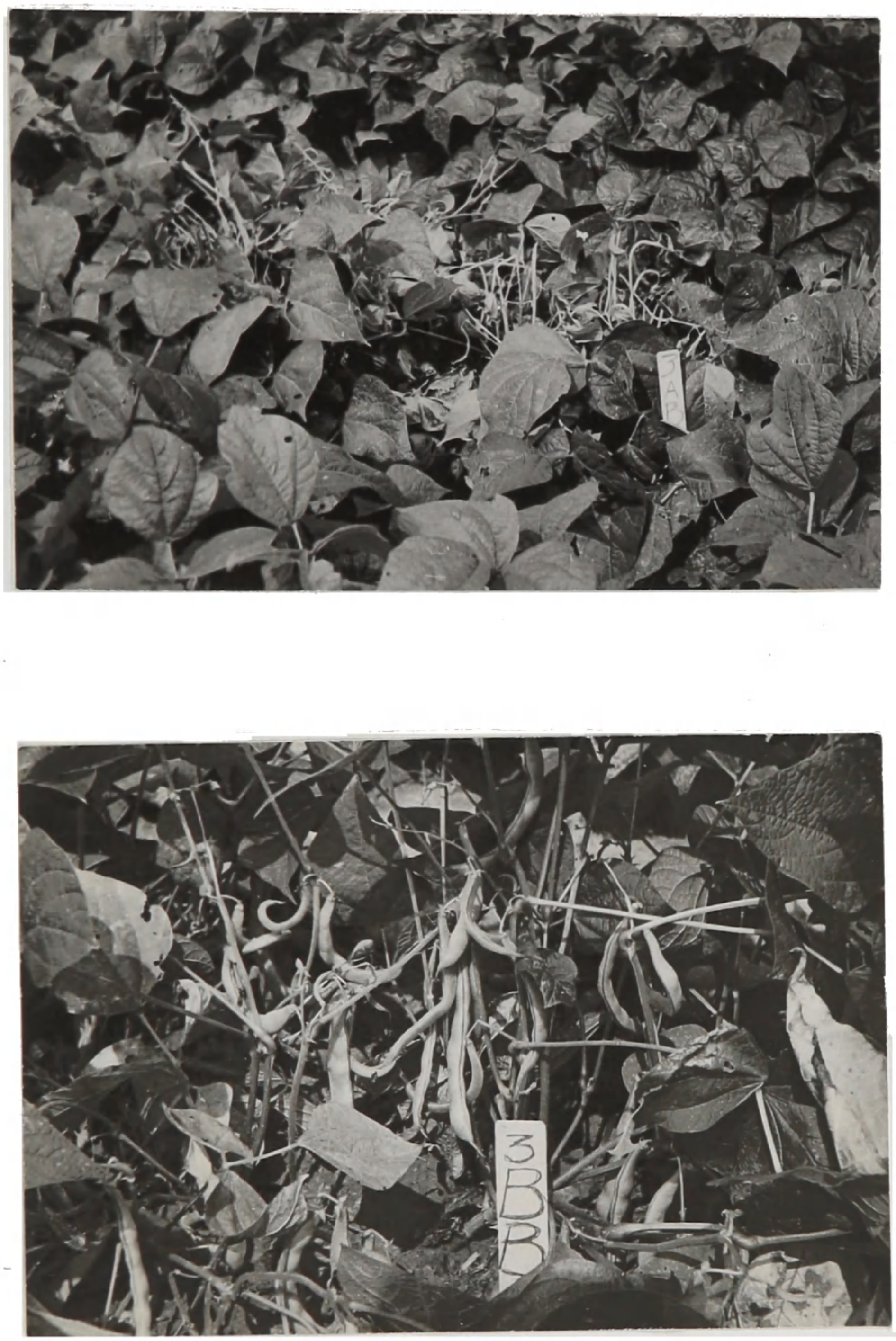


Figure 6. The Effect of .9 Per Cent Para-chlorophenoxyacetic Acid on the Plants (upper) and the Pods (lower) of Snap Beans.

Figure 7. The Effect of .9 Per Cent Para-chlorophenoxyacetic Acid on the Stems of Snap Beans. Check left, Treated right.

Figure 8. The Effect of Para-chlorophenoxyacetic Acid on the Pods of Snap Beans. Check left, Treated right.

fiber pressure tester again showed the treated beans to have less resistance to shearing than the check. The taste panel found no significant difference between the treated and untreated samples as far as fiber and maturity were concerned. However, as before, the treated beans were graded significantly lower for color, flavor, and over-all grade. In both experiments CLPA had no significant effect on the yield.

It can be stated that applications of CLPA to snap beans significantly retarded the development of the seed and fiber, and did not affect the yield. On the other hand, it was found to reduce quality as measured by color, flavor and over-all grade, as well as cause a higher percentage of misshapen pods.

It was noted in the midsummer crop that the highest concentration of .9 per cent, and in some cases .3 per cent, caused considerable damage to the plant. Three or four days after application the leaves became curled and burned and plants opened up, while in later stages the stems became thickened and misshapen and in some cases there was severe leaf drop (Figure 5 and 6). This was especially true of the variety Bountiful. These effects were not noted as extensively on the fall crop.

Maleic Hydrazide. The results of the experiments with maleic hydrazide are presented in Tables 13 and 14 and Figure 9. Actually the data presented in the figures are the interactions between the concentration of maleic hydrazide and time of application. The results indicated that maleic hydrazide applications were highly specific in relation to the stage of development of the plant. It was found for example, that when a 1 per cent solution was sprayed on the plant at the early blossom stage, all flowers and flower buds had abcissed in a few days. The plants were not killed, but remained stunted and unproductive.

As shown in Figure 9, application of maleic hydrazide at the full bloom or early pod stage, significantly retarded seed and pod development. Those beans sprayed at full bloom with a 1 per cent solution contained only 6.2 per cent seed when the check had reached 24.3 per cent seed.

Maleic hydrazide had less effect on the fiber content than CLPA although in the midsummer experiments there was found to be a significant difference between the check and the plots treated with maleic hydrazide. This difference may have been due to the varieties used. In the experiments with CLPA two of the varieties, Black Valentine and Bountiful, have potentially high fiber contents while all three of the varieties used in the maleic hydrazide experiments are potentially low fiber content types.

When judged organoleptically (Figure 9), treated beans were found to be much tougher even though they appeared to be much younger as far as maturity was concerned. This toughness was apparently not due to increased fibrousness, but rather to a brittle condition.

The flavor of the treated beans was found to be significantly less desirable than those which were not treated. The over-all grade of the beans sprayed with maleic hydrazide was also found to be significantly less than the untreated checks.

The yields of those plots treated with maleic hydrazide were found to be significantly lower than those which were not treated. It is interesting to note that these data are significantly correlated (.728) with the retardation of seed development.

The data obtained with applications of maleic hydrazide at different concentrations and at different time in the development of snap beans, has shown that full bloom and early pod applications significantly retarded

Table 13. The Effect on Snap Beans of Three Levels of Maleic Hydrazide Applied at Four Stages of Maturity. Experiment I. (June, 1950).

Maleic Hydrazide Treatment	Per Cent Seed Raw	Blendor Fiber mg./100gms.	Fiber Pressure Tester (lbs.)	Color	Maturity	Fiber	Flavor	Overall Grade	Yield in lbs. per 15 ft. Row
Concentration									
Check	15.7	43	5.7	5.3	4.9	6.2	5.3	5.2	6.1
.04%	15.1	56	6.0	5.3	4.8	5.9	5.0	4.9	6.1
.2%	12.1	64	6.0	5.1	5.0	5.2	4.6	4.5	4.0
1.0%	10.8	63	5.5	5.1	5.5	4.2	3.8	3.9	2.2
L.S.D. 5% level	2.0	18	.3	.5	.4	.5	.7	.4	.7
F value	10.88**	2.37	7.72**	.37	4.72**	26.81**	18.64**	19.86**	62.14**
Applied at									
Full Bloom	11.6	45	5.6	5.3	5.7	5.1	4.1	4.4	3.5
Early Pod	11.4	66	5.8	5.0	4.8	5.1	4.4	4.4	4.3
4% seed	14.5	48	5.9	5.3	4.9	5.5	4.8	4.8	5.3
8% seed	16.2	65	5.9	5.3	4.8	6.0	5.2	5.0	5.4
L.S.D. 5% level	2.0	18	.3	.5	.4	.5	.7	.4	.7
F value	10.74**	3.04*	2.90*	.50	7.47**	6.78**	10.30**	6.78**	14.82**

* Significant 5% level
**Significant 1% level

Table 14. The Effect of Snap Beans of Three Levels of Maleic Hydrazide Applied at Four Stages of Maturity. Experiment II. (August, 1950).

Maleic Hydrazide Treatment	Per Cent Seed Raw	Blendor Fiber mg./100gms.	Fiber Pressure Tester (lbs.)	Color	Maturity	Fiber	Flavor	Overall Grade	Yield in lbs. per 15 ft. Row
Concentration									
Check	25.8	187	7.2	5.3	4.2	5.2	5.4	4.7	8.3
.04%	23.2	211	7.3	5.3	4.6	5.2	5.3	4.8	9.2
.2%	18.9	176	7.2	5.2	4.5	4.9	4.9	4.5	7.2
1.0%	15.1	180	6.9	5.2	5.2	4.1	4.1	4.0	5.0
L.S.D. 5% level	2.6	24	.5	.3	.4	.5	.3	.3	1.0
F value	30.12**	2.69*	1.12	.60	12.66**	12.84**	25.13**	11.69**	28.11**
Applied at									
Full Bloom	15.6	146	7.0	5.2	5.1	4.7	4.5	4.2	5.3
Early Pod	18.2	226	7.3	5.2	4.7	4.5	4.6	4.3	7.1
4% Seed	24.2	198	7.3	5.3	4.5	5.2	5.2	4.7	8.4
8% Seed	25.0	184	7.1	5.3	4.2	5.0	5.4	4.8	8.9
L.S.D. 5% level	2.6	24	.5	.3	.4	.5	.3	.3	1.0
F value	28.69**	36.63**	.74	.60	13.02**	4.50**	14.56**	6.51**	22.69**

* Significant 5% level
**Significant 1% level

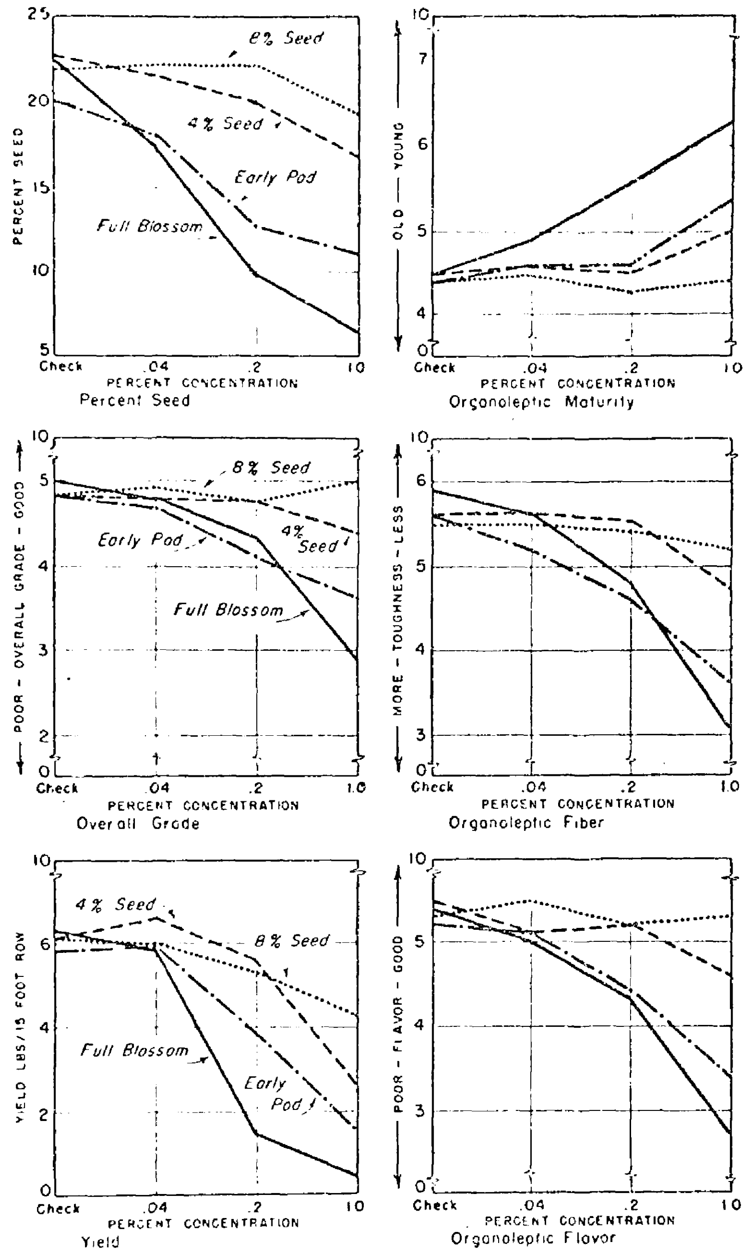


Figure 9. The Effect of Maleic Hydrazide on Organoleptic and Objective Tests of Quality of Snap Beans.

development of the pod and in effect retarded maturation, but at the same time the yield and quality were significantly reduced.

Storage Studies

Beans are often transported long distances from farm to processing plant or market. Further delays in handling are often encountered because of processing or marketing procedures. It is, therefore, important to know what changes take place in the quality of the snap bean during storage.

In 1948 studies were made on the effect of temperature and duration of storage on quality. The data obtained are presented in Tables 15 and 16 and Figures 10 and 11.

Physical and Chemical Composition. The duration and temperature of storage had no effect on the per cent seed content of snap beans; however, when graded organoleptically by a panel of judges, those beans stored for 10 days were scored lower for maturity than those not stored. No effect of temperature of storage was noted by the panel.

No change in the fiber content was noted when fiber was determined by the official F.D.A. method or by the fiber pressure tester. However, when the fiber was determined by the Blendor method the fiber was found to increase from 74.4 mg. to 134.5 mg./100 gms. of fresh material. This is in agreement with the panel grades which indicated that beans stored from 4 to 7 days contained more fiber than the checks. Scott and Kramer (46) found a similar situation in asparagus, where the Blendor method was more closely correlated with the organoleptic grade than the Official method. It is possible that there is an accumulation of hardened cellular substances as the storage is prolonged. Perhaps these substances are dissolved by the hot alkali and therefore no increase is indicated by the

Table 15. The Effect of Duration and Temperature of Storage on Maturity and Fibrousness of Snap Beans.

	Maturity			Fiber			
Storage Variable	Per Cent Seed Raw	Per Cent Seed Canned	Organo-leptic Maturity	Fiber Pressure Test/lbs.	F.D.A. Fiber mg./100gms.	Blendor Fiber mg./100gms.	Organo-leptic Fiber
Duration of Storage:							
0 days	13.2	12.4	6.5	8.08	69.3	74.4	8.5
1 day	12.8	12.2	6.5	8.19	67.8	91.3	8.4
4 days	13.9	12.6	6.3	8.54	61.3	112.3	8.1
7 days	14.2	13.1	6.1	8.72	75.7	123.5	8.0
10 days	13.1	13.1	5.7	8.69	66.7	134.5	7.5
L.S.D. 5% level	1.20	1.24	.4	.4	18.0	---	.4
F value	1.9	.48	6.07**	4.93	.66	---	9.14**
Temperature of Storage:							
35°F.	12.9	11.8	6.4	8.34	59.4	96.8	8.2
50°F.	13.9	13.3	6.2	8.41	74.8	112.4	8.1
70°F.	13.5	13.0	6.1	8.58	70.3	114.2	8.0
L.S.D. 5% level	.9	1.0	.3	.3	14.0	---	.3
F value	2.71	2.71	1.36	1.59	2.59	---	1.21

**Significant 1% level

Table 16. The Effect of Duration of Storage, and Temperature of Storage on the Moisture Content, Ascorbic Acid Content, and Color of Snap Beans.

Storage Variable	Per Cent Moisture	Ascorbic Acid mg./100gms.	Green Pigment Raw/ppm	Yellow Pigment Raw/ppm	Green Pigment Canned /ppm	Yellow Pigment Canned /ppm	Organo-leptic Color Grade
Duration of Storage							
0 days	87.5	22.0	103.0	8.3	66.8	8.7	7.0
1 day	87.9	19.2	104.0	7.8	60.9	7.9	6.5
4 days	88.0	13.8	93.8	7.5	47.8	6.8	6.2
7 days	87.6	11.3	98.7	7.2	51.7	7.1	5.5
10 days	87.6	11.0	90.8	6.8	49.1	6.6	5.5
L.S.D. 5% level	.7	1.5	10.8	.6	—	—	.4
F value	.25	86.3**	12.3**	7.2**	—	—	21.9**
Temperature of Storage							
35°F.	87.8	15.7	104.2	8.0	56.3	7.8	6.5
50°F.	87.6	15.9	95.8	7.3	55.4	7.4	6.2
70°F.	87.7	14.7	94.1	7.2	54.2	7.0	5.7
L.S.D. 5% level	.5	1.2	8.2	.5	—	—	.3
F value	.3	2.3	3.4*	7.4**	—	—	12.7**

* Significant at 5% level
**Significant at 1% level

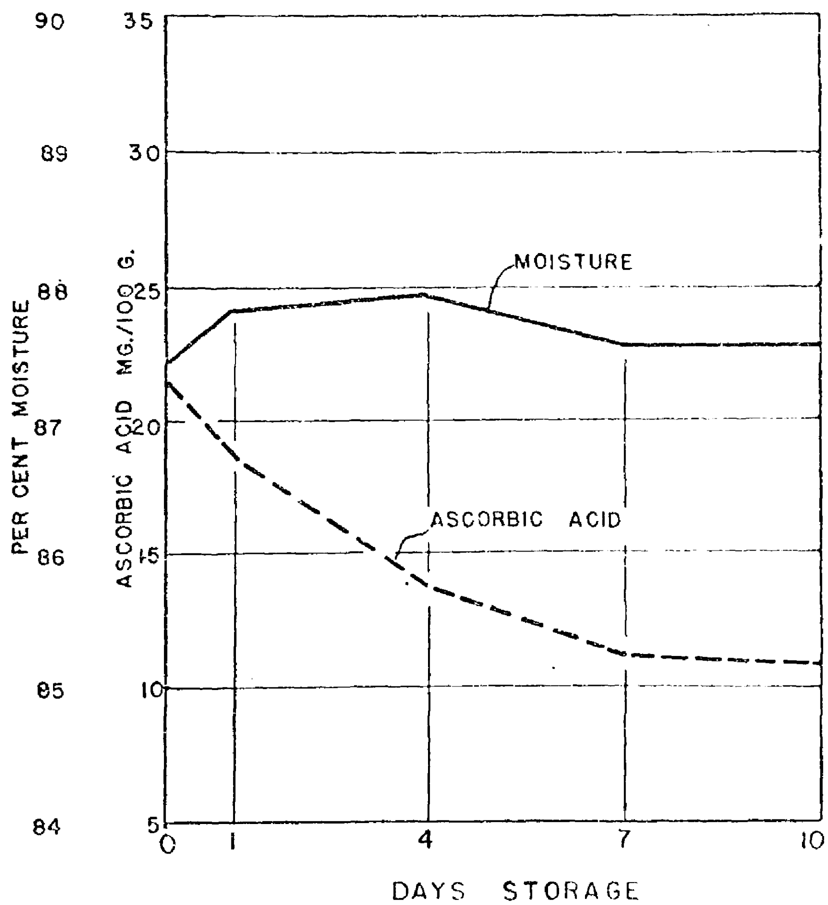


Figure 10. The Effect of Duration of Storage on the Moisture and Ascorbic Acid Content of Snap Beans.

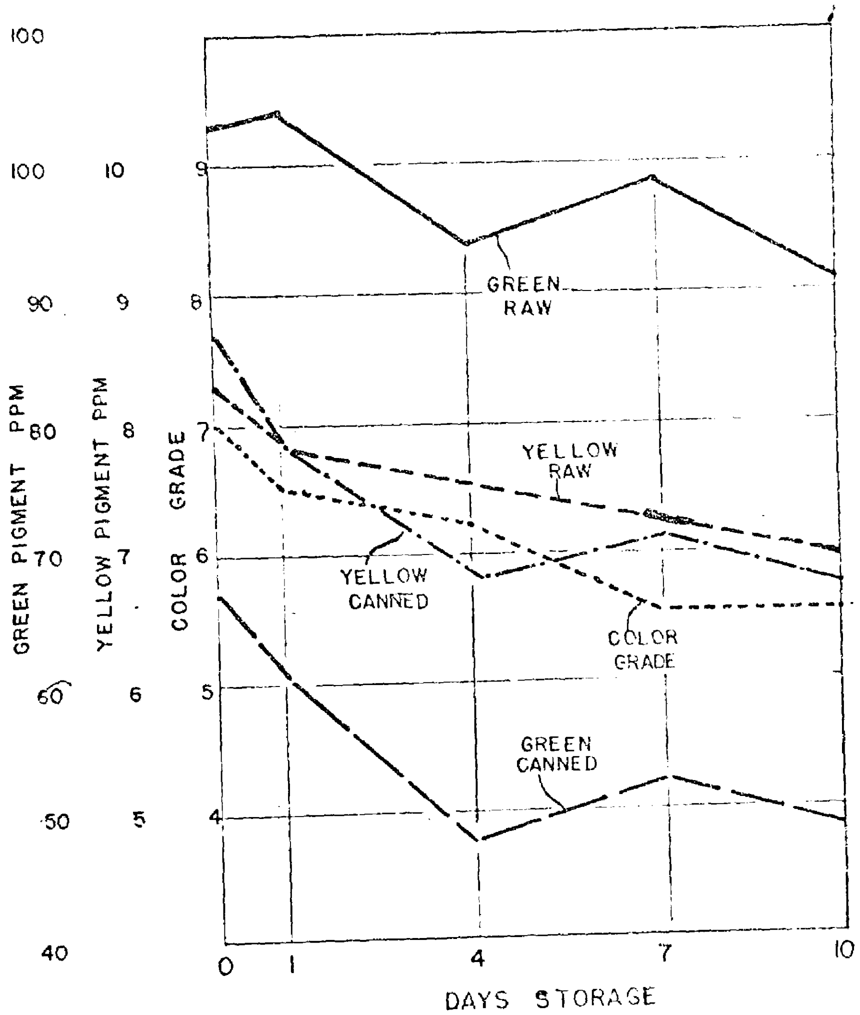


Figure 11. The Effect of Duration of Storage on the Pigmentation of Snap Beans. (Green pigment reported as ppm chlorophyll and yellow pigment as ppm carotene.)

FDA method. On the other hand the Blendor method may not break these pieces up finely enough to allow their passage through on the screen.

The moisture content was found to remain the same throughout the storage period regardless of the temperature of storage. This is in agreement with Parker and Stuart (42) who found no change in the moisture content of beans held at 28°C. (83°F.) for 95 hours. When the pods were split and beans removed they did find a reduction of moisture from 87.9 to 85.7 per cent in the pods only, during a period of 58 hours, and a reduction of moisture in the beans from 77.3 to 73.8 per cent when the beans were held at room temperature. This loss was probably due to exposure of cut surfaces.

The ascorbic acid content was reduced by 50 per cent, from 22.0 mg. to 11.0 mg./100 gms. of fresh material, by a storage period of 10 days. This loss during storage is not peculiar with snap beans but has been found to occur in asparagus (46) and lima beans (47) as well as in other vegetables.

Color measured both organoleptically and objectively, was found to decrease as the duration of storage increased. The beans stored at 35° F were found to have better color than those stored at 70° F (Table 16).

Loss in Weight. Probably the most important loss in storage is the loss in weight. Table 17 shows the losses in weight of sieve sizes 4 and 5 at 35, 50, and 70° F. The green beans were found to lose 41 per cent of their weight in a fifteen day period when stored either at 35 or 50° F and 58 per cent in a fifteen day storage period when stored at 70° F. Wax beans lost 42 per cent when stored at 35 and 50° F and 63 per cent of their original weight when stored at 70°F. These results seemed exceptionally high; therefore a similar experiment was carried out in 1950 using the varieties Tendergreen and Topcrop. These varieties lost 21 to 23 per cent of

Table 17. Weight in Grams of Snap Beans Held in Storage at 35°, 50°, and 70° F. (1948).

	35° F.			50° F.			70° F.		
Days Stored	Sieve Size #4[1]	#5[2]	Ave. Per Cent Loss	Sieve Size #4[1]	#5[2]	Ave. Per Cent Loss	Sieve Size #4[1]	#5[2]	Ave. Per Cent Loss
				Burpee's Stringless Green Pod					
0	308	308		308	308		308	308	
1	308	308		307	308		305	305	1.0
2	304	304	1.3	304	304	1.3	296	299	3.5
7	290	294	5.2	295	294	5.0	265	264	14.0
15	179	184	41.3	185	180	40.8	137	126	57.4
				Pencil Pod Black Wax					
0	308	308		308	308		308	308	
1	308	308		308	308		308	308	
2	304	304	1.3	304	304	1.3	294	299	3.8
7	292	293	5.1	291	291	5.6	252	269	15.5
15	179	181	41.6	179	181	41.6	103	135	61.4

[1]Sieve #4 - 18/64"
[2]Sieve #5 - greater than 18/64"

their original weight in a 7-day storage period at room temperature (Table 18). The beans were shriveled and dried and although the per cent moisture remained the same in those beans stored for a ten-day period, there was actually a decrease in the moisture content of the snap beans, accounting for the loss in weight.

Table 18. The Loss of Weight of Snap Beans During Storage at Room Temperature for Six Days (1950).

	Tendergreen				Topcrop			
Days Stored	Weight in gms.	Per Cent Wt. Loss	Weight in gms.	Per Cent Wt. Loss	Weight in gms.	Per Cent Wt. Loss	Weight in gms.	Per Cent Wt. Loss
0	1000		1000		1000		1000	
1	961	3.9	956	4.4	956	4.4	961	3.9
2	912	8.8	906	9.4	908	9.2	916	8.4
3	889	11.1	878	12.2	882	11.8	880	12.0
4	857	14.3	845	13.5	845	13.5	845	13.5
5	820	18.0	807	19.3	805	19.5	807	19.3
6	789	21.1	766	23.4	768	23.2	775	22.5

Parker and Stuart (42) found that green beans had an exceedingly high respiration rate. Small beans liberated an average of 211.8 mgms. of CO_2 per hour per kilogram of fresh weight while large beans had a somewhat higher rate. However, upon calculation of the loss due to respiration it was found that respiration accounted for only an insignificant amount. Lieberman et al. (31) studying the effect of films on weight loss and other factors, found that moisture loss in cellophane packages was insignificant. The unpackaged lots on the other hand lost considerable weight, especially after 10 days at 40° F, or after 1 to 3 days at 70° F, following a week's storage at 32 or 40° F.

Objective Tests

For many crops objective methods have been established for determining maturity - for example the tênderometer (54) for peas and the succulometer (30) for corn. The need for a standard way of measuring maturity in snap beans is strikingly brought out by a review of papers concerning research on this crop. A few examples of the various methods used to indicate maturity are presented as follows:

Parker and Stuart (42) in their work on changes in the chemical composition of green beans after harvest used for their studies commercially picked beans divided into two groups. "Small beans were those that had a smooth pod without noticeable bean formation, and large beans were those with a noticeable bulging of the pod due to bean formation." Culpepper (7) used tagging or recorded age as a method of measuring maturity. Beans were harvested 10, 15, 20, 25, and 30 days after date of flowering. This method is applicable for a specific crop, but as was shown in a preceding section[2] seasons and varieties greatly influence the time from blossoming to any given stage of maturity.

Gould in his series of papers (16, 17, 18, 19, 20) reports harvesting at three stages of maturity - "Grade A, B, C," where A may refer to a range of 2.3 to 9.5 per cent seed, B from 5.0 to 15.6 per cent seed, and C from 8.7 to 25.0 per cent seed.

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[2]See page 25.

Hibbard and Flynn (23) graded snap beans for Vitamin studies into 5 stages of maturity according to seed length. These were as follows: stage 1, less than 7 mm. in length; stage 2, 7 to 10 mm.; stage 3, 10 to 14 mm.; stage 4, 14 to 18 mm.; and stage 5, over 18 mm. It should be pointed out that some varieties have smaller pods and seeds than do others so that by the time one variety reaches 16 mm. in length of seed, it may be much further along as far as maturity is concerned than other with the same seed length.

Caldwell and coworkers (3, 4) used seven stages of maturity in their dehydration studies. These stages of maturity were based on per cent seed and per cent hull.

It has been shown in the preceding sections that there were increases in per cent seed, fiber content, and resistance to shearing; and a decrease in pigment concentration, moisture and ascorbic acid as the beans were allowed to mature. All of these factors present possible ways of measuring maturity objectively. In order to evaluate methods of measuring the above changes it is necessary to find out if a method is correlated with some other established objective test, such as the tenderometer or AIS in the case of peas (54), or with organoleptic grades determined on a series of samples by a panel of judges. For the purpose of evaluating objective tests a correlation coefficient (r) of .800 between method and panel evaluation has been established as the lower limit of acceptability. However, if a test is found to have an r value of .700 the test is still considered for further study.[3]

Per Cent Seed. The correlations (r) between per cent seed, raw and

[3] Conference on taste testing panels - Bureau of Human Nutrition and Home Economics Mimeo., Washington, D. C. 1950.

canned, and organoleptic grades and other objective tests are presented in Table 19. As might be expected the per cent seed does not change materially upon processing. Increases in per cent seed were found to be highly correlated with increases in fiber development regardless of the method of fiber determination used. Per cent seed was also found to be highly correlated with organoleptic grades for maturity and fiber. The effect of flavor and color graded organoleptically, which are poorly correlated with the development of snap beans, probably lowered the correlation between the per cent seed and the over-all organoleptic grade.

Fiber. The fiber pressure test, which measures resistance to shearing, was found to be fairly highly correlated with organoleptic grades for maturity and fiber and other objective methods for determining fiber (Table 20). However, on the basis of three years' results, it was found that this test did not meet the limits set up for acceptability. The shear-press developed by Kramer and coworkers (28) eliminates some of the problems found in the pressure tester, since it has a greater range and measures more than one pod at a time. Perhaps additional work with this instrument might indicate its usefulness for this purpose.

The F.D.A. and blendor methods for determining fiber were found to be highly correlated in 1948 and 1949. In 1950 the three varieties used were low in fiber content making relatively small differences in fiber loom large, which in turn lowered the correlation between the two methods. Taking all factors into consideration the blendor method appears to be equal in accuracy to the alkali digestion method proposed by the Food and Drug Administration, while it is approximately six times as rapid as the FDA method. It also does not involve the use of hot lye which must be handled carefully.

Table 19. The Relationship, Expressed as Correlation Coefficients, Between Per Cent Seed, and Other Objective and Organoleptic Tests for Snap Beans.

	Per Cent Seed Raw			Per Cent Seed Canned		
	1948	1949	1950	1948	1949	1950
Per Cent Seed Raw	--	--	--	.900	.937	.883
Per Cent Seed Canned	.900	.937	.883	--	--	--
Organoleptic Maturity	-.790	-.800	-.818	-.647	-.810	-.841
Fiber Pressure Test	.747	.750	.698	.734	.774	.710
FDA Fiber Method	.814	.638	.848	.869	.678	.836
Blendor Fiber Method	.863	.750	.781	.837	.773	.768
Organoleptic Fiber	-.791	-.706	-.824	-.748	-.797	-.821
Organoleptic Overall Grade	--	-.537	-.700	--	-.535	-.694

Table 20. The Relationship Expressed as Correlation Coefficients, Between Methods of Determining Fiber and Other Objective and Organoleptic Tests of Maturity for Snap Beans.

	Fiber Pressure Tester			F.D.A. Fiber			Blendor Fiber		
	1948	1949	1950	1948	1949	1950	1948	1949	1950
Per Cent Seed Raw	.747	.750	.698	.814	.638	.848	.863	.750	.781
Per Cent Seed Canned	.734	.774	.710	.869	.678	.836	.837	.773	.768
Organoleptic Maturity	-.761	-.664	-.762	-.620	-.568	-.705	-.933	-.565	-.648
Fiber Pressure Tester	--	--	--	.682	.718	.643	.396	.747	.524
F.D.A. Fiber Method	.682	.718	.643	--	--	--	.903	.911	.757
Blendor Fiber Method	.396	.747	.524	.903	.911	.757	--	--	--
Organoleptic Fiber	-.761	-.736	-.754	-.734	-.707	-.551	-.708	-.806	-.548
Organoleptic Overall Grade	--	.631	-.470	--	-.477	-.532	--	-.542	-.517

Color. The data presented in Table 21 shows that color, whether determined by objective methods or measured organoleptically, is not highly correlated with other objective tests or organoleptic grades for maturity. The high correlation between the green pigment determinations made on the raw beans and the organoleptic color grades indicates that the judges based their grades almost entirely on the presence of the green and not the yellow pigment.

Moisture and Ascorbic Acid. The loss of moisture as the beans matured was found to be fairly well correlated with seed and fiber development. The increase in ascorbic acid was not too well correlated with the increase in maturity as measured by other objective and organoleptic tests. Both methods involve time, and laboratory facilities as well as a trained technician.

Of the methods tested in the course of this experiment the determination of per cent seed in the field is the best method for determining maturity. The blendor fiber method was found to be the most rapid and accurate method of determining fiber of canned beans. Combining per cent seed and fiber determinations, a multiple correlation coefficient (R) .94 was obtained, indicating that the two methods together give the most accurate evaluation of maturity in snap beans.

Weighting of Grades and Standards. The method of assigning weights to factors considered in grades and standards has been one of trial and error. The data obtained during the course of this experiment lent itself to a study of this problem. Kramer (27) has proposed a mathematical method of weighting these values. The data used for this method are presented in Table 22.

Table 21. The Relationship of Color Determinations to Other Objective Tests Expressed as Correlation Coefficients.

	Green Pigment Raw	Yellow Pigment Raw	Green Pigment Canned	Yellow Pigment Canned	Moisture Per Cent	Ascorbic Acid
Per Cent Seed Raw	-.190	-.077	-.157	-.169	-.555	.594
Per Cent Seed Canned	.090	.092	-.123	-.133	-.881	.623
Organoleptic Maturity	.134	.212	.239	.234	.754	-.391
Fiber Pressure Tester	.234	.312	.001	-.056	.419	-.770
F.D.A. Fiber Method	.186	.168	.121	.078	-.842	.491
Blendor Fiber Method	.076	.129	-.019	-.026	-.820	.207
Organoleptic Fiber	.121	.176	.133	.157	.686	-.308
Green Pigment Raw	—	.974	.846	.650	.009	.127
Yellow Pigment Raw	.974	—	.886	.974	.009	.150
Green Pigment Canned	.846	.886	—	.805	.003	.334
Yellow Pigment Canned	.650	.974	.805	—	.027	.285
Organoleptic Color	.936	.658	.670	.583	.330	.016
Moisture Per Cent	.009	.009	.003	.027	—	.607
Ascorbic Acid mg./100gms.	.127	.150	.334	.285	-.607	—

The method involves a multiple correlation procedure where grades for each factor involved are correlated with an over-all grade. The influence of each quality factor is thus established mathematically.

The standards for canning quality set up by the U.S.D.A. (58) are as follows: clearness of liquor, 10 points; color, 15 points; absence of defects, 35 points; and maturity, 40 points. It was not possible to compare the U.S.D.A. grades with those used in this experiment since the factors selected were concerned primarily with maturity, eliminating the effect of defects and clearness of liquor.

Table 22. Correlated Coefficients of Organoleptic Grades.

	1949	1950	1949 & 1950 Combined
Maturity X Fiber	.720	.881	.739
Maturity X Flavor	-.274	-.291	-.280
Maturity X Color	.512	.442	.442
Maturity X Overall	.668	.693	.677
Fiber X Flavor	-.057	.101	-.029
Fiber X Color	.462	.508	.396
Fiber X Overall	.832	.772	.772
Flavor X Color	.176	-.128	.082
Flavor X Overall	.265	.214	.296
Color X Overall	.668	.712	.620
Altogether X Overall	.919	.943	.927

Of the factors under study the results in 1949 indicated that fiber contributed 50 per cent, flavor 15 per cent, color 25 per cent and maturity 10 per cent, toward the over-all grade. It must be noted that the varieties involved show tremendous differences in fiber content. Hence the importance of fiber. A similar analysis of the 1950 data indicated that fiber contributed only 20 per cent of the grade, flavor 20 per cent color 20 per cent, and maturity 40 per cent. These results were obtained with 3 varieties all of which were potentially low in fiber content. By combining the data for 1949 and 1950 fiber was found to contribute 25 per cent, flavor 30 per cent, color 15 per cent, and maturity 30 per cent.

SUMMARY AND CONCLUSIONS

Field studies were made on factors affecting quality in snap beans. These studies included seven varieties which were grown over a three-year period. The factors under consideration were growth and maturation, relationship of yield to quality, the effect of application of certain growth regulators on rate of maturation and quality, the effect of duration and temperature of storage on quality and a study of objective and organoleptic tests of quality. The results may be summarized as follows:

1. As snap beans mature the per cent seed was found to increase from 4 to 24 per cent seed in a period of two to three weeks for most varieties. The fiber content also increased as the beans matured. There was a pronounced varietal difference in fiber content. Bountiful and Black Valentine developed fiber at a much faster rate, and to a much greater extent than did Tendergreen, Ranger, and Topcrop.

2. As the beans matured their moisture content decreased from 90.7 per cent at the 4 per cent seed stage to 82.7 per cent at the 24 per cent seed stage. Ascorbic acid increased from 11.1 to 22.2 mg./100 gms. of fresh material for the same maturity range. Color, flavor, and over-all grade were found to decrease as the beans matured.

3. Seasonal differences were found in the number of days required to reach maturity, the summer crop maturing most rapidly.

4. The number of degree hours necessary to bring snap beans to the eight per cent stage of maturity in 1949 was 29,333 and in 1950 was 24,470

indicating that the use of temperature summations for setting planting dates and for predicting harvesting dates may not be as practical for snap beans as for other crops.

5. A study of the relationship of yield to quality showed that as the harvests were delayed the yield increased at the expense of quality. Harvesting two or three times, when the beans have matured to the 8 or 12 per cent seed stage of maturity appears to be a reasonable compromise where quality would be maintained and yields would also be high.

6. Application of para-chlorophenoxyacetic acid to snap beans at concentrations of .1 to .9 per cent for the purpose of retarding maturation had the following results: The development of the seed and fiber was retarded as measured by objective tests. In effect maturation was slowed down without a reduction in yield. However, this was offset by a reduction in the quality as measured by organoleptic tests for color, flavor, and over-all grade and shape of pod. Application of maleic hydrazide at concentrations of .04 to 1.0 per cent retarded seed and pod development when applied at full bloom and early pod stage. However, large reductions in yield as well as quality as measured organoleptically accompanied this retardation.

7. There was no change in the seed or fiber content of snap beans that were stored up to 10 days at 35°, 50°, and 70° F when the beans were measured by Food and Drug Administration Method. However, increases in fiber were noted when the beans were measured by the blendor method and organoleptically graded. There was no change in per cent moisture although there was in some cases more than a 30 per cent loss in weight. The

ascorbic acid content (mg./100 gms. of fresh material) decreased by 50 per cent in a 10-day storage period. All organoleptic grades showed poorer quality for those beans stored than for the checks.

8. Off all the methods tested for determining quality in snap beans the determination of per cent seed appears to be the most useful for determining the quality of beans before processing or for the fresh market. The more rapid blendor method of determining fiber appears to be equal in accuracy to the alkali digestion method proposed by the Food and Drug Administration. A test combining per cent seed and blendor fiber determinations is an excellent indicator of snap bean quality.

9. A multiple correlation analysis (R^2 .86) indicated that the weights to be assigned to the quality factors studied should be; maturity 30 per cent, fiber 25 per cent, flavor 30 per cent, and color 15 per cent.

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Appendix Table 1. The Interaction of Time of Harvest and Variety of Snap Beans (1948).

Variety	Harvest	Per Cent Seed Raw	Per Cent Seed Canned	Organ. Maturity	Fiber Pressure Tester (lbs.)	F.D.A. Fiber mg./100gms.	Fiber	Green Raw	Yellow Raw	Organ. Color	Moisture	Ascorbic Acid
Tendergreen	1	4.3	4.3	8.2	6.9	19	9.3	190	13.7	8.4	90.3	11.3
	2	9.4	10.3	6.9	8.7	39	8.7	147	12.0	7.9	89.1	13.0
	3	14.3	15.1	5.4	9.7	91	7.9	168	12.1	7.4	87.1	15.6
	4	29.1	27.3	4.4	11.0	226	6.3	137	10.0	5.7	81.7	22.2
Pencil Pod Wax	1	3.1	3.6	7.9	5.9	20	9.3	37	4.9	6.7	91.0	10.8
	2	7.8	6.5	6.5	8.0	19	8.6	33	2.7	5.0	89.7	11.4
	3	12.0	11.7	5.7	8.0	34	7.5	39	2.9	4.3	89.5	13.3
	4	27.0	22.8	4.6	9.3	77	6.9	33	2.8	3.8	83.9	20.3
L.S.D. 5% level		1.5	2.1	.5	.5	23	.5	18	.8	.5	.9	1.9
F value		.37	2.55*	1.73	2.90*	24.50**	3.14*	10.42**	9.34**	.76	5.62**	3.36*

* Significant 5% level
**Significant 1% level

Appendix Table 2. The Interaction of Time of Harvest and Duration of Storage of Snap Beans (1948).

Harvest	Storage (days)	Per Cent Seed Raw	Per Cent Seed Canned	Organ. Maturity	Fiber Pressure Tester (lbs.)	F.D.A. Fiber mg./100 gms.	Fiber	Green Raw	Yellow Raw	Organ. Color	Mois-ture	Ascorbic Acid
Harvest 1	0	4.1	3.3	8.5	6.6	23	9.4	108	8.8	8.9	90.4	18.2
	1	3.7	3.3	7.9	6.1	21	9.1	114	8.7	7.3	90.4	12.3
	4	3.8	4.1	7.9	6.4	15	9.3	109	8.8	7.5	90.3	7.2
	7	3.4	3.8	7.7	6.4	18	9.2	139	8.7	7.1	90.2	7.8
	10	3.6	5.1	8.0	6.3	22	9.3	96	8.9	6.8	91.9	10.0
Harvest 2	0	8.6	6.6	6.9	8.9	27	9.1	95	8.3	7.2	88.7	18.6
	1	6.7	6.7	7.2	8.3	22	9.1	106	7.4	7.3	89.3	16.6
	4	8.6	8.7	6.8	7.8	24	8.6	84	7.6	7.2	91.5	11.7
	7	8.3	9.7	6.5	8.4	34	8.4	72	6.8	5.1	89.4	9.0
	10	10.7	10.1	6.3	8.0	38	8.0	89	6.6	5.2	88.8	7.4
Harvest 3	0	11.9	10.9	4.9	8.4	52	7.9	122	8.3	6.2	87.8	21.9
	1	13.6	12.4	5.9	8.1	48	8.0	113	8.0	6.7	89.2	18.4
	4	12.1	13.5	6.0	8.9	60	8.2	87	7.9	5.5	88.3	15.4
	7	14.5	15.7	6.0	9.0	91	7.7	91	6.8	5.3	88.2	11.1
	10	13.4	14.2	4.7	9.5	59	6.7	104	6.4	5.4	88.2	12.1
Harvest 4	0	28.1	28.7	5.5	8.3	174	7.5	87	7.7	5.7	83.1	29.6
	1	27.1	26.3	5.0	10.0	178	7.0	81	7.0	4.8	82.7	29.5
	4	30.8	24.2	4.3	10.8	146	6.3	93	5.3	4.3	82.6	20.9
	7	30.4	22.9	4.1	10.9	159	6.4	90	6.5	4.3	82.9	16.3
	10	24.5	22.9	3.5	10.8	146	5.7	72	5.2	4.2	81.9	14.6
L.S.D. 5% level		2.4	3.3	.7	.7	36	.7	21	1.2	.7	1.4	3.0
F value		3.95**	3.01**	3.40**	6.66**	.92	2.16*	3.31**	1.90	3.0**	2.11	4.59**

* Significant 5% level
**Significant 1% level

Appendix Table 3. The Interaction of the Duration of Storage and the Variety of Snap Beans (1948).

Variety	Storage (days)	Per Cent Seed Raw	Per Cent Seed Canned	Organ. Maturity	Fiber Pressure Tester (lbs.)	F.D.A. Fiber mg./100gms.	Fiber	Green Raw	Yellow Raw	Organ. Color	Moisture	Ascorbic Acid
Tendergreen	0	13.7	13.7	6.4	9.1	85	8.6	167	12.7	7.9	86.9	22.1
	1	13.7	13.9	6.5	8.8	98	8.3	168	12.6	7.6	86.9	21.5
	4	14.9	13.7	6.4	9.1	85	8.0	156	11.9	7.3	86.6	14.2
	7	15.6	15.6	6.2	9.2	136	8.0	163	11.3	6.9	87.0	13.1
	10	13.9	14.2	5.7	9.2	89	7.5	141	11.3	7.0	87.1	13.0
Pencil Pod Wax	0	12.7	11.1	6.5	7.1	54	8.4	38	3.8	6.1	88.0	21.8
	1	11.9	10.5	6.5	7.6	37	8.4	33	3.0	5.5	88.9	16.9
	4	12.8	11.6	6.2	8.0	38	8.2	30	3.0	5.1	89.2	12.9
	7	12.7	10.5	6.0	8.2	38	7.8	33	3.1	4.4	88.1	9.4
	10	12.2	12.0	5.6	8.2	45	7.4	40	2.3	3.9	88.0	9.2
L.S.D. 5% level		1.6	2.2	.5	.5	25	.5	15.1	.8	.5	1.0	2.1
F value		3.95**	3.01**	3.40**	6.66**	.92	2.16*	3.31**	1.90	3.0**	2.11	4.59**

* Significant 5% level
**Significant 1% level

Appendix Table 4. The Interaction of the Temperature of Storage and the Variety of Snap Beans (1948).

Variety	Temp. of Storage	Per Cent Seed Raw	Per Cent Seed Canned	Organ. Maturity	Fiber Pressure Tester (lbs.)	F.D.A. Fiber mg./100gms.	Organ. Fiber	Green Raw	Yellow Raw	Organ. Color	Mois-ture	Ascorbic Acid
Tendergreen	35°F.	13.6	13.0	6.3	8.9	84	8.3	171	12.6	7.8	86.9	16.8
	50°F.	15.0	14.9	6.2	9.0	99	8.0	158	11.6	7.3	86.9	12.7
	70°F.	14.4	14.7	6.0	9.2	97	7.8	153	11.5	6.7	87.2	16.1
Pencil Pod Wax	35°F.	12.1	10.6	6.3	7.7	34	8.0	37	3.4	5.2	88.6	14.6
	50°F.	12.7	11.5	6.0	7.7	49	8.1	33	2.9	5.0	88.4	14.1
	70°F.	12.5	11.1	6.1	7.7	43	8.1	34	2.8	4.4	88.5	13.4
L.S.D. 5% level		1.2	1.8	.4	.4	20	.4	12	.6	4	.7	1.6
F value		.52	.52	149	.14	.07	1.19	1.62	1.41	.62	.01	.66

Appendix Table 5. The Interaction of Time of Harvest and Temperature of Storage of Snap Beans (1948).

Temp. of Storage	Harvest Times	Per Cent Seed Raw	Per Cent Seed Canned	Organ. Maturity	Fiber Pressure Tester (lbs.)	F.D.A. Fiber mg./100gms.	Fiber	Green Raw	Yellow Raw	Organ. Color	Mois- ture	Ascorbic Acid
35°F.	1	3.7	4.0	8.3	6.3	17	9.4	12.1	9.6	8.0	90.6	12.0
	2	7.7	7.4	6.7	8.3	21	8.7	9.4	7.7	6.7	89.6	12.5
	3	12.8	11.7	5.7	8.8	44	8.1	11.0	8.1	6.2	88.4	16.1
	4	27.2	24.5	4.7	10.1	156	6.7	9.1	6.9	5.4	82.9	22.6
50°F.	1	3.6	3.7	8.2	6.3	21	9.4	11.2	8.5	7.6	90.8	10.6
	2	9.1	8.8	6.7	8.3	29	8.6	8.6	7.1	6.5	89.4	13.5
	3	13.3	13.8	5.4	8.8	74	7.4	10.5	7.5	5.8	88.8	16.2
	4	29.7	26.9	4.5	10.3	175	6.8	8.1	6.2	4.9	81.9	23.4
70°F.	1	3.9	3.9	7.7	6.7	22	9.1	10.8	8.5	7.1	90.7	10.7
	2	9.1	9.0	6.9	8.5	37	8.7	8.9	7.3	6.2	89.3	13.2
	3	13.4	14.9	5.5	9.1	70	7.7	9.6	7.0	5.6	87.9	14.5
	4	27.7	23.8	4.3	10.1	153	6.4	8.4	6.0	4.0	83.4	20.7
L.S.D. 5% level		1.8	2.5	.5	.5	28	.5	16	9.0	.6	1.0	2.3
F value		1.11	2.13	.82	.57	.67	.83	.29	.53	.76	.54	1.06

Appendix Table 6. The Interaction of Duration and Temperature of Storage of Snap Beans (1948).

Storage Duration	Storage Temp.	Per Cent Seed Raw	Per Cent Seed Canned	Organ. Maturity	Fiber Pressure Tester (lbs.)	F.D.A. Fiber mg./100gms.	Fiber	Green Raw	Yellow Raw	Organ. Color	Mois-ture	Ascorbic Acid
At Harvest	35°F.	13.2	12.4	6.4	8.0	69	8.5	103	8.3	7.0	87.5	22.0
	50°F.	13.2	12.4	6.4	8.0	69	8.5	103	8.3	7.0	87.5	22.0
	70°F.	13.2	12.4	6.4	8.0	69	8.5	103	8.3	7.0	87.5	22.0
1 day	35°F.	13.5	11.2	6.7	8.1	65	8.4	106	8.0	6.4	87.8	22.3
	50°F.	13.1	13.8	6.3	8.0	79	8.2	104	7.7	6.5	87.9	18.7
	70°F.	11.7	11.5	6.5	8.2	58	8.4	101	7.7	6.6	88.0	16.6
4 days	35°F.	13.8	12.1	6.3	8.2	54	8.0	93	7.5	6.7	88.0	13.8
	50°F.	13.8	12.9	6.3	8.5	67	7.9	84	7.7	6.5	87.4	14.9
	70°F.	13.9	12.9	6.2	8.7	62	8.1	82	6.9	6.5	87.9	12.7
7 days	35°F.	12.5	11.7	6.4	8.6	59	8.4	108	7.9	6.1	87.5	10.6
	50°F.	14.7	13.6	6.1	8.7	81	7.9	96	6.9	5.6	87.4	11.9
	70°F.	15.3	13.8	5.7	8.7	85	7.5	81	6.7	4.8	88.0	11.2
10 days	35°F.	11.2	11.6	5.8	8.5	47	7.6	109	8.3	6.3	88.1	9.9
	50°F.	14.7	13.5	5.6	8.5	77	7.5	80	5.9	5.2	87.5	12.0
	70°F.	13.1	14.0	5.6	8.9	75	7.1	82	6.1	4.8	87.3	11.2
L.S.D. 5% level		2.1	2.8	.6	.6	31	.6	19	1.0	6.0	1.2	2.6
F value		2.25	.54	.56	.33	.63	1.14	.85	2.66*	.72	.64	2.75*

* Significant 5% level

Appendix Table 7. The Interaction of Time of Harvest and Variety of Snap Beans (1949).

Variety	Harvest	Per Cent Seed Raw	Per Cent Seed Canned	Organo-leptic Maturity	F.D.A. Fiber	Blendor Fiber	Fiber Pressure Tester	Organoleptic Fiber	Organoleptic Flavor	Organoleptic Color	Over-all Grade
Bountiful	1	5.1	5.3	6.8	24	19	6.2	6.9	5.5	5.9	5.4
	2	7.7	7.5	5.9	36	33	6.6	6.5	5.5	5.5	5.2
	3	12.6	13.9	4.8	120	105	8.4	5.4	6.4	5.6	5.0
	4	16.7	17.3	3.9	214	223	9.7	4.1	6.7	5.4	4.4
	5	23.6	25.6	2.9	419	486	10.9	3.3	6.4	5.2	4.1
Tendergreen	1	4.1	4.4	7.9	11	6	6.4	8.9	6.9	8.5	7.7
	2	7.8	7.5	6.5	29	19	7.2	8.3	7.1	8.0	7.0
	3	11.1	11.1	5.6	46	38	8.1	7.6	7.1	7.6	6.7
	4	15.4	14.7	4.3	68	80	8.6	6.6	7.3	7.2	6.0
	5	25.1	23.9	3.1	167	246	8.6	5.3	7.3	6.1	5.2
Black Valentine	1	4.7	4.3	7.9	68	28	6.4	7.7	5.7	7.4	6.1
	2	7.6	8.2	6.3	191	100	7.7	6.0	6.1	6.7	5.5
	3	13.2	13.9	5.7	373	328	9.4	4.9	6.5	6.9	5.3
	4	18.0	17.1	4.5	565	488	10.6	4.4	6.6	7.2	4.8
	5	25.5	25.9	4.0	768	677	10.6	3.2	7.0	7.1	4.5
L.S.D. 5% level		2.1	1.8	.6	76	62	1.6	.7	.5	.6	.6
F value		1.18	1.32	1.73	18.66**	19.23**	11.78**	1.82	1.76	5.62**	1.28

**Significant 1% level

Appendix Table 8. The Interaction of Season and Variety of Snap Beans (1949).

Variety	Crop	Per Cent Seed Raw	Per Cent Seed Canned	Organo-leptic Maturity	F.D.A. Fiber	Blendor Fiber	Fiber Pressure Tester	Organoleptic Fiber	Organoleptic Flavor	Organoleptic Color	Overall Grade
Bountiful											
	Spring	12.5	12.8	5.0	143	156	7.8	5.4	6.1	5.8	4.9
	Summer	13.6	14.7	4.6	204	229	8.4	4.8	6.0	5.1	4.6
	Fall	13.3	14.2	5.0	141	135	8.9	5.6	6.1	5.6	4.9
Tendergreen											
	Spring	11.6	11.6	5.4	53	44	7.8	7.3	7.2	7.6	6.5
	Summer	12.8	11.9	5.6	77	96	8.4	7.3	7.4	6.9	6.7
	Fall	13.7	13.4	5.5	62	93	7.2	7.3	6.6	7.8	6.3
Black Valentine											
	Spring	12.7	12.2	5.8	325	333	8.3	5.4	6.4	7.3	5.4
	Summer	13.7	14.5	5.5	533	394	9.9	4.7	6.3	6.4	4.9
	Fall	15.0	14.9	5.8	322	346	8.6	5.7	6.3	7.2	5.4
L.S.D. 5% level		1.6	1.4	.5	58	48	.4	.5	.4	.4	.5
F value		.69	1.68	.92	7.75**	6.26**	17.29**	1.94	2.8*	5.66**	1.86

* Significant 5% level
**Significant 1% level

Appendix Table 9. The Interaction of Time of Harvest and Season (1949).

Crop	Harvest	Per Cent Seed Raw	Per Cent Seed Canned	Organo-leptic Maturity	F.D.A. Fiber	Blendor Fiber	Fiber Pressure Tester	Organoleptic Fiber	Organoleptic Flavor	Organoleptic Color	Overall Grade
Spring	1	4.8	4.9	7.6	47	21	6.6	7.8	6.1	7.6	6.5
	2	7.2	7.2	6.3	56	47	6.9	7.1	6.3	7.0	6.2
	3	12.0	11.9	5.4	178	183	8.1	5.9	6.9	6.7	5.8
	4	16.2	15.3	4.2	206	222	9.0	5.1	6.9	7.0	4.9
	5	21.3	20.7	3.7	379	418	9.5	4.4	6.9	6.4	4.8
Summer	1	4.6	4.5	7.3	31	18	7.0	7.7	6.4	6.7	6.4
	2	8.3	7.9	6.0	127	69	8.0	6.4	6.5	6.4	5.7
	3	12.2	13.8	5.5	252	207	8.9	6.0	6.9	6.6	5.7
	4	16.8	16.7	4.2	400	376	10.2	4.6	6.8	5.9	4.8
	5	25.3	25.7	3.4	549	527	10.4	3.6	6.5	5.3	4.5
Fall	1	4.6	4.6	7.8	26	13	5.6	8.1	5.6	7.4	6.4
	2	7.8	8.1	6.6	56	38	6.8	7.6	5.9	6.8	6.0
	3	12.9	13.3	5.4	110	83	8.8	6.2	6.3	6.8	5.6
	4	17.1	17.2	4.4	241	192	9.9	5.5	7.0	6.9	5.5
	5	26.9	27.6	3.1	426	467	10.3	3.8	7.3	6.6	4.6
L.S.D. 5% level		2.1	1.8	.6	76	62	1.6	.7	.5	.6	.6
F value		3.26**	3.18**	1.35	3.21**	4.42**	6.24**	1.34	2.88**	1.54	1.06

**Significant 1% level

Appendix Table 10. The Interaction of Time of Harvest and Variety of Snap Beans (1950).

Variety	Harvest	Per Cent Seed Raw	Per Cent Seed Canned	Organoleptic Maturity	F.D.A. Fiber	Blendor Fiber	Fiber Pressure Tester	Organoleptic Fiber	Organoleptic Flavor	Organoleptic Color	Overall Grade
Tendergreen	1	4.5	4.3	7.7	8	3	4.6	8.9	6.0	6.6	6.6
	2	8.2	8.2	6.6	17	6	5.9	8.3	6.8	6.2	6.7
	3	12.0	12.6	4.8	27	19	6.3	6.9	6.5	6.0	5.8
	4	15.8	16.4	4.1	59	21	7.0	6.0	6.5	5.9	5.7
	5	24.0	22.8	3.1	115	209	7.5	5.3	6.5	5.4	4.5
Topcrop	1	3.8	4.0	7.5	8	3	4.5	9.1	6.1	6.8	6.8
	2	8.4	8.0	6.2	12	9	5.8	7.9	7.0	6.0	6.0
	3	12.2	13.8	4.4	32	23	6.1	6.5	6.5	6.2	5.8
	4	17.4	17.7	4.1	58	38	6.9	5.6	6.5	5.9	4.8
	5	26.8	21.8	2.7	121	176	7.2	5.2	6.1	5.0	4.4
Ranger	1	3.8	3.6	7.9	12	4	4.4	9.0	5.5	6.2	6.1
	2	7.9	8.2	6.4	13	14	5.3	8.2	6.6	5.5	5.7
	3	11.2	11.1	6.1	32	34	5.5	7.5	6.1	5.1	5.4
	4	15.2	15.8	5.8	64	36	5.5	7.1	6.1	4.7	5.1
	5	21.6	23.6	3.6	117	182	6.0	5.9	6.1	3.9	4.3
L.S.D. 5% level		3.0	2.7	.9	6	39	.5	.8	.9	.8	.7
F value		2.18*	1.66	3.73**	133	1.58	5.24**	3.0**	.40	1.5	2.37*

* Significant 5% level
**Significant 1% level

Appendix Table 11. The Interaction of Season and Variety of Snap Beans (1950).

Variety	Season	Per Cent Seed Raw	Per Cent Seed Canned	Organo-leptic Maturity	F.D.A. Fiber	Blendor Fiber	Fiber Pressure Tester	Organoleptic Fiber	Organoleptic Flavor	Organoleptic Color	Overall Grade
Tendergreen											
	Spring	13.9	12.8	5.1	43	65	6.2	7.0	6.0	5.7	5.4
	Summer	13.5	13.6	4.9	45	43	6.7	6.8	6.9	5.9	5.7
	Fall	11.2	11.6	5.7	40	46	5.9	7.4	6.5	6.5	6.4
Topcrop											
	Spring	14.1	14.4	4.7	46	49	5.2	6.5	6.1	6.0	5.4
	Summer	14.8	13.9	5.0	43	56	6.5	6.7	6.6	5.9	5.7
	Fall	12.3	12.6	5.1	39	44	5.8	7.3	6.5	6.3	6.0
Ranger											
	Spring	12.2	11.8	6.1	47	51	5.2	7.8	5.8	5.0	5.2
	Summer	11.9	13.2	5.9	56	64	5.7	7.6	6.3	5.2	5.5
	Fall	11.7	12.4	5.9	50	47	5.3	7.3	6.1	5.1	5.3
L.S.D. 5% level		2.3	2.1	.7	14	48	.6	.6	.7	.6	.5
F value		1.56	1.50	.63	1.41	1.52	.81	3.10**	.27	1.70	2.42*

* Significant 5% level
**Significant 1% level

Appendix Table 12. The Interaction of Season and Time of Harvest (1950).

Season	Harvest	Per Cent Seed Raw	Per Cent Seed Canned	Organo-leptic Maturity	F.D.A. Fiber	Blendor Fiber	Fiber Pressure Tester	Organoleptic Fiber	Organoleptic Flavor	Organoleptic Color	Overall Grade
Spring	1	4.4	4.3	7.9	7	3	4.4	8.9	5.8	6.4	6.4
	2	8.2	8.3	6.4	9	7	5.8	8.1	6.5	6.0	5.9
	3	12.6	12.9	4.7	21	23	5.8	7.0	6.0	5.7	5.4
	4	16.6	16.8	4.6	61	26	6.5	6.4	6.1	5.7	5.2
	5	25.2	22.9	2.8	113	216	6.5	5.0	5.7	4.0	3.7
Summer	1	4.0	3.9	7.1	7	4	5.0	8.9	6.0	6.3	6.3
	2	8.9	8.2	6.2	11	11	5.8	8.2	7.2	6.1	6.6
	3	11.3	12.8	5.1	43	28	6.4	6.6	6.6	5.5	5.5
	4	16.2	16.9	4.6	74	25	6.6	5.9	6.3	5.4	5.0
	5	26.7	26.2	3.4	142	205	7.6	5.7	6.8	5.2	4.8
Fall	1	3.7	3.7	8.1	14	4	4.1	9.1	5.8	7.0	6.8
	2	7.4	8.0	6.4	22	11	5.2	8.1	6.6	6.2	6.4
	3	11.4	11.8	5.5	28	25	5.7	7.4	6.5	6.2	6.1
	4	15.6	16.3	4.8	46	43	6.6	6.4	6.7	5.5	5.4
	5	20.5	21.1	3.0	98	146	6.6	5.7	6.2	5.0	4.7
L.S.D. 5% level		3.0	2.7	.9	6	39	.5	.8	.9	.8	.7
F value		3.64**	2.49*	2.23*	5.92**	3.63**	4.70**	3.13**	1.29	3.09**	2.42*

* Significant 5% level
**Significant 1% level

Appendix Table 13. The Interaction of Variety and Delay of Harvest After Application of Para-chlorophenoxy-acetic Acid to Snap Beans (1949).

Variety	Days After Application	Per Cent Seed Raw	Per Cent Seed Canned	Organoleptic Maturity	F.D.A. Fiber	Blendor Fiber	Fiber Pressure Tester	Fiber	Flavor	Color	Over-all Grade	Yield lbs./30' row
Black Valentine												
	4	4.1	5.0	7.8	176	136	8.1	7.3	5.6	7.1	5.8	6.6
	7	6.2	8.5	5.6	384	284	8.0	5.7	6.0	5.9	5.1	10.1
	10	9.6	9.3	4.8	492	346	9.4	4.3	6.3	5.4	4.7	11.6
Bountiful												
	4	6.7	7.2	5.8	21	38	5.6	6.5	5.7	5.5	5.1	7.4
	7	11.5	13.1	3.9	199	141	9.0	3.9	6.0	4.3	3.8	10.1
	10	19.5	17.9	3.3	448	446	10.2	3.1	6.4	3.8	3.5	12.3
Tendergreen												
	4	8.3	7.6	6.4	82	32	8.2	7.3	7.3	7.1	6.5	7.0
	7	12.6	10.0	5.0	126	90	8.3	7.0	6.6	6.0	6.9	8.9
	10	15.3	13.5	4.7	123	140	9.9	6.0	7.2	4.8	5.1	11.2
L.S.D. 5% level		2.8	2.5	.7	58	73	.7	.9	.6	.6	.6	2.5
F value		4.80**	4.02**	.52	29.82**	11.83**	18.76**	3.91**	1.61	.98	.52	1.24

**Significant 1% level

Appendix Table 14. The Interaction of Time of Application and Concentration of Para-chlorophenoxyacetic Acid Applied to Snap Beans (1949).

Days After Application	Per Cent Concentration	Per Cent Seed Raw	Per Cent Seed Canned	Organoleptic Maturity	F.D.A. Fiber	Blendor Fiber	Fiber Pressure Tester	Organoleptic Fiber	Organoleptic Flavor	Organoleptic Color	Over-all Grade	Yield lbs./30' row
4	0	7.1	7.8	6.3	117	94	7.7	6.3	6.9	6.9	6.1	7.1
	.1	6.0	6.1	6.4	83	65	7.4	7.2	6.0	6.7	5.9	6.0
	.3	5.7	6.4	6.6	64	58	7.4	7.0	6.3	6.4	6.0	7.6
	.9	6.5	6.1	7.1	108	57	7.2	7.4	5.4	6.4	5.4	7.5
7	0	14.1	12.8	4.6	254	229	9.0	5.4	6.6	5.8	5.3	10.9
	.1	9.6	10.1	5.1	195	134	8.0	5.5	6.0	5.3	4.8	10.8
	.3	8.3	9.9	5.3	264	142	8.7	6.2	6.4	5.2	5.2	9.2
	.9	8.4	9.6	4.4	234	183	8.2	5.1	6.0	5.2	4.4	10.6
10	0	18.9	18.4	4.3	481	348	10.1	4.7	6.8	5.4	4.8	12.5
	.1	12.9	13.0	3.8	300	287	10.0	4.3	7.2	4.6	4.6	12.3
	.3	14.2	13.0	3.6	348	343	10.0	4.5	6.3	4.5	4.3	11.4
	.9	12.0	9.9	4.0	290	265	9.3	4.5	5.9	4.2	4.0	11.7
L.S.D. 5% level		3.8	3.8	.9	65	81	.8	1.1	.7	.7	.7	2.1
F value		1.70	2.02	1.98	4.09**	.99	.93	1.39	1.63	.36	.50	.73

**Significant 1% level

Appendix Table 15. The Interaction of Variety and Concentration of Para-chlorophenoxyacetic Acid Applied to Snap Beans (1949).

Variety	Per Cent Concentration	Per Cent Seed Raw	Per Cent Seed Canned	Organoleptic Maturity	F.D.A. Fiber	Blendor Fiber	Fiber Pressure Tester	Organoleptic Fiber	Organoleptic Flavor	Organoleptic Color	Over-all Grade	Yield lbs./30' row
Black Valentine												
	0	13.5	10.8	5.8	457	327	8.9	5.5	6.5	6.5	5.7	10.6
	.1	10.0	6.6	6.1	302	213	8.4	5.9	6.0	6.1	5.1	9.2
	.3	7.7	6.9	6.2	314	253	8.6	6.1	6.2	6.0	5.5	9.0
	.9	7.2	6.2	6.1	336	228	8.3	5.7	5.4	6.0	4.6	9.0
Bountiful												
	0	12.5	14.7	4.8	263	202	8.7	4.5	6.2	5.0	4.5	10.2
	.1	9.2	12.1	4.3	172	204	8.2	4.7	6.6	4.6	4.2	11.2
	.3	9.2	12.8	4.1	250	223	8.4	4.7	6.2	4.5	4.2	10.6
	.9	9.8	11.2	4.1	208	204	7.8	4.1	6.1	4.2	3.7	10.4
Tendergreen												
	0	14.2	13.5	4.8	152	141	9.3	6.5	7.3	6.6	6.0	9.8
	.1	9.3	10.4	4.9	103	69	8.7	6.5	7.2	6.0	6.0	8.8
	.3	10.3	9.6	5.3	114	68	8.7	7.1	6.6	5.5	5.7	9.1
	.9	9.9	8.0	5.3	89	72	8.5	7.2	6.2	5.8	5.4	9.3
L.S.D. 5% level		3.8	3.8	.9	65	81	.8	1.1	.7	.7	.7	2.1
F value		2.08	2.14	1.10	5.21**	.56	.10	.66	.80	.50	.66	.63

**Significant 1% level

Appendix Table 16. The Interaction of Time of Application and Concentration of Para-chlorophenoxyacetic Acid Applied to Snap Beans (1949).

Time of Application	Per Cent Concentration	Per Cent Seed Raw	Per Cent Seed Canned	Organoleptic Maturity	F.D.A. Fiber	Blendor Fiber	Fiber Pressure Tester	Organoleptic Fiber	Organoleptic Flavor	Organoleptic Color	Over-all Grade	Yield lbs./30' row
Early Pod	0	6.6	5.7	7.3	33	14	6.0	7.4	6.4	7.6	6.9	7.9
	.1	5.1	4.4	7.2	45	13	6.1	7.7	5.8	6.4	6.0	8.0
	.3	4.5	4.4	7.0	42	22	5.7	7.6	6.4	6.3	6.3	8.2
	.9	4.3	3.6	7.1	23	9	5.7	7.6	5.9	6.3	6.1	8.9
2% Seed	0	9.0	9.3	6.5	88	34	8.2	6.6	7.0	7.1	6.4	10.3
	.1	7.0	7.3	6.1	87	38	7.6	6.6	6.4	6.4	5.8	11.8
	.3	7.3	7.6	6.6	104	27	7.4	7.3	6.5	6.6	6.2	10.4
	.9	6.9	6.2	5.7	67	36	7.8	6.6	6.5	6.4	5.9	11.5
6% Seed	0	15.6	16.4	5.0	239	170	9.7	5.6	7.4	6.8	6.0	11.8
	.1	13.3	14.8	5.1	227	180	8.9	5.3	7.0	6.9	5.5	12.6
	.3	13.4	13.7	5.1	217	155	9.4	5.6	6.9	7.0	5.8	11.7
	.9	13.6	12.5	5.6	238	148	8.5	5.9	6.7	7.2	5.8	12.4
L.S.D. 5% level		1.8	1.9	.7	50	24	.7	.7	.5	.7	.4	1.6
F value		.17	.52	1.59	.53	1.18	2.06	1.06	.58	2.68*	1.15	.45

*Significant 5% level

Appendix Table 17. The Interaction of Variety and Time of Application of Para-chlorophenoxyacetic Acid to Snap Beans (1949).

Variety	Time of Application	Per Cent Seed Raw	Per Cent Seed Canned	Organoleptic Maturity	F.D.A. Fiber	Blendor Fiber	Fiber Pressure Tester	Organoleptic Fiber	Organoleptic Flavor	Organoleptic Color	Over-all Grade	Yield lbs./30'row
Black Valentine												
	Early Pod	5.6	5.1	7.8	53	29	5.7	7.4	6.0	6.8	6.3	10.8
	2% Seed	7.11	6.9	6.7	185	63	6.7	6.5	6.5	6.6	6.1	12.2
	6% Seed	17.7	19.1	5.4	480	335	10.3	4.3	6.7	7.9	5.4	12.2
Bountiful												
	Early Pod	5.0	4.6	6.1	41	8	5.8	6.4	5.6	5.4	5.3	10.2
	2% Seed	8.2	8.4	5.4	52	27	8.6	5.8	6.0	5.0	4.8	11.0
	6% Seed	14.3	14.5	4.4	169	127	9.5	4.5	6.6	5.2	4.5	11.8
Tendergreen												
	Early Pod	4.7	4.4	7.6	13	6	6.1	8.8	6.9	7.8	7.3	9.4
	2% Seed	7.4	6.8	6.6	23	12	5.8	8.1	7.4	8.3	7.4	9.1
	6% Seed	9.9	9.5	5.8	42	28	7.6	8.0	7.8	7.7	7.4	9.3
L.S.D. 5% level		1.5	1.6	.6	43	21	.6	.6	.5	.6	.4	1.6
F value		16.88**	22.27**	.88	47.5**	115.92**	28.81**	9.34**	.3	6.71**	5.05**	1.63

**Significant 1% level

Appendix Table 18. The Interaction of Variety of Variety and Concentration of Para-chlorophenoxyacetic Acid to Snap Beans (1949).

Variety	Per Cent Concentration	Per Cent Seed Raw	Per Cent Seed Canned	Organoleptic Maturity	F.D.A. Fiber	Blendor Fiber	Fiber Pressure Tester	Organoleptic Fiber	Organoleptic Flavor	Organoleptic Color	Over-all Grade	Yield lbs./30'row
Black Valentine												
	0	10.3	10.8	6.5	243	149	7.5	5.7	7.0	7.7	6.3	10.4
	.1	10.2	10.9	6.6	246	148	7.9	6.5	5.9	6.9	5.7	12.2
	.3	10.0	10.7	6.8	227	146	7.4	6.3	6.5	6.8	6.2	12.2
	.9	10.0	9.0	6.6	240	127	7.5	5.9	6.1	6.9	5.7	12.3
Bountiful												
	0	11.6	10.9	5.6	87	50	8.7	5.5	6.1	5.5	5.3	10.2
	.1	8.1	8.9	5.1	88	67	7.6	5.3	6.0	4.9	4.5	11.0
	.3	8.4	8.6	5.1	107	49	8.0	5.8	6.1	5.3	4.7	9.7
	.9	8.6	7.6	5.4	68	48	7.6	5.8	6.0	5.2	5.0	11.8
Tendergreen												
	0	9.3	9.7	6.8	31	18	7.6	8.5	7.8	8.2	7.7	9.4
	.1	7.1	6.8	6.6	25	16	7.1	8.0	7.3	7.8	7.2	9.1
	.3	6.8	5.4	6.8	29	10	7.1	8.4	7.3	7.8	7.4	8.3
	.9	6.2	5.6	6.4	20	18	6.9	8.4	7.1	7.9	7.1	8.5
L.S.D. 5% level		1.8	1.9	.7	50	24	.7	.7	.5	.7	.4	1.6
F value		1.84	1.83	.79	.41	.79	1.83	2.08	3.2**	.41	1.36	1.63

**Significant 1% level

Appendix Table 19. The Interaction of Variety and Concentration of Maleic Hydrazide Applied to Snap Beans (Spring 1950).

Variety	Per Cent Concen- trations	Per Cent Seed Raw	Organo- leptic Maturity	Blendor Fiber	Fiber Pressure Tester	Organoleptic Fiber	Organoleptic Flavor	Organoleptic Color	Overall Grade	Yield lbs./15' row
Tendergreen	Check	16.0	4.7	33	5.6	6.1	4.9	5.2	4.8	4.8
	.04	17.1	4.5	71	6.0	5.9	5.2	5.3	4.9	4.8
	.2	11.8	4.4	77	6.0	5.0	4.4	4.9	4.2	2.3
	1.0	11.0	5.3	70	5.6	3.8	3.5	4.7	3.4	.8
Topcrop	Check	16.8	4.1	55	6.7	6.1	5.8	5.6	5.3	6.7
	.04	16.9	4.2	74	6.6	5.5	5.2	5.3	4.9	6.9
	.2	13.7	4.8	92	6.8	5.0	4.8	5.5	4.5	5.1
	1.0	12.5	5.1	83	6.0	4.1	4.2	5.7	4.5	3.7
Ranger	Check	14.2	5.6	39	4.8	6.5	5.0	5.2	5.4	6.8
	.04	11.4	5.7	25	5.4	6.2	4.6	5.3	5.1	3.6
	.2	10.7	5.7	22	5.0	5.7	4.6	5.0	4.8	4.5
	1.0	8.9	6.0	34	4.8	4.9	3.7	5.0	4.3	2.1
L.S.D. 5% level		4.9	1.0	43	.6	1.1	1.0	1.1	.9	2.1
F value		.73	.92	1.83	1.72	.42	1.32	.54	.73	.90

Appendix Table 20. The Interaction of Variety and Time of Application of Maleic Hydrazide Applied to Snap Beans (Spring 1950).

Variety	Time of Application	Per Cent Seed Raw	Organoleptic Maturity	Blendor Fiber	Fiber Pressure Tester	Organoleptic Fiber	Organoleptic Flavor	Organoleptic Color	Overall Grade	Yield lbs./15' row
Tendergreen										
	Full Bloom	13.0	4.9	33	5.4	5.2	4.3	5.0	4.3	2.3
	Early Pod	10.8	4.5	70	5.8	4.7	4.3	4.8	4.0	2.6
	4% Seed	14.2	4.9	72	6.1	5.3	4.6	5.2	4.4	4.1
	8% Seed	17.9	4.6	78	5.8	5.4	5.0	5.2	4.6	3.8
Topcrop	Full Bloom	12.5	5.5	84	6.5	4.6	4.3	5.8	4.2	3.9
	Early Pod	13.4	4.6	82	6.5	5.1	4.9	5.3	4.5	5.6
	4% Seed	16.0	4.1	48	6.4	5.4	5.4	5.4	5.0	6.3
	8% Seed	18.1	4.1	90	6.7	5.7	5.6	5.5	5.1	6.6
Ranger	Full Bloom	9.4	6.4	19	4.9	5.4	3.9	5.1	4.6	4.3
	Early Pod	10.0	5.3	46	5.0	5.4	4.2	5.1	4.5	4.6
	4% Seed	13.2	5.7	25	5.2	5.8	4.2	5.1	5.0	5.4
	8% Seed	12.7	5.7	29	5.1	6.7	5.2	5.1	5.3	5.7
L.S.D. 5% level		6.1	1.1	47	.7	1.1	1.0	1.1	.9	2.1
F value		.83	1.82	2.30*	2.38	.60	.73	.38	.62	.90

* Significant 5% level

Appendix Table 21. The Interaction of Time of Application and Concentration of Maleic Hydrazide Applied to Snap Beans (Spring 1950).

Per Cent Concen-trations	Time of Applica-tion	Per Cent Seed Raw	Organo-leptic Maturity	Blendor Fiber	Fiber Pressure Tester	Organoleptic Fiber	Organoleptic Flavor	Organoleptic Color	Overall Grade	Yield lbs./15' row
Check	Full Bloom	17.0	4.9	41	5.4	6.4	5.3	5.5	5.3	6.3
	Early Pod	15.9	4.6	49	5.8	6.2	5.3	4.9	5.2	5.8
	4% Seed	15.7	5.1	32	5.8	6.1	5.3	5.4	5.2	6.1
	8% Seed	15.8	4.7	49	5.8	6.2	5.3	5.5	5.0	6.1
.04	Full Bloom	15.3	5.2	45	6.0	5.9	4.9	5.6	4.9	5.8
	Early Pod	11.5	4.6	62	6.0	5.6	4.9	5.3	4.7	5.9
	4% Seed	16.5	4.3	51	6.1	5.6	4.7	5.1	4.9	6.6
	8% Seed	17.3	5.0	67	6.0	6.5	5.5	5.1	5.2	6.0
.2	Full Bloom	8.1	6.0	43	5.8	4.8	3.7	4.9	4.2	1.4
	Early Pod	9.1	4.5	64	5.9	4.6	4.3	4.8	4.0	3.8
	4% Seed	14.7	4.9	57	6.2	5.7	5.3	5.6	4.9	5.6
	8% Seed	16.5	4.6	91	5.9	5.8	5.0	5.2	4.9	5.2
1.0	Full Bloom	6.2	6.4	53	5.1	3.2	2.7	5.1	3.1	.4
	Early Pod	9.1	5.5	90	5.4	3.8	3.3	5.2	3.6	1.6
	4% Seed	11.1	5.4	54	5.5	4.6	4.0	4.9	4.1	2.6
	8% Seed	17.0	4.7	54	5.9	5.4	5.3	5.3	5.0	4.2
L.S.D. 5% level		4.7	1.0	43	.6	1.1	1.0	1.1	.9	2.3
F value		3.96**	1.94	.91	.77	2.23*	3.42**	.90	2.83**	5.74**

* Significant 5% level
**Significant 1% level

Appendix Table 22. The Interaction of Variety and Concentration of Maleic Hydrazide Applied to Snap Beans (Summer 1950).

Variety	Per Cent Concen- trations	Per Cent Seed Raw	Organo- leptic Maturity	Blendor Fiber	Fiber Pressure Tester	Organoleptic Fiber	Organoleptic Flavor	Organoleptic Color	Overall Grade	Yield lbs./15' row
Tendergreen	Check	25.9	4.1	209	8.0	4.9	5.3	5.3	4.6	6.7
	.04	23.4	5.1	210	7.9	5.2	5.2	5.6	4.8	6.5
	.2	18.2	4.8	155	8.1	5.0	5.1	5.4	4.6	4.3
	1.0	14.4	5.5	150	7.5	3.9	4.0	5.2	4.1	3.3
Topcrop	Check	27.7	3.8	234	8.4	4.9	5.4	5.2	4.3	8.2
	.04	27.2	3.9	238	8.7	4.5	5.4	5.4	4.5	9.5
	.2	23.7	4.2	206	8.3	4.5	5.1	5.2	4.5	8.0
	1.0	20.2	4.9	247	7.9	3.9	4.3	5.4	3.8	6.3
Ranger	Check	23.8	4.6	118	5.1	5.9	5.4	5.4	5.1	10.1
	.04	19.0	4.8	185	5.3	5.8	5.4	5.0	5.0	11.5
	.2	14.7	4.7	168	5.3	5.3	4.7	5.0	4.6	9.3
	1.0	10.6	5.1	143	5.3	4.4	3.9	5.0	4.0	5.9
L.S.D. 5% level		5.7	.9	39	.8	1.2	.9	1.0	.9	1.9
F value		.61	1.58	8.46**	.46	.84	.39	1.30	.84	1.32

**Significant 1% level

Appendix Table 23. The Interaction of Variety and Time of Application of Maleic Hydrazide to Snap Beans (Summer 1950).

Variety	Time of Application	Per Cent Seed Raw	Organoleptic Maturity	Blendor Fiber	Fiber Pressure Tester	Organoleptic Fiber	Organoleptic Flavor	Organoleptic Color	Overall Grade	Yield lbs./15' row
Tendergreen	Full Bloom	15.9	5.5	133	7.6	4.8	4.5	5.4	4.4	3.8
	Early Pod	17.5	4.9	265	8.0	4.2	4.2	5.2	4.2	4.3
	4% Seed	23.0	4.7	182	8.2	5.3	5.3	5.4	4.8	6.0
	8% Seed	25.6	4.3	226	7.8	4.9	5.6	5.4	4.8	6.8
Topcrop	Full Bloom	20.9	4.8	206	8.2	4.3	4.6	5.1	4.0	6.2
	Early Pod	23.5	4.4	271	8.5	4.3	4.8	5.3	4.0	7.3
	4% Seed	26.9	4.0	226	8.4	4.7	5.3	5.4	4.4	8.8
	8% Seed	27.3	3.8	222	8.2	4.5	5.4	5.4	4.6	9.3
Ranger	Full Bloom	9.8	5.1	101	5.1	4.9	4.4	5.1	4.3	6.0
	Early Pod	13.5	4.8	142	5.3	5.1	4.7	5.1	4.6	9.6
	4% Seed	22.5	4.8	187	5.3	5.8	5.0	5.2	4.8	10.3
	8% Seed	22.2	4.4	185	5.4	5.6	5.3	5.1	5.0	10.7
L.S.D. 5% level		5.2	1.0	40	.6	1.1	1.0	1.1	.9	2.1
F value		1.52	.43	15.35**	.26	.66	.92	.33	.28	1.71

**Significant 1% level

Appendix Table 24. The Interaction of Time of Application and Concentration of Maleic Hydrazide Applied to Snap Beans (Summer 1950).

Per Cent Concentrations	Time of Application	Per Cent Seed Raw	Organoleptic Maturity	Blendor Fiber	Fiber Pressure Tester	Organoleptic			Overall Grade	Yield lbs./15' row
						Fiber	Flavor	Color		
Check										
	Full Bloom	22.3	4.2	181	7.2	5.9	5.4	5.4	5.0	7.1
	Early Pod	20.1	4.2	218	7.0	5.6	5.2	5.2	4.8	7.2
	4% Seed	22.6	4.1	153	7.5	5.6	5.3	5.4	4.8	7.6
	8% Seed	21.9	4.1	196	7.0	5.5	5.3	5.3	4.8	7.8
.04										
	Full Bloom	17.4	4.8	172	6.9	5.6	5.0	5.2	4.7	7.9
	Early Pod	18.1	4.6	199	7.5	5.2	5.1	5.5	4.8	8.0
	4% Seed	21.7	4.8	272	7.7	5.6	5.1	5.2	4.8	8.4
	8% Seed	22.0	4.2	200	7.1	5.5	5.5	5.2	4.9	7.5
.2										
	Full Bloom	9.9	5.3	122	7.1	4.8	4.3	5.2	4.3	3.0
	Early Pod	12.7	4.6	222	7.6	4.6	4.4	5.2	4.1	6.1
	4% Seed	20.0	4.8	196	6.9	5.5	5.2	5.3	4.8	7.0
	8% Seed	20.0	4.0	165	7.3	5.4	5.3	5.1	4.8	7.6
1.0										
	Full Bloom	6.3	6.3	110	6.6	3.0	2.7	4.8	2.9	.5
	Early Pod	11.1	5.4	265	7.0	3.6	3.4	4.9	3.6	2.6
	4% Seed	16.8	4.8	172	7.0	4.7	4.6	5.5	4.4	5.5
	8% Seed	19.3	4.3	173	7.0	5.2	5.3	5.6	5.0	7.0
L.S.D. 5% level		4.9	1.3	52	.7	1.2	1.1	1.0	.9	2.0
F value		2.69**	2.52*	7.25*	.53	3.65**	5.78**	1.73	6.17**	4.65**

* Significant 5% level

**Significant 1% level

APPENDIX

VITA

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University of Maryland, 1945-1947, Bachelor of Science

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Publications:

Guyer, Richard B. The effect of soil types, nitrogen, and growth regulators on the growth and maturation of Alaska peas. Master's thesis. University of Maryland, 1949.

Guyer, Richard B. and A. Kramer. Objective methods of measuring quality in snap beans as affected by para-chlorophenoxyacetic acid and maleic hydrazide. Submitted for publication Proc. Amer. Soc. Hort. Sci.

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Scott, L. E., A. Kramer, and R. B. Guyer. Effect of Storage upon ascorbic acid content, fibrousness and color of asparagus. Ice and Refrigeration. July, 1949.

Positions Held:

U. S. Army Air Force, 1943-1945

Research Assistant, University of Maryland, 1946-1947

Graduate Assistant, University of Maryland, 1947-1951