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Title DATE OF PLANTING AS A FACTOR IN THE GROWTH, DEVELOPMENT, AND YIELD OF SNAP BEANS

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In previous years, at Corvallis, yields of bush snap beans varied among planting dates. In order to obtain additional information on the effect of planting dates on the growth, development and yield of snap beans, four field plantings and two greenhouse plantings of the variety O.S.U. 2051 were made.

Results indicated that the late-June and early-July plantings gave higher yields than the mid-May and early-June plantings. In the greenhouse, the April planting had a higher yield than the February planting. The number of flowers per plant increased as the date of planting was delayed. The number of pods per plant was the maximum in the early-July planting. High temperatures during the major part of the flowering period reduced the number of pods per plant.

The fresh weights and dry weights of the plants were highest when the planting date was delayed. The number of nodes and height of the plants increased in the first three field plantings but were decreased in the last planting.

The data on the heat unit requirements of the different plantings did not show any close relationship. The later plantings had higher heat unit requirements.

DATE OF PLANTING AS A FACTOR IN THE GROWTH, DEVELOPMENT, AND YIELD OF SNAP BEANS

by

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF TABLES (Continued)

DATE OF PLANTING AS A FACTOR IN THE GROWTH, DEVELOPMENT, AND YIELD OF SNAP BEANS

INTRODUCTION

The snap bean, Phaseolus vulgaris L., is grown commercially in large acreages in the United States, either for dry-shell or green-pod consumption. About 181,210 acres of snap or green beans with a value of approximately $46,817,000 were grown in the United States in 1962. Green beans are also among the leading vegetables grown in home gardens throughout the nation.

The snap bean is one of the major vegetable crops grown for processing in Oregon and the Pacific Northwest. Oregon ranks first among the states in snap bean production, having about 16,300 acres grown mainly for canning and freezing. The growing of green beans in Oregon is therefore a high-value industry. The most important variety in this area is the stringless Blue Lake, a pole type which requires trellis culture. Recently there has been increased interest in the growing of bush beans which can be harvested mechanically.

The growth, development, yield and quality of snap beans are influenced by environmental factors, among which the influence of temperature is of great importance. Since temperature fluctuates considerably throughout the growing season, the date of planting becomes an important factor affecting growth, development, and yield of beans.

Earlier observations at Corvallis had indicated that June and early-July plantings usually yielded higher than late-April, early-May, or late-July plantings. In order to gain more information in this regard and also to investigate some of the factors involved, a study was undertaken to determine the behavior of bean plants in different planting dates under field and greenhouse conditions. The characteristics of the growth and development of the plants were measured in each planting to make comparisons. The study was on bush beans and air temperature was the environmental factor which received particular attention throughout the study.

While a number of studies concerning the effect of the planting date on growth and development have been made with other processing vegetables such as peas and sweet corn, little has been done with snap beans in this connection.

The results of the present study should provide additional information on the best date of planting for the maximum growth and yield of bush snap beans in the Willamette Valley. The study also provides information on the relationship of temperature accumulation data to growth and development of bush snap beans planted on different dates during the season.

REVIEW OF LITERATURE

In a survey of literature one cannot find many reports concerning research on planting dates of snap beans. However, studies have been made by investigators in this connection with soybeans.

Smith and Pryor (36, p. 12; 37, p. 669-687) studied the best dates for planting bean varieties. Five varieties of beans for dry seed production were planted at dates varying from late April to late July at two week intervals. Results indicated that under conditions of the Sacramento Valley, four varieties out of five increased in production between late-April plantings up to mid-June and early July, when yields were maximum. The yields of the late-July plantings declined in all varieties. They also studied the effect of high temperatures on growth, development and yield of bean plants and indicated that high temperature reduced the percent of flowers that set seed. If plants were in bloom on days of high temperatures, there was a high mortality of the flowers.

Inoue and Shibuya (23, p. 244) studied the effect of the planting date on pod characteristics and yield of beans (Phaseolus vulgaris L.) near Tokyo, Japan. They reported that the plants of late-April, mid-May, and late-May plantings had more pods than those in mid-April, mid-June, late-June, mid-July, and late-July plantings. The number of pods increased in mid- and late-August plantings. The lowest yields were observed in the July plantings. They further indicated that the low yields of the June and July plantings can be attributed to the adverse effects of the high temperatures at the time of flower-bud differentiation and during the flowering period or pod set of bean plants.

In planting date experiments the effect of high temperatures on flower mortality and pod set of bean plants is important. Binkley (7, p. 489-492) reported that in garden beans the abscission of flowers associates with high air temperatures and low soil moisture and rapid fluctuation of temperature from high to low. Van Shank and Probst (41, p. 192-197) concluded from studies with soybeans in climatically controlled chambers that day temperature is the first factor in limiting flower formation, and not until it is sufficiently high does the night temperature exert a limiting effect.

In planting date experiments with soybeans, photoperiod appears to be the most important variable associated with the influences of the date of planting on growth, development, maturity and yield of plants. The highest soybean seed yields in the United States usually are obtained from early-May plantings (17, 22, 31), but in the more northern latitudes plantings in late May produce the highest yields (13, 40).

Camper (13, p. 91-92) reported that in soybeans late-May and early-June plantings tend to give higher yields than earlier or later seedings regardless of the variety or location. Late-July planting always reduces yields but still gives good quality beans and fair yields when timely moisture is available.

Abel (2, p. 95-98) studied the responses of soybeans to the date of planting in bi-weekly plantings from May 2 to August 2. He reported that the number of days to flowering was essentially unaffected by planting time of the earliest variety but was reduced substantially in successive plantings of later varieties. In contrast, the number of days from flowering to maturity of the latest variety was essentially the same in all plantings, but this period was greatly reduced by delayed planting of the earliest varieties.

In snap beans photoperiod does not appear to influence the growth and development of the plants to a great extent. Allard and Zaumeyer (3) in studying the photoperiod requirement of bean varieties reported that 24 green-podded and 11 wax-podded varieties of bush beans tested showed day neutral behavior and can be grown in a wide range of latitudes. They also indicated that the bush bean varieties grown in the United States belong to this group. Therefore, it appears that temperature is the most important environmental factor affecting growth, development, and yield of snap beans.

In general, temperature influences every chemical and physical process connected with plants--solubility of minerals, absorption of water, gases and mineral nutrients, diffusion, synthesis--as well as vital processes such as growth and reproduction (29).

For each species and variety there is a temperature below which growth is not possible--the minimum growth temperature. There is likewise a maximum temperature above which growth ceases. These two points are called the cardinal growth temperatures (15, p. 177; 35, p. 203). Between these limits there is an optimum temperature at which growth proceeds with maximum velocity.

At the minimum point growth proceeds very slowly. From somewhat above the minimum to the optimum, the rate of growth generally follows Van't Hoff's law; that is, for every ten degrees Centigrade (18 degrees F) rise in temperature the rate of growth approximately doubles. Above the optimum, the rate of growth falls off rapidly until the maximum is reached, beyond which growth stops (11). Cardinal temperatures may differ for the same function in different plants. Also, various organs of the same plant may have different cardinal temperatures for the same function. Roots appear to have lower threshold temperatures for growth than do shoots (30, p. 294-309). Cardinal temperatures vary also with the age of the plant, with its physiologic condition, with the duration of particular temperature levels, and with variations in other environmental factors (15, p. 178 43, p. 789).

Considered primarily from the standpoint of temperature, some plants require relatively low temperatures for flowering (beet, cabbage), some require relatively high temperatures (lettuce, pepper), and others flower over a wide range of temperatures. Flowering of plants in the first category is adversely affected in warm climates; flowering of those in the second is adversely affected in cool climates (29, p. 485).

The fact that the temperature of the dark period is much more critical in its influence on the reproductive growth of many plants than the temperature of the photoperiod has been the subject of many investigations. The effect of night temperatures on fruit set of the tomato has been carefully studied by Went (44, 45) and many other investigators.

The patterns of plant behavior in relation to temperature come largely under the heading of thermoperiodic reactions. It is often not a matter of temperatures within a certain range being conducive to reproductive development, but that cyclical patterns of alterations between certain day and certain night temperatures are required (15).

On the basis of studies by Rappaport and Carolus (32), night temperature may not be as critical during early growth in influencing production and maturity of lima beans. Nevertheless, it was found that low night temperature after early bud development consistently delayed, whereas high night temperatures accelerated green maturity of lima beans. High night temperatures reduced pod weights in Henderson lima beans.

Viglierchio and Went (42, p. 449-453) studied growth and fruiting of the Kentucky Wonder bean (Phaseolus vulgaris) under controlled conditions. The results indicated that the plants show greater stem growth at the higher temperatures. During the early stages the rate of stem elongation was a function of night temperature. The number and size of leaves increased with increasing night temperature. Low night temperatures decreased and delayed the onset of flower opening. Low day temperatures delayed the onset but increased the number of opening flowers. It was concluded that night temperature was the most critical factor influencing developmental processes of bean plants. The variety of bean used was found to be day neutral, though a long photoperiod greatly improved both growth and fruit production.

The knowledge of plant response-temperature relationships is of a great importance in studying developmental processes of the plants. Although this relationship can greatly be influenced by other environmental factors, many investigators have worked on the subject. The determination of the quantities of heat required to bring a certain crop to a given stage of development and maturity is one approach in studying the response of plants to temperature. This has been done by the accumulation of daily mean temperature above a base line of temperature during the growing season and has commonly been termed a heat unit system. Heat units have been used as a tool for scheduling planting dates and predicting harvest maturities of processing crops.

Reaumur (33) in 1735 adopted simply the sum of the mean daily temperatures of the air as recorded by a thermometer in the shade and counting from any given phenological period to any other period. He found from his observations that the sum of these daily temperatures was approximately constant for the period of development of any plant from year to year. In 1905 Abbe (1, p. 15-386) worked on the subject and reported the heat requirements of different crops. During the years 1913 to 1921, Livingston (24, 25) and co-workers published papers on the use of physiological temperature indices for the study of plant growth in relation to climatic conditions. These studies were followed in the late 1920's and early 1930's by the work of Appleman and Eaton (5, p. 795-805), Boswell (9, p. 178-187; 10, p. 341-382), and Magoon and Culpepper (26, p. 11-311; 27). Close relationships were shown between the time of development to a given stage in sweet corn and peas and the mean temperature for that period.

Based on the above studies, many investigators found that planting schedules could be formulated in advance of actual plantings, and that harvest dates could be predicted.

It has been the practice of most investigators studying the effect of temperature upon the growth of plants to consider 40 degrees F as the base growth temperature (1, 27). This, however, may vary considerably under different environmental conditions and from one crop to another. Bomalaski (8, p. 51-59) considered 40 degrees F as the base temperature for English peas. Gould (20, p. 35-37) used 50 degrees F for determining the heat units necessary to mature snap beans. Maurice (28, p. 308-314) suggested 44 degrees F base temperature for heat unit summation in southern peas.

While the heat unit system has been favored by many investigators, its accuracy and importance has been the subject of criticism by others. Wang (43, p. 785-790) pointed out that the different responses of plants to the same environmental factors during various stages of their life cycle has been ignored in the system. Also the base temperature values change with the advancing age of the plants. He further indicated that when values from 32 to 50 degrees F for the base temperature were tested systematically, none were found which would give any improvement in the heat unit system. Arnold (6, p. 430-445) reported that considerable error may be involved in the system by determination of an erroneous base temperature. Guyer and Kramer (21) working with green and wax beans, stated that the use of temperature summations alone would be of limited value for planning planting dates and predicting harvest maturities, since there seems to be no exact numbers of heat units necessary to bring the pods to a commercial picking stage of maturity.

MATERIALS AND METHODS

I. Field Experiment

Plot Layout. The experimental plots were located at the Oregon State University Vegetable Research Farm at Corvallis. The bean plants were grown on a Chehalis silt loam soil which is widely used for growing beans in the Willamette Valley.

Four planting dates were designed for these studies as follows:

First Planting	May 12, 1962
Second Planting	June 4, 1962
Third Planting	June 20, 1962
Fourth Planting	July 9, 1962

Twenty-four plots in total were used for different planting dates. Plots were arranged in a randomized block design and six replications were used for each planting. Plots consisted of four rows, each thirty feet long and three feet apart.

General Culture. Seeds were planted on the above-mentioned dates by a mechanical planter at about two inches depth and plants were thinned to six plants per foot in about ten days after emergence.

The variety used in these studies was O.S.U. 2051. This variety, with a bush or dwarf type of growth habit, is one of the selections made from back crosses with the Blue Lake variety in the Oregon State University bean breeding program.

About 500 pounds per acre of 8-24-8 fertilizer were banded by machine, two to three inches deeper than the soil surface, at the time of planting. No more fertilizer materials were used throughout the experiments.

Good cultural practices were maintained during the experiments and sprinkler irrigation at intervals of seven to ten days was provided to give sufficient water necessary for the best growth of the plants.

Observations and Sampling. To determine rate of growth, plant samples were taken about two weeks after emergence and then were continued at weekly intervals for each of the planting dates. At each time of sampling a total of sixty plants--ten from each plot--for each planting were taken. After removing the roots, the samples were taken to the laboratory for the fresh weight determination. The samples were then placed in a forced-draft dryer at about 60 degrees Centigrade for a period of 48 hours. Subsequently, dry-weight determinations were made.

The date of the beginning of the blooming stage was recorded for each planting. At about this time the number of nodes and also length of internodes were determined in all samples. The determination of the number of flowers per plant in each planting was done when about fifty percent of the flowers were considered to be fully open, and included the small pods, open flowers and flower buds.

Harvesting. For each planting four different harvests were made. Harvest dates for each planting were one or two days apart. Approximately ten feet of row containing 50 plants were harvested in each plot. Harvest was by hand on a once-over basis to simulate machine harvest. Weights were taken on individual plots.

At each harvest the pods from the six replications were combined and mechanically graded at the pilot plant of the Department of Food Science and Technology. Since the weight of pods in each grade was determined, the percent of sieve size distribution could be calculated.

One out of four harvests was considered the ideal harvest, or stage of optimum maturity of pods; that is, when the total distribution of sieve sizes 1 to 4 or 5 to 7 was approximately fifty percent.

Temperature Data. Air temperatures were taken inside an official instrument shelter at a height of approximately three feet above ground level. The shelter was located approximately 50 yards from the experimental plots.

In order to calculate the heat units, the maximum and minimum temperatures for each day were added together and divided by two to obtain the mean temperature for that day. By using 40 degrees and 50 degrees F base temperature, the number of heat units in degree days for each given day was calculated. Having the number of degree days for each day, the total number of heat units for a given period of growth and development was determined.

Plant Analyses. In order to study the influence of the planting date on the chemical composition of the plants, the samples taken at the blooming stage from different plantings were analysed for phosphorus, potassium, calcium, and magnesium. Phosphorus was determined colorimetrically by the molybdenum blue method of Fiske and Subbarow (18, p. 375-400), potassium and calcium with the flame photometer (12, p. 337-342), and magnesium by the thiazole yellow procedure of Drosdoff and Nearpass (16, p. 673-674). The average of the percentages for the six replications was used as the representative percentage for each sampling.

II. Greenhouse Experiment

In order to determine the influence of the date of planting on growth and yield of snap beans grown under greenhouse conditions, two experiments with two different planting dates were conducted.

The first planting was made on February 6, 1963, and the second on April 26, 1963. The same variety as in the field experiment (O.S.U. 2051) was used.

In each experiment, 40 one-gallon cans were used. The cans were filled with a Chehalis sandy loam type of soil into which was mixed thoroughly about 800 pounds of 8-24-8 fertilizer per acre. In order to overcome a slight chlorosis shown by lower leaves of the plants at about three weeks after emergence, one-fourth teaspoon of ammonium nitrate was applied at the surface of the soil in each can.

At each planting eight seeds per can were planted, which were thinned to four plants per can after emergence of seedlings.

At about one week after emergence, in each experiment, the cans were divided into five replications, each consisting of eight cans with a total of thirty-two plants.

Throughout the duration of the experiments, suitable conditions necessary for good growth in the greenhouse were maintained.

Methods of sampling were similar to those mentioned for the field experiments. At weekly intervals after emergence of the seedlings, one can out of each replication was sampled, and after removing the roots, fresh weight and dry weight of the plants were determined. The date of blooming for each planting was recorded and the number of flowers were counted when about fifty percent of the flowers on the plant were fully open. Also, number of nodes and height of plants were measured at flowering time.

For each planting, four harvests, at three-day intervals, were provided. At each harvest time, one can containing four plants out of each replication was picked, making a total of twenty plants. The pods were then counted, weighed, and graded. Grades were made by a small hand grader and percent of sieve size distribution was calculated in order to determine the ideal harvest time or optimum maturity of pods.

A one-pen thermograph (seven-day continuous recording) was used for recording temperatures. Heat units were calculated in the same manner as stated for field experiments.

No chemical analyses were made of the plant samples in the greenhouse plantings.

RESULTS

Effect of Date of Planting on the Yield and Sieve Size Distribution of Snap Beans

Yield data expressed in tons per acre for successive harvests are presented in Table 1. Except for the second planting, all harvests were made in successive days. The harvests for the second planting were two days apart. One harvest out of four in each planting was selected as the ideal harvest or the optimum stage of maturity of pods. This refers to a harvest in which the distribution of sieve sizes 1 through 4 or 5 through 7 was almost fifty percent (Tables 2 and 3).

Regardless of sieve size distribution, yields in the second field planting were the lowest. In each planting the pods became more mature and the yields increased as the harvest dates were delayed. The increase in yields in successive field plantings averaged 0.88, 0.52, 0.67, and 0.57 tons per acre each day, respectively. The changes in distribution of sieve sizes 1 through 4 were 8, 4, 9, and 6 percent per day in each planting, respectively.

In the optimum stage of maturity of pods, yield per plant and yield per acre were the lowest in the second field planting (Table 3). The first planting yielded slightly higher than the second planting, however, this difference was not significant. Yields for the third

Table 1. Yield of Snap Beans (tons per acre) in Four Field Plantings in Successive Harvests.

Planting	Harvest 1	Harvest 2	Harvest 3	Harvest 4
First	3.87	4.50	5.20	6.53
Second	3.04	3.24	4.01	5.66
Third	4.05	5.22	5.33	6.06
Fourth	6.07	6.40	6.96	7.77

Table 2. Percent Sieve Size (1 to 4) Distribution in Four Field Plantings in Successive Harvests.

Planting	Harvest 1	Harvest 2	Harvest 3	Harvest 4
First	57	49	36	32
Second	57	56	48	35
Third	76	66	57	50
Fourth	50	43	40	33

Table 3. Average Yield of Bean Plants at Optimum Maturity in Different Planting Dates.

Planting	Yield Per Plant (grams)	Yield Per Acre (tons)
(Field)		
First	51.33	4.50
Second	45.30	4.01
Third	68.33	6.06
Fourth	68.46	6.07
(Greenhouse)		
First	12.15	---
Second	13.80	---
L.S.D. (.05)		1.22
L.S.D. (.01)		1.69

and fourth plantings showed almost the same values and were significantly higher than those of the first and second plantings. In the greenhouse plantings, the second planting had slightly higher yields although the number of pods per plant was higher in the first planting (Tables 3 and 4).

Effect of Date of Planting on Production of Flowers and Pods of Snap Beans

The data for the production of flowers and pods of bean plants are presented in Table 4.

The number of flowers per plant increased both in field and greenhouse experiments as the date of planting was delayed. In the field plantings, the lowest number of flowers was observed in the first planting which had an average of 47 flowers per plant. The fourth planting showed the maximum value for the number of flowers per plant having an average of 84 flowers.

As the mean temperature increased during the period from emergence up to flowering, the number of flowers per plant increased considerably. Also, the number of total heat units for this period increased by delaying the planting date (Tables 8 and 9). This was true in the greenhouse plantings also. The mean temperature during the period from emergence to flowering in the first greenhouse planting was 72 degrees F, compared to 76 degrees F in the second planting, and the number of flowers per plant in the first planting was considerably lower than that in the second planting.

Thus, under the conditions of these experiments, the highest number of flowers per plant--in the field plantings--was obtained when the mean temperature for the period from emergence to flowering was 67 degrees F in the fourth planting which was made early

Table 4. Average Number of Flowers and Pods Per Plant in Different Planting Dates.

Planting	Number of Flowers per Plant	Number of Pods Per Plant
(Field)		
First	47	18.2
Second	53	15.2
Third	79	17.4
Fourth	84	20.4
(Greenhouse)		
First	9	5.2
Second	15	3.9
L.S.D. (Field Planting)		
(0.05):		2.4
(0.01):		3.4

in July.

The number of pods per plant showed a different pattern of distribution from number of flowers per plant. In field plantings, the fourth planting had the highest number of pods per plant as well as the highest number of flowers. The second planting showed the lowest number of pods per plant although the number of flowers per plant was not the lowest. In the first planting the number of pods showed the second highest value among four plantings while it had the lowest number of flowers per plant. The third planting was intermediate in this respect. These differences in the number of pods, as affected by the date of planting, were significant.

No relationship was found between the number of pods per plant and the mean temperatures during the period from emergence to flowering. However, there appears to be a relationship between the number of pods per plant and the average maximum temperature during the second week of the flowering period. This may be the critical period for pod set of bean plants. In the second field planting, which had the lowest number of pods per plant, the average maximum temperature for the second week of the flowering period was 92 degrees F which was the highest among any other values for the field plantings (Table 5). The average maximum temperature for the first planting, which had the lowest number of flowers per plant and the second highest number of pods per plant, was 77 degrees F, while the temperature for the fourth field planting, which had the highest number of flowers and pods per plant, was 81 degrees F.

A similar relationship was found in the greenhouse plantings. The first planting showed a greater number of pods per plant although the number of flowers was considerably lower than that in the

Table 5. Average Maximum Temperature for the First, Second, and Third Week of Blooming Stage of Bean Plants in Different Planting Dates.

Planting	Maximum Temperature		
	First Week	Second Week	Third Week
(Field)			
First	72	77	76
Second	76	92	80
Third	84	70	83
Fourth	81	81	81
(Greenhouse)			
First	90	88	88
Second	79	101	86

second planting. However, the value for the average maximum temperature in the second planting during the second week of flowering was much greater than that for the first planting, being 101 degrees F compared to 88 degrees F.

Under the conditions of these studies, it appears that in different planting dates, regardless of the number of flowers per plant, there is a close relationship between the number of pods per plant and the maximum temperature during the blooming and pod setting period. Increase in average maximum temperature in this period up to a certain point (about 81 degrees F) increased the number of pods per plant. Above an average maximum temperature of 90 degrees F, there was a pronounced decrease in the number of pods (Tables 3, 4 and 5).

Effect of Date of Planting on the Growth of Bean Plants

The data for fresh weights and dry weights of the samples taken at weekly intervals from two weeks after emergence up to nearly harvest time, are shown in Tables 6 and 7. Changes in dry weights of field samples in successive plantings are also shown in Figure 1. In the greenhouse plantings only four samples were taken since the time from emergence to harvest was much shorter than that in the field plantings (Table 7).

At any given period of growth, the first field planting had the lowest values for fresh weights and dry weights than any other field plantings. The values increased as the date of planting was delayed, being maximum in the fourth planting. In the greenhouse plantings, the same pattern of results was noted. The first planting had lower values for the fresh weights and dry weights of the plants than the second planting.

The data for the effect of planting date on the number of nodes and height of plants are presented in Table 8. Delay in the planting date increased the number of nodes and height of the plants in the field experiments up to the fourth planting. In the fourth planting, the number of nodes and height of the plant were decreased. Among the field plantings the highest average value for the number of nodes

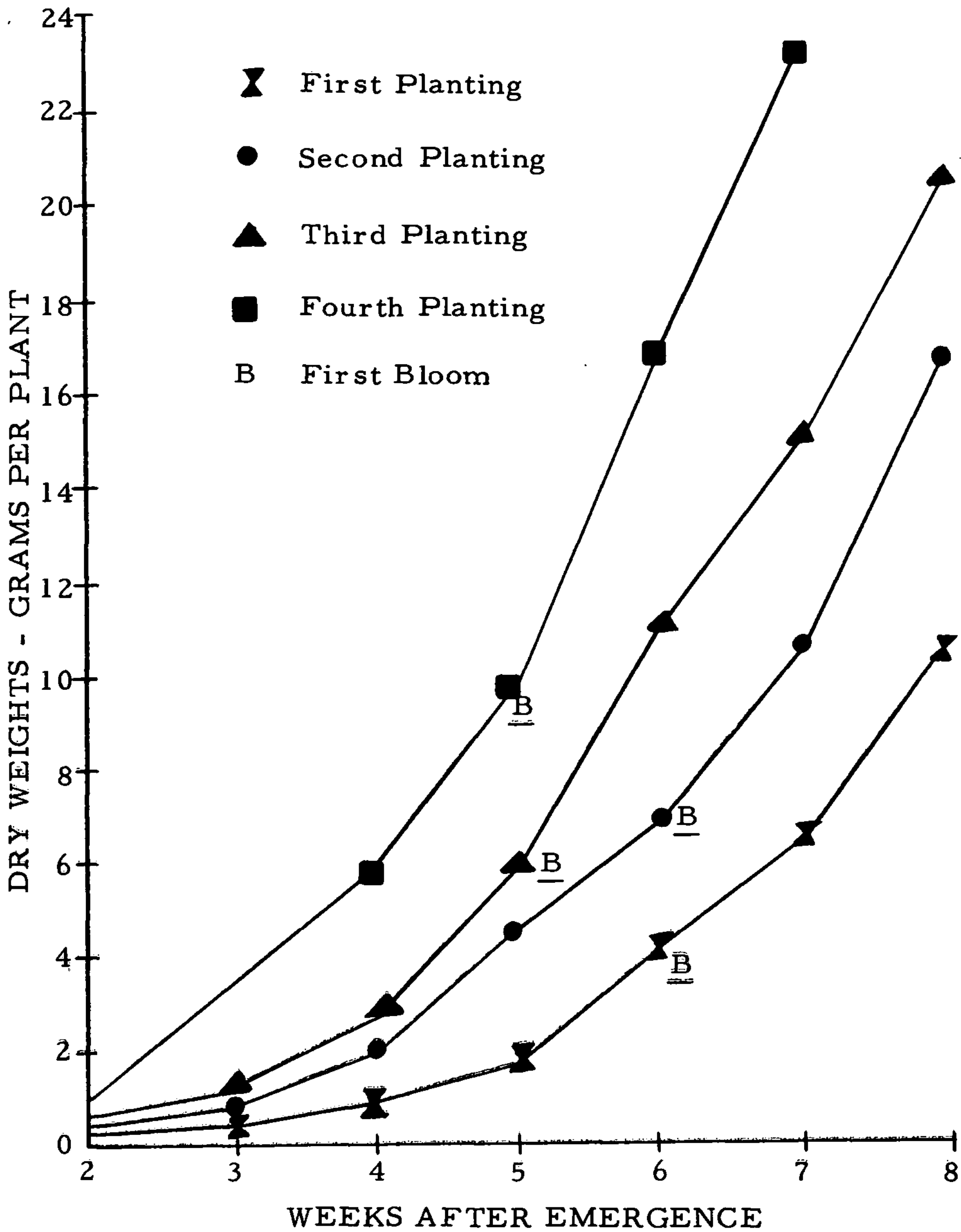

Figure 1. Changes in Dry Weight of the Samples in Different Plantings.

Table 6. Fresh Weight and Dry Weight of Bean Plants at Weekly Samplings in Four Field Plantings.

Weeks from emergence	First Planting		Second Planting		Third Planting		Fourth Planting	
	Fresh Weight	Dry Weight	Fresh Weight	Dry Weight	Fresh Weight	Dry Weight	Fresh Weight	Dry Weight
2	1.40	0.17	1.72	0.26	3.16	0.41	7.40	0.97
3	2.23	0.33	4.66	0.73	7.55	1.12	21.96	3.30
4	5.86	0.80	12.25	1.83	16.40	2.59	45.58	5.71
5	10.92	1.63	25.68	4.43	36.51	5.64	63.00	9.56
6	25.95	4.01	44.15	6.72	78.66	10.95	102.33	16.65
7	40.03	6.31	77.18	10.43	103.25	14.80	156.41	23.01
8	74.05	10.46	125.90	16.55	133.25	20.16	--	--

Table 7. Fresh Weight and Dry Weight of Bean Plants in Two Greenhouse Plantings at Weekly Samplings.

Weeks from Emergence	First Planting		Second Planting	
	Fresh Weight	Dry Weight	Fresh Weight	Dry Weight
2	3.30	0.36	3.65	0.62
3	5.35	0.80	7.05	1.16
4	6.90	1.14	11.50	1.98
5	7.80	1.55	14.50	2.85

Table 8. Average Number of Nodes and Height of Bean Plants at Flowering and the Mean Temperatures from Emergence to Flowering in Different Planting Dates.

Planting	Number of Nodes Per Plant	Height of Plants (Inches)	Mean Temperature from Emergence to Flowering
(Field)			
First	4.0	7.7	60
Second	5.0	16.1	63
Third	5.3	16.9	65
Fourth	4.5	14.5	67
(Greenhouse)			
First	5.0	19.3	72
Second	4.0	18.7	76

L.S.D. (Field Plantings)
(0.05): 0.2
(0.01): 0.3

was 5.3 and the greatest height was 16.9 inches which was observed in the third planting. The lowest values belonged to the first planting. The differences in the number of nodes as affected by the date of planting were significant.

Heat Units and Number of Days Required for the Growth and Development of Bean Plants

The number of heat units above 50 degrees F and the number of days required for different stages of growth and development of bean plants are presented in Tables 9 and 10, respectively.

The first planting required the least number of heat units from planting to harvest. The heat unit requirements of other plantings, including two greenhouse plantings, were increased as the date of planting was delayed.

The number of days required from emergence to flowering was different in all plantings. The highest number of days were required in the first planting for this period. The number of days from flowering to harvest was almost the same in the first, second, and fourth field plantings and the second greenhouse planting, while the duration of time from planting to harvest was almost the same in the second, third, and fourth field plantings. The first field planting required the highest number of days for maturity.

Table 9. Number of Heat Units Above 50 Degrees F Required for Different Stages of Growth and Development of Bean Plants.

Planting	Planting to Emergence	Emergence to Flowering	Flowering to Harvest	Planting to Harvest
(Field)				
First	41	394	352	787
Second	49	454	405	908
Third	89	487	452	1028
Fourth	88	564	400	1052
(Greenhouse)				
First	135	481	604	1220
Second	247	767	558	1572

Table 10. Number of Days Required for Different Stages of Growth and Development of Bean Plants.

Planting	Planting to Emergence	Emergence to Flowering	Flowering to Harvest	Planting to Harvest
(Field)				
First	8	41	24	73
Second	5	35	23	63
Third	5	32	27	64
Fourth	7	34	23	64
(Greenhouse)				
First	5	22	29	56
Second	9	29	24	62

Effect of Planting Date on Mineral Content of Snap Beans

The percentages of phosphorus, potassium, calcium, and magnesium of bean plants in different field plantings are shown in Table 11. The values are the representative percentages for the blooming stage of plants.

Relationships were found between phosphorus and magnesium content of the plants and the mean temperatures and total heat units from emergence up to blooming stage (Tables 8 and 9). The percent of phosphorus was increased with delay in planting date and increase in mean temperature and total heat units. However, this increase was not significant. Potassium and calcium contents did not show any relations with mean temperature or total heat units. Percent potassium was highest in the second planting and lowest in the first planting. The highest value for calcium was shown in the third planting and the lowest in the second planting. Magnesium content was almost the same in the first and second plantings, but was increased in the third and fourth plantings.

Table 11. Percent of Phosphorus, Potassium, Calcium, and Magnesium of Bean Plants in Field Plantings at Blooming Stage.

Planting	% P	% K	% Ca	% Mg
First	0.203	2.10	1.88	0.524
Second	0.219	2.35	1.86	0.518
Third	0.230	2.31	2.13	0.636
Fourth	0.256	2.21	1.92	0.695

DISCUSSION

It is recognized that the results obtained in this work have certain limitations. First of all, they apply primarily to the one variety--O.S.U. 2051--grown under the conditions of the Willamette Valley near Corvallis for only one season. Secondly, as stated previously, the only factor which received particular emphasis throughout this study was air temperature. This made it somewhat difficult to generalize the results and interpret them properly. Better interpretation of results might be made if some other factors had been measured, such as light intensity or total solar radiation, photoperiod, and soil moisture.

According to the results obtained in this work, the date of planting is an important factor affecting the growth, development, and yield of snap beans. Among the four field plantings, the early-June (second) planting produced the lowest yields. The highest yields were obtained from late-June (third) and early-July (fourth) plantings. This agrees with the results of the studies by Smith and Pryor (36, p. 12) who indicated that in most varieties of dry beans grown in California, maximum yields were obtained in mid-June and early-July plantings.

It should be pointed out that the late-June planting (third planting) had fewer pods per plant than the early-July (fourth) planting.

This difference in the number of pods did not result in differences in yields between the two plantings because of the higher weight of the pods in the late-June (third) planting. The higher weights of the pods in the late-June planting may have resulted from the greater length of the pods. In general, the later plantings (third and fourth) in these experiments showed considerably higher fresh weights of plants. It may be concluded, therefore, that the large bearing areas as well as food manufacturing tissues may have resulted in the higher yields. However, the influence of many environmental factors, such as light intensity and available soil moisture in the flowering period could have been related to the increased yields in these plantings.

The early-June planting (second field planting) which gave the lowest yield had the least number of pods per plant. Mid-May planting (first planting) which gave slightly higher yields than the early-June planting had the second highest number of pods among the other plantings. In this planting the low yield may have been due to the fact that the growth of the plants was limited because of the lower temperatures during the early growth of the plants. Fresh weights and dry weights as well as the height of the plants were minimum for this planting.

In the early-June planting the low yield can be related to at least two factors: First, the limited vegetative growth of the plants, second, the lower number of pods per plant resulting from the adverse effects of high temperatures on pod set. In this planting the average maximum temperature for the second week of the flowering period of bean plants, was the highest among the temperature values for the same period in the other plantings. Smith and Pryor (37), working with three bean varieties, indicated that the high temperatures reduced the percent of flowers that set seed, and if plants were in bloom on days of high temperatures, there was a high mortality of the flowers. Similar results were obtained by Binkley (7) and Inoue and Shibuya (23) working with garden beans. They found that the abscission of flowers associates with high air temperatures at the time of the flowering period.

The number of flowers per plant apparently does not necessarily affect the number of pods per plant. For instance, in the first field planting which had 18 pods per plant, the number of flowers was the lowest, being an average of 47 flowers per plant, while in the third planting which gave 17 pods per plant, the number of flowers was 79. It seems that environmental factors, particularly temperature during the flowering of the plants, exert a great influence on the number of pods produced.

In the greenhouse, the April planting gave a lower number of pods than the February planting although the number of flowers was higher in the April planting. The yield was higher in the April planting, being 13.8 grams per plant compared to 12.15 grams. However, since the heat control during the month of May was very difficult in the greenhouse because of the unusually high and fluctuating temperatures, no clear cut conclusions can be drawn about the yield of bean plants in the greenhouse.

The vegetative growth of the plants, as well as the reproductive growth, was greatly influenced by the date of planting. As stated previously, the delay in planting increased the fresh weights and dry weights of the plants considerably. The latest plantings, both in the field and in the greenhouse experiments, had the maximum values in this regard. As the mean temperatures during the growth and development of the plants increased, the values for the fresh weights and dry weights increased also. However, the importance of environmental factors other than temperature in increasing these values should be emphasized. Viglierchio and Went (42, p. 449-453), studying the behavior of the Kentucky wonder beans under controlled conditions, found that the plants showed greater stem growth at the higher temperatures but in the early stages the rate of stem elongation was a function of night temperatures. They also indicated that the night temperature was the most critical factor influencing developmental processes of bean plants. They found that the variety was day-neutral, but the plants under long-day conditions grew faster than those under short days. This suggested that the production of photosynthates may have been limiting growth in the short-day regime.

The phosphorus content of bean plants increased as the date of planting was delayed, although this increase was not significant. The minimum value for the phosphorus content of the bean plants was 0.203 percent--shown in mid-May (first) planting, compared to 0.256 percent--the maximum value, shown in the early-July (fourth) planting. The increase in phosphorus content of the plants may be attributed to the effect of the increase in mean temperatures and consequently, increase in total heat units in later plantings. Apple and Butts (4, p. 325-332) worked with pole beans grown on Chehalis soil in the greenhouse at two different soil temperatures with and without adding phosphorus. They reported that the effect of high soil temperature in increasing the percentage of phosphorus in the plants was significantly greater when no phosphorus was applied. In the studies under discussion, only air temperatures were taken into consideration, and since the soil temperature is primarily related to air temperature, the increase in phosphorus content in later plantings appears to be related to the increase in soil temperatures. Average mean air and soil temperatures in a level of 4 inches for the period from emergence to flowering are presented in Appendix Table 1.

The effect of high transpiration rate resulting from higher temperatures in increasing the uptake of some elements should be kept in mind. Freeland (19, p. 373-374) showed that in corn and beans the uptake of macroelements was directly correlated with the transpiration rate, but was not necessarily proportional to the rate of water uptake.

With the limitations of these experiments, no conclusion can be drawn for the effect of the planting date on potassium and calcium contents of the plants. No consistent relationship was found between the temperature records and percent of these elements.

The later plantings, both in field and greenhouse, showed greater number of heat units requirements for maturity when heat units were summed above 50 degrees F. The heat unit requirement of the early-July (fourth) planting for maturity was 265 degree days more than mid-May (first) planting. In the use of the heat unit system, the number of heat units necessary for a variety to reach a given stage of growth and development is assumed to be approximately the same regardless of the planting date or the duration of the time required. On the other hand, the time required for the plants to reach a certain stage of growth and development will be longer if the mean temperature during that period is low and vice versa. Under the conditions of the present study no such relations were found when heat units were calculated above 50 degrees F. Using 40 degrees F as the base temperature did not result in any improvement of the heat unit system (Appendix Table 2). Guyer and Kramer (21) working with snap beans indicated that the crops planted in the spring required a lower number of heat units than those maturing in mid-summer and fall. Also, they found that the bean plants in two successive years showed different heat unit requirements to reach a commercial stage of maturity.

In general, it seems that the use of temperature summations alone would be of limited value for scheduling planting dates and predicting harvest maturities of bush snap beans. These limitations have been pointed out by many investigators (4, 15, 21, 43). As stated previously, cardinal temperatures vary with the age of plants as well as with variations in other environmental factors, and therefore, a cardinal temperature is a range rather than a fixed point on the temperature scale, and this should be considered in the system. In most plants, normal functioning may be more closely governed by day than night temperatures (34, p. 265-266). Means obviously cover up the differences in day and night temperatures. Also the length of day differs among months, and this governs the duration of high temperatures without necessarily affecting the mean as usually calculated. The significance of mean temperatures can be heightened by taking day length into account (39, p. 55-94). Also, as stated by Wang (43), a quantitative evaluation should be made of the negative effects of temperatures beyond the threshold values for both upper and lower extremes.

SUMMARY

In order to investigate the effect of the planting date on the growth, development, and yield of snap beans, four field plantings and two greenhouse plantings were made.

The data can be summarized as follows:

1. The yield of bean plants varied with dates of planting. In the field, the early-June planting produced the lowest yield. The mid-May planting gave slightly higher yields than the early-June planting. The late-June and early-July plantings produced the highest yields. In the greenhouse, the April planting had higher yields than the February planting.

2. The number of flowers per plant was increased as the date of planting was delayed. This increase was associated with an increase in the mean temperatures during the period from emergence to flowering.

3. The number of pods per plant was at a maximum in the early-July (fourth) planting.

4. Relations were found between the number of pods per plant and the average maximum temperatures of the flowering period. High temperatures during the major part of the blooming and pod setting period reduced the number of pods per plant.

5. The fresh weights and dry weights of the plants increased

with the delay in the planting date.

6. The delay in the date of planting increased the number of nodes and height of the plants in the first three field plantings. The number of nodes and height of the plants decreased in the latest planting.

7. The phosphorus content of bean plants increased as the date of planting was delayed.

8. No close relationship was found between the number of heat units required by different plantings. The number of heat units increased with the delay in planting.

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APPENDIX

Appendix Table 1. The Average Mean Air and Soil Temperatures at 4-Inch Level from Emergence to Flowering in Different Plantings.

Planting	Air Temperature	Soil Temperature
First	60	70
Second	63	76
Third	65	79
Fourth	67	79

Appendix Table 2. Total Heat Units Above 40 Degrees F Required for Different Stages of Growth and Development in Different Plantings.

Planting	Planting to Emergence	Emergence to Flowering	Flowering to Harvest	Planting to Harvest
(Field)				
First	121	804	592	1517
Second	99	804	635	1538
Third	139	807	722	1668
Fourth	158	904	630	1692
(Greenhouse)				
First	185	701	874	1760
Second	337	1057	798	2192

Appendix Table 3. Total Heat Units Above 50 Degrees F Required for Different Stages of Growth in Different Plantings.

Weeks from Emergence	Planting					
	1	2	3	4	1 (Greenhouse)	2 (Greenhouse)
2	80	96	122	240	323	441
3	137	209	207	395	481	606
4	215	297	302	494	639	767
5	294	390	440	599	785	896
6	394	489	616	734	--	--
7	474	616	694	843	--	--
8	584	786	795	--	--	--

Appendix Table 4. Analysis of Variance Calculations of Yield Per Acre of Bean Plants in Different Plantings.

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Squares	F Value
Total	60.87	23		
Replications	14.62	5	2.924	2.941
Planting Date	31.33	3	10.443	10.506 **
Error	14.92	15	0.994	

Appendix Table 5. Analysis of Variance Calculations of Number of Pods of Bean Plants in Different Plantings.

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Squares	F Value
Total	7380.74	239		
Replications	79.69	5	15.938	--
Planting Date	824.57	3	274.856	6.729 **
Planting Date x Replications (Experimental error)	612.68	15	40.845	1.504
Error (Sampling	5863.80	216	27.147	

Appendix Table 6. Analysis of Variance Calculations of Number of Nodes of Bean Plants in Different Plantings.

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Squares	F Value
Total	116.00	239		
Replications	1.97	5	0.394	--
Planting Date	57.41	3	19.136	77.161 **
Planting Date x Replications (Experimental error)	3.72	15	0.248	1.016
Error (Sampling)	52.90	216	0.244	