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The effects of fertilizer placement on the yield and quality of snap beans

Paul Colditz

To the Graduate Council:

I am submitting herewith a thesis written by Paul Colditz entitled "The effects of fertilizer placement on the yield and quality of snap beans." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Landscape Architecture.

B. S. Pickett, Major Professor

We have read this thesis and recommend its acceptance:

G. E. Hunt, M. E. Springer

Accepted for the Council:
Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

August 7, 1958

To the Graduate Council:

I am submitting herewith a thesis written by Paul Colditz entitled "The Effects of Fertilizer Placement on the Yield and Quality of Snap Beans." I recommend that it be accepted for nine quarter hours of credit in partial fulfillment of the requirements for the degree of Master of Science, with a major in Horticulture.

B. Wetzel [signature]
Major Professor

We have read this thesis
and recommend its acceptance:

B. Wetzel [signature]

Gordon E. Hunt [signature]

Homer D. Swingle [signature]

Accepted for the Council:

Dale Wantling [signature]
Dean of the Graduate School

THE EFFECTS OF FERTILIZER PLACEMENT ON THE YIELD AND QUALITY OF SNAP BEANS

A THESIS

Submitted to
The Graduate Council
of
The University of Tennessee
in
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for the degree of
Master of Science

by

Paul Colditz

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P. C.

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CHAPTER I

INTRODUCTION

Snap beans rank third in importance among the vegetable crops grown in Tennessee and are exceeded only by Irish potatoes and sweet potatoes. In 1957 snap beans ranked twelfth in importance of all crops grown in Tennessee, and in that year 7,600 acres were seeded to snap beans. A total of 15,940 tons of beans were produced in 1957, and the value of the crop was estimated at $2,008,000 (4). Of the total tonnage produced 2,500 tons were sold on the fresh market, and 13,440 tons were sold to the processor. In 1957 the average yield of snap beans in Tennessee was 2.1 ton per acre.

Among the varieties generally planted in Tennessee are Wade, Top Crop, New Improved Tendergreen, and Tenderlong 15. The fertilizer is usually applied at the time of planting, in bands at each side of the seed, and some growers add supplementary nitrate at bloom. Fertilizer rates vary with the section and grower. Most beans at the present time are harvested by hand.

It has been a recognized fact for several years that bean seed and seedlings are very susceptible to fertilizer injury. By placement of a complete fertilizer in bands this danger can be reduced, but it is possible that the fertilizer so placed may not be as readily available in time for the plant to make the most efficient use of the nutrients. It has been established that phosphorus is necessary for early root development (15). If the phosphorus, as a part of the complete fertilizer, is placed in bands it is possible that the source may be located too far from the young bean roots for maximum early benefit to the plant. Banding also presents the problem that the roots will be restricted to a small area of nutrient supply, and moisture may become the limiting factor in growth and production.

Nitrogen has been found to encourage above ground vegetative growth and impart to the leaves a deep green color. Nitrogen acts as a regulator and governs to a great extent the utilization of phosphorus and potassium. However, when nitrogen is oversupplied, the results may be just as disastrous as when a deficiency occurs. Nitrogen, when present in excess, may cause a delay in plant maturity, cause weakened plant stems, and may decrease disease resistance (10).

The movement of nitrogen in the soil must be considered in the placement of the fertilizer with respect to the seed. This is true with respect to most of the inorganic nitrate materials, such as ammonium nitrate, which enter into solution soon after application. Nitrogen tends to move from the zone of placement, and this movement is largely vertical, depending upon the direction of capillary water movement. The movement of capillary water being dependent on adhesion and cohesion between soil particles and the film of water which surround them (10). Due to the mobility of nitrogen, it is not always desirable to add all of the nitrogen at planting since heavy rainfalls may cause the loss of nitrogen by leaching. Since nitrate nitrogen is mobile, it is possible to add part of the nitrogen at planting and more later on in the season as a side-dressing or top-dressing.

The purpose of the experiments reported in the following work was to determine the effect of times of application and placement of phosphorus, and the effect of various times of nitrate placement under irrigated and non-irrigated conditions on the yield and quality of snap beans.

CHAPTER II

LITERATURE REVIEW

Fertilizer experiments on snap beans have increased in number since the early 1930's, and the results of these experiments reported in the literature are often different and frequently conflicting due to soil type, fertilizer placement, fertility level of the soil, moisture, season and the variety of beans being grown.

Knott (9) reports in his handbook, that 4,000 pounds of snap bean pods remove ninety-five pounds of nitrogen, seven pounds of phosphorus, and twelve pounds of potassium. The 16,000 pounds of leaves and stems required to produce the above crop remove forty pounds of nitrogen, five pounds of phosphorus and forty pounds of potassium.

Sayer (15) conducted fertilizer studies on several vegetable crops. In his experiments he used two methods of fertilizer placement to study the effects of fertilizer on root development. Three hundred pounds of a 4-16-4 analysis fertilizer was used per acre. When fertilizer was applied in a single continuous band, two and one-half inches from bean seed and one inch deeper than the seed, Sayer found that bean roots on reaching this fertilizer band branched out into many fine fiberous roots. Bean roots which missed the fertilizer band did not branch out. When all the fertilizer was placed under the seed row, the bean roots had a larger mass of fiberous feeding roots. Sayer found that bean roots develop more rapidly downward than to the side. Sayer seeded beans at the same time, using the fertilizer placements above. After nine days it was found that no bean roots had reached the fertilizer placed two and one-half inches from the seed, while plants with all fertilizer placed under the seed had developed roots after nine days and were in the fertilizer zone and branching out.

Heck (6) states that soils vary greatly in the extent to which they permit penetration of soluble phosphates. He found that the amounts of iron, aluminum and calcium carbonate contained in a soil governs whether phosphate would be tied up in an unavailable form. He concludes that the greatest phosphate penetration occurs in soils of neutral to slightly acid reaction which contain little active iron or aluminum. Active calcium, iron, or aluminum inhibits the downward movement of phosphates. In general he found that phosphorus was usually fixed and held in a difficult and unavailable form close to the point of application.

Fertilizer toxicity was recognized in the early 1930's and research workers began designing experiments to study the effect of various fertilizer placements on seed and seedling injury. In 1931 Cumins and others (2) investigated the possibilities of placing fertilizer in bands when growing snap beans. These workers conclude that larger yields at the first picking were obtained with the fertilizer placed in bands, at each side and below the seed level. When these investigators placed fertilizer in either two or four inch bands to the side of the seed and one and one-half inches deeper than the seed, the best stands of beans were obtained with more rapid growth, earlier blooming and setting of blooms, and larger yields. These investigators conclude that for their conditions, 350 pounds of 10-14-10 analysis fertilizer or 700 pounds of a 5-7-10 fertilizer gave the best results.

Parker (14) states that the true value of a fertilizer element or elements may be obscured in field fertilizer studies because the placement of the fertilizer material is such that factors other than supplying a given amount of nutrient become involved. These factors, according to Parker, are interference with the germination of the bean seed, root injury and interference with moisture uptake.

A study of the effects of potassium on yields of snap beans in South Carolina was conducted by Mitchell in 1936 (11). His data led him to believe that when a high annual rate of complete commercial fertilizer has been added to soils, a residual build-up of potassium occurs. Mitchell's experiments were conducted on soils which had received various annual rates of commercial fertilizer over a period of years, and the soils ranged from 180 to 400 pounds of available potash per acre. Mitchell concludes that failure of snap beans to respond to applied potash in his experiments were due to residual potash, and in most cases yields were reduced in direct proportion to increases in amounts of available potash added.

Forsee and Hoffman (5), conducting experiments on organic soils in Florida, concluded that no fertilizer is required when a soil test indicates that the available phosphorus is above seven pounds per acre and the available potash above seventy-five pounds per acre. They state that for each pound of phosphorus below seven pounds of available phosphorus, fifteen pounds of phosphorus should be added. Fertilizer tests conducted in Pennsylvania during 1954-55 by Smith (17) indicate that when available phosphorus, as reported by a soil test, is very-low low, to low medium, the phosphorus becomes the limiting factor in snap bean production. Smith states that yield responses to the fertilizer treatment were completely dominated by the phosphoric acid treatments. He reports that no yield increase was found from the addition of nitrogen or potash when the soil test indicated a medium high for potassium. Ware (19) studied earliness and total yield as affected by the major fertilizer elements. He used Norfolk, Eutaw, Cecil and Ruskin soil types in his experiments and concluded that potash had little effect on early yield except that at the maximum rate less early yield was noted. On the soils where potash had no effect on total yield, early yield was not influenced. Phosphorus, when applied to newly cleared land, greatly increased both early and total yield. Nitrogen decreased the per cent of early beans, but increased actual total yields.

Hills and his co-workers (7) report that on the sandy soils of Florida, beans did not respond to rates of nitrogen over 50 to 60 pounds. Phosphorus gave no added response when used at a rate of over 60 pounds. These investigators state that a response to 90 pounds of potash per acre was noted on all plots. They recommend that 1000 pounds per acre of a 5-6-9 analysis fertilizer be used on such soils.

Parker (13) mixed fertilizer with the soil immediately before planting bean seed and found that a reduction in stand ranged from as little as one per cent to as high as thirty-three per cent. Injury from salts were very pronounced during dry years, but during seasons of adequate rainfall little or no injury was noted. When fertilizer was placed on top of the seed row, injury occurred when there was enough rainfall to carry the salts downward to the vicinity of the seed. Salinity damage was least severe when no rain fell for several days after planting.

Bernstein and Ayres (1) studied the tolerance of six varieties of snap beans to fertilizer salts. They found that all varieties tested were extremely sensitive to salinity. Their results indicate that at a soil conductance of 3.3 millimhos/cm. there was a corresponding fifty per cent decrease in yield.

Katton and Fleming (8) used portable plastic sheds in their study of irrigation requirements for snap beans. By placing the plastic sheds over the bean rows during the periods of natural rainfall they could maintain various levels of drought conditions. Wade variety of snap beans was used in their study. These workers conclude that the water requirements of the above variety of bean increases as the season progresses. They found that approximately one inch of rain per week is required from emergence to blooming, and then one and one-half inch of rain per week is optimum. Dry conditions from emergence to bloom did not impair quality if the available soil moisture did not fall below fifty per cent after pod development. The effect of various levels of irrigation was studied in Florida by Nettles (12). He found that light irrigations applied to snap beans gave higher yields than less often irrigations of higher rates. He concludes that light irrigations applied more often than heavy irrigations were more effective in maintaining even soil moisture than were the heavier irrigations.

Singleton (17) used soils known to be infested with Rhizoctonia and planted various varieties of snap beans. He found that Wade's Bush had very little wilt. He states that a few plants died when they first emerged but a good stand was secured. He states that no mosaic or mildew was noted in plots seeded to Wade variety of snap beans.

CHAPTER III

MATERIAL, METHOD AND PROCEDURE

This study was conducted in three phases. The phosphate study was the first investigation undertaken and was conducted earliest in the season, with field operations starting April 26, 1957. Irrigated and non-irrigated nitrate studies started on May 11, 1957.

Individual treatments in each study consisted of three rows arranged in a randomized block design of four replications. The Wade variety of snap bean (*Phaseolus vulgaris*) was planted in each plot at the rate of six seeds per foot. Individual seed lots were counted out for each row in each study and dusted with Seedguard for protection against harmful soil organisms.

All pre-planting band applications of fertilizer were applied in a single band, approximately two inches wide, and located three inches to the side of the seed row and two inches deeper than the seed. All fertilizer placed under the seed was covered with one inch of soil. When a post-emergence side-dressing was used, the fertilizer was applied in a single two inch band three inches to the side of the seed row opposite to the pre-planting band application. All fertilizer applications were made at the rate of 800 pounds per acre using a 5-10-5 fertilizer, compounded from ammonium nitrate, 33.5 per cent; muriate of potash, 60 per cent; and triple superphosphate, 46 per cent. All fertilizer and all seed was placed by hand to insure even distribution and uniform plant stands.

Phosphate Study

The phosphate placement study conducted at the Agricultural Experiment Station farm at Knoxville started April 26, 1957.

Soil samples were collected and sent to the Soil Testing Laboratory at Nashville. Organic matter was determined by the investigator using the method described by Dunton et al. (3). Results of the soil test indicated the following:[1]

pH------------------6.4

Organic matter-----1.75 per cent

Phosphate-----------High

Potash--------------High

The site selected for this study had a gentle southern slope, the upper half being classified as gently sloping, Wolftever silt loam and the lower half as the local alluvial phase, Lindside silt loam. Rows were laid off across the slight slope, permitting two replications to be located in each of the two soil types.

There were four placements of phosphate used at the rate of eighty pounds per acre. Treatments were as follows:

Treatment Number	Placement of Phosphate
1	At planting, one-half under row, one-half in a band.
2	At planting, all under row.

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[1]High phosphate indicates 26 pounds available P_2O_5 / acre or above. High potash indicates 190 pounds available K_2O / acre or above.

Treatment Number	Placement of Phosphate
3	At planting, one-half under row. At post-emergence, one-half in a band.
4	At planting, all in a band.

In each of the preceding treatments, 40 pounds of nitrate and 40 pounds of potash per acre were applied in a band three inches to the side of the seed row.

Seed rows were twenty-seven feet long and three feet apart. Three rows per treatment were used with treatments replicated four times in a random block design. Fertilizer applications and seeding were carried out on April 26, 1957. The post-emergence phosphate application was made May 21. Germination counts were recorded for each row, seventeen and twenty-two days after planting. Rainfall for April, May and June was 4.05 inches, 3.42 inches and 5.43 inches respectively. Standard cultural practices were used and insects were controlled with five per cent malathion dust.

Harvest started on June 21 and continued through July 1. Beans were harvested by hand with yield records and quality measurements taken from the center row of each three row treatment. Harvested beans were placed in paper bags which had been marked with the appropriate treatment and replication. All beans were weighed to the nearest hundredth of a pound and were weighed as soon after harvest as possible. When time did not permit grading on the same day as harvest, the beans were stored under refrigeration at 38 degrees Fahrenheit until the following day.

Nitrate Studies

Nitrate placement studies were conducted on the Horticultural irrigation range at the Agricultural Experiment Station farm at Knoxville starting May 11, 1957. Soil samples were collected and sent to the Soil Testing Laboratory at Nashville for analysis. Organic matter was determined by the investigator using the method described by Dunton *et al.* (3).

The placement of nitrogen was the same in both the nitrate studies. The times of application and the position of placement for nitrogen were as follows:

Treatment	Placement of Nitrogen
1	All banded one week after emergence.
2	One-half banded one week after emergence. One-half banded at bloom.
3	All banded at planting.
4	One-half banded at planting. One-half banded one week after emergence.

In each of the above placements, eighty pounds of phosphate and forty pounds of potash per acre were applied in a band three inches to the side of the seed row at planting.

The treatments were randomized and replicated four times. The length of rows in the nitrate study were twenty-five feet. The rows were spaced three feet apart. Fertilizer applications and seeding were carried out on May 11, 1957.

Two sets of four replicates each were planned, one to be irrigated and the other not irrigated. The season was such that irrigation was not necessary. The data from the two sets were combined for study of the nitrate factor. One of the two sets was on Wolftever and Etowah silt loams with Wolftever occupying most of the experimental area. The other was on a gently sloping slightly eroded phase of Etowah silt loam (18).

The soil in the first set of four replicates had a pH of 6.3, an organic matter content of 1.63 per cent, and a high phosphate and potash level as indicated by the results from the Agricultural Extension Service Soils Laboratory. The plot used for replicates five through eight had a pH of 6.5, and had an organic matter content of 1.73 per cent, and had a high level of phosphate and potash.

The rainfall for the thirty days preceding seeding was 4.49 inches with 0.44 inches falling during the last sixteen days. The crop was seeded May 16, and 3.08 inches of rain fell during the last fifteen days of the month. There were 5.43 inches of rainfall in June and 2.83 inches in July through the harvest period.

The beans were cultivated with a spring-tooth tractor cultivator. After the first cultivation, May 28, the side-dressing that was to be applied at one week after emergence was placed down. At this time, an outbreak of Southern Wilt (<u>Sclerotium rolfsii</u>) was noted. This disease cleared up in about ten days.

The nitrogen to be applied at bloom as a side-dressing application was made June 12, 1957. Application was delayed three days because of wet ground due to natural rainfall.

Insects were controlled by frequent dusting with five per cent malathion every two to three weeks, depending on the amount of rainfall received.

Harvest began on June 27 and continued through July 9. A total of three pickings were made. All yield and quality measurements were made on the center row of each three row treatment. Weights were recorded to the nearest hundredth pound and in all cases the weights were recorded as soon after harvest as possible.

Grading

The grading of snap beans presents various problems to both the grower and to the purchaser. Some of the factors considered in grading are: general appearance, color, freedom from disease, straightness, length, and diameter of pods. In order to judge the various qualities of snap beans in this experiment, a numerical scale was set up for the qualities being tested. A description of the scoring system used is presented below:

Straightness:

1-2-3	Beans very slightly crooked, very few in S shape or C shape.
4-5-6	Beans moderately crooked, some moderately crooked in S shape.
7-8-9	Beans varying in severe crooking, many in severe S shape.
10	Beans not meeting the above grades.

Fullness:

1-2-3	Beans uniformly filled with both ends filled.
4-5-6	Beans not as uniformly filled, the ends not filled or only one end filled.
7-8-9	Beans not uniformly filled, both ends not filled.
10	Beans not meeting the above grades.

Cavity Size:

1-2-3	1.0mm. to 0.9mm. X less than 0.8mm.
4-5-6	1.1mm. to 1.2mm. X 0.8mm. to 0.9mm.
7-8-9	1.3mm. to 1.4mm. X 1.0mm. to 1.1mm.
10	Over 1.4mm. X over 1.1mm.

Sieve Size:

Diameter was measured with a Chisholm-Ryder Company bean sieve and the largest part of the pod was measured.

Sieve size	Diameter
1	beans 14.5/64 of an inch and under.
2	beans over 14.5/64 to 18.5/64 of an inch inclusive.
3	beans over 18.5/64 to 21/64 of an inch inclusive.
4	beans over 21/64 to 24/64 of an inch inclusive.
5	beans over 24/64 to 27/64 of an inch inclusive.
6	beans over 27/64 of an inch.

Pod Length and Weight:

Score	Pod Length in Inches	Pod Weight in Grams
1	5.1 - 5.0	7.1 - 7.0
2	4.9 - 4.8	6.9 - 6.8
3	4.7 - 4.6	6.7 - 6.6
4	4.5 - 4.4	6.5 - 6.4
5	4.3 - 4.2	6.3 - 6.2
6	4.1 - 4.0	6.1 - 6.0
7	3.9 - 3.8	5.9 - 5.8
8	3.7 - 3.6	5.7 - 5.6
9	3.5 - 3.4	5.5 - 5.4
10	Below 3.4	Below 5.4

In all of the above cases, the smaller the number, the better the quality of bean.

CHAPTER IV

RESULTS AND DISCUSSION

Phosphate Study

Plants stands in the phosphate study were counted seventeen and twenty-two days after seeding. These were taken in order to determine if any of the phosphate placements reduced germination. Plants were counted in each row, and the results calculated in per cent emergence of the total seed planted. The per cent germination by treatment is presented in Table I. Contrary to some experiments which report that phosphorus reduces bean seed germination when placed too close to the seed (14), the average per cent germination reported in Table I shows that there were very little differences due to the treatments used. According to the data in Table I, phosphate was not supplied in sufficient quantities to reduce plant stands or placed close enough to the seed to reduce germination. One of the four placements used corresponds closely to the common fertilizer practice of placing all phosphate in a band along with nitrogen and potassium. Germination of seed averaged 72.7 per cent with plant stands averaging 4.36 plants per foot of row, to 74.7 per cent germination with 4.48 plants per foot of row. The results of the germination counts show that under the conditions which the phosphate placement studies were carried out, none of the four phosphate placements affected germination to such an extent as to be undesirable.

TABLE I

THE EFFECTS OF PHOSPHATE PLACEMENT
ON THE GERMINATION OF SNAP BEANS

(AVERAGE OF FOUR REPLICATIONS)

Phosphate Treatment	Per Cent Germination	Plants Per Foot of Row
At planting, one-half under row. One-half banded.	72.7	4.36
At planting, all under row.	73.7	4.42
At planting, one-half under row. Post-emergence, one-half banded.	74.7	4.48
At planting, all banded.	72.7	4.36
L. S. D. 0.05 Level[1]	N. S.	N. S.

[1] N. S. denotes no significance as determined by the F test.

The first two harvests of snap beans from the phosphate placement study were considered as early yields and are reported in Table II. The total harvest of snap beans picked from the phosphate placement study is reported in Table III and a summary of the harvest data is presented in Table IV. As indicated in Table IV, there were no significant differences found between yields from any of the phosphate treatments. Early yields ranged between 49 per cent to 57 per cent of the total harvest. It is probable that under conditions which existed during the time of the above study, none of the nutritional factors which affects yields were limiting. Since no significance was found to exist in yields as affected by phosphate placement, any of the four phosphate placements used would be acceptable from the standpoint of early or total yields. The second and third harvests from each of the phosphate placement treatments were evaluated for quality using standards reported previously in Chapter III. A summary of these evaluations is reported in Table V. The data presented in this table indicates that some difference occurred in pod length and weight between the treatments, but when overall grades were considered, little differences were noted. Due to the grading system established for quality standards, statistical analysis of the data was not deemed necessary. The greatest variation between the average grades reported in Table V exists in pod length. Bean pods from treatments where all phosphate was placed in bands, received an average score of 3.3. Those from treatments where one-half of the phosphate was placed under the seed row, and the other one-half applied at post-emergence, were given an average score of 3.5. Beans from this

TABLE II

EFFECT OF PHOSPHATE PLACEMENT ON
EARLY YIELD OF SNAP BEANS

(BUSHELS PER ACRE)

	Replication					L.S.D.
Phosphate Placement	I	II	III	IV	Mean	.05 Level[1]
At planting, one-half under row. One-half banded.	127.4	191.9	178.1	177.2	168.0	N. S.
At planting all under row.	114.0	128.3	167.7	165.4	168.9	N. S.
At planting, one-half under row. Post-emergence, one-half banded.	184.4	187.8	149.6	191.0	178.2	N. S.
At planting, all banded.	116.5	179.7	135.6	164.3	149.0	N. S.

[1]N. S. denotes no significance as determined by the F test.

TABLE III

EFFECT OF PHOSPHATE PLACEMENT ON
TOTAL YIELD OF SNAP BEANS

(BUSHELS PER ACRE)

Treatment	Replication I	II	III	IV	Mean	L.S.D. 0.05 Level[1]
At planting, one-half under row. One-half banded.	267.2	318.0	299.8	286.6	292.9	N. S.
At planting all under row.	345.0	262.2	283.5	262.2	288.2	N. S.
At planting, one-half under row. Post-emergence, one-half banded.	307.4	336.6	295.9	350.8	322.7	N. S.
At planting, all banded.	301.6	329.4	283.4	297.7	303.0	N. S.

[1]N.S. denotes no significance as determined by the F test.

TABLE IV

COMPARISON OF EFFECT OF PHOSPHATE PLACEMENT ON EARLY AND TOTAL YIELD OF SNAP BEANS

(BUSHELS PER ACRE)

Treatment	Average of four replications. Early Yield	Total Yield
At planting, one-half under row. One-half banded.	168.0	292.9
At planting, all under row.	168.9	288.2
At planting, one-half under row. Post-emergence, one-half banded.	178.2	322.7
At planting, all banded.	149.0	303.0
L. S. D. 0.05 Level[1]	N. S.	N. S.

[1]N.S. denotes no significance as determined by the F test.

TABLE V

THE EFFECTS OF PHOSPHATE PLACEMENT
ON THE QUALITY OF SNAP BEANS

(FIGURES EXPRESSED AS AVERAGES FROM TWO HARVESTS
OF FOUR REPLICATIONS PER TREATMENT)

Quality Measured*	Treatment			
	All P_2O_5 Under Seed Row	All P_2O_5 in a band	½ P_2O_5 Under Seed Row at Planting ½ P_2O_5 as Post-emergence side-dress	½ P_2O_5 Under Seed ½ in Band
Sieve size	4.0	3.9	3.9	3.6
Straightness	3.7	3.6	4.0	3.6
Length	4.3	3.3	3.5	4.3
Fullness	3.4	3.8	3.7	3.8
Cavity size	6.3	6.4	6.0	6.1
Pod weight	4.0	3.8	3.5	5.8
Mean	4.29	4.13	4.10	4.53

*A score of one denotes the most desirable and ten denotes the least desirable score.

treatment averaged slightly shorter than those from the treatment where all phosphate was banded. A score of 4.3 for pod length is shown for the treatments where all phosphate was placed under the seed row, and where one-half was placed under the row and one-half in bands. The range in length between the best grade of 3.3 and poorest grade of 4.3 was from 4.67 inches to 4.45 inches.

Snap bean pods from the four phosphate treatments were found to vary also in average pod weight, as indicated in Table V. The best score average for pod weight was 3.5 from the phosphate treatment where one-half was applied under the row at planting and one-half applied at post-emergence. From the treatment where all phosphate was placed in a band the pods scored 3.8 for pod weight. This corresponds to a pod weight which was slightly less than the best score of 3.3. A score of 4.0 for pod weight was given beans from the treatment where all the phosphate was placed under the row. The treatment which produced bean pods weighing the least was that in which one-half of the applied phosphate was placed under the seed row at planting and the other one-half placed in bands. Pods from this treatment had an average score of 5.8. Pod weight ranged between 6.65 grams for the 3.3 score to 6.22 grams for the 5.8 score.

The average scores listed in Table V indicate that there were very little differences between sieve size, straightness, fullness of pod, or cavity size. The difference in treatment means were due mostly to variations in pod length and weight of pods, but as seen in Table IV, yields were not significantly affected.

Nitrate Study

The first two harvests of snap beans from the nitrate plots were considered as early yields and are reported in Table VI. There were no significant differences found between treatment means at the ninety-five per cent level of probability. Total yields from the nitrate plots are reported in Table VII. No significant differences were found between treatments as affected by time of nitrate placement. Early yields ranged between forty-seven to fifty-two per cent of the total harvest.

The evaluation of snap beans from the nitrate plots are reported in Table VIII. The means for the total scores show very little variation in that they vary only from 4.14 to 4.53. Average scores for length of pod varied more than any of the other scores on quality. Pods with the greatest length were harvested from the treatment where all nitrate was banded at planting. Beans from this treatment graded 3.30 for length. Where one-half of the nitrate was applied at planting, and the other one-half applied one week after emergence, the pods received an average score of 4.50 for length. This indicates an average pod length which is considerably shorter than in the above treatment where all nitrate was banded at planting. For treatments where all nitrate was banded one week after emergence, or where one-half was banded at planting and one-half banded at bloom, the average score for length was 3.50 and 3.90 consecutively. Except for affecting length of pod, no other significance can be attached to the effect of different nitrate treatments on the quality of beans in this study. Since time of nitrate placement in this study did not significantly affect bean

TABLE VI

TIME OF NITRATING EFFECT ON EARLY YIELD OF SNAP BEANS

(BUSHELS PER ACRE)

Replication	Nitrate Treatment: All Banded One Week After Emergence	One-half Banded One Week After Emergence One-half Banded at Bloom	All Banded At Planting	One-half Banded at Planting One-half Banded One Week After Emergence
I	78.2	84.2	53.4	76.0
II	85.7	103.5	79.9	77.0
III	75.5	79.9	103.5	100.4
IV	87.8	103.5	107.2	130.8
V	120.4	100.4	156.2	162.8
VI	124.0	93.1	146.9	96.8
VII	97.9	89.4	103.3	84.6
VIII	115.1	52.4	57.1	85.9
Av/Bu/Acre	98.0	88.3	100.9	101.7
L.S.D. 0.05 Level[1]	N. S.	N. S.	N. S.	N. S.

[1]N.S. denotes no significance as determined by the F test.

TABLE VII

TIME OF NITRATING EFFECT ON
TOTAL YIELDS OF SNAP BEANS

(BUSHELS PER ACRE)

Replication	All Banded One Week After Emergence	One-half Banded One Week After Emergence One-half Banded At Bloom	All Banded At Planting	One-half Banded at Planting One-half Banded One Week After Emergence
I	182.7	163.5	114.8	148.2
II	146.1	169.9	145.5	147.5
III	162.0	162.2	160.1	196.6
IV	209.0	209.0	212.8	203.4
V	218.9	235.9	261.2	339.2
VI	200.3	187.4	267.4	212.5
VII	237.7	244.3	238.3	268.5
VIII	255.7	105.7	139.0	168.6
Av/Bu/Acre	201.5	184.7	192.3	210.5
L.S.D. 0.05 Level[1]	N. S.	N. S.	N. S.	N. S.

[1]N. S. denotes no significance as determined by the F test.

TABLE VIII

TIME OF NITRATING EFFECT
ON QUALITY OF SNAP BEANS

(AVERAGE OF TWO HARVEST,
EIGHT REPLICATIONS PER TREATMENT)

Quality	Nitrate Treatment			
	All Banded at Planting	All Banded One Week After Emergence	½ Banded One Week After Emergence Banded At Bloom	½ Banded At Planting ½ banded One Week After Emergence
Sieve size	3.3	3.5	3.5	3.4
Straightness	3.7	3.8	3.9	3.9
Length	3.3	3.5	3.9	4.5
Fullness	4.8	5.0	4.6	5.0
Cavity size	5.7	5.6	5.2	5.9
Mean	4.14	4.25	4.21	4.53

yields, and since the only major difference in pod quality found was a slight increase in pod length by one treatment, any of the four placements would be acceptable under the condition of this experiment.

CHAPTER V

SUMMARY

The effects of phosphorus and nitrogen on the yield and quality of snap beans were studied during the spring and summer of 1957.

The data presented show that at the same level of fertilization, there is no practical significant difference due to placement in respect to yield, either early or total, or to quality of beans, except possibly length of pod and weight of pod, in which cases the data were insufficient for exact analysis.

The placement of phosphorus and nitrogen on fertile land, when the moisture supply is ample, does not significantly modify yields. It seems probable that if the amount of nutrients believed to be required by the bean crop is applied in any of the methods investigated, equally good results may be expected. Therefore, the simplest and least costly method of fertilizer application should be employed.

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