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DIFFERENTIAL RESPONSE OF VEGETABLE SOYBEAN VARIETIES TO FERTILITY LEVELS AND SEASONS

A THESIS SUBMITTED TO THE GRADUATE SCHOOL OF THE
UNIVERSITY OF HAWAII IN PARTIAL FULFILLMENT
OF THE REQUIREMENTS FOR THE DEGREE OF
MASTER OF SCIENCE

JUNE, 1963

by

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ACKNOWLEDGMENTS

I wish to express my sincere appreciation to the East-West Center for the grant which made my stay possible at the University of Hawaii to pursue my Master of Science Degree.

I would similarly like to express my gratitude and appreciation for the advice and guidance given by the members of my Thesis Committee: Dr. James C. Gilbert, Chairman of the Committee, Dr. Robert M. Warner and Dr. Roman R. Romanowski, Department of Horticulture, and Dr. Robert L. Fox of the Soil Science Department. Thanks are also extended to Dr. James L. Brewbaker and Dr. Thomas Sheehan of the Horticulture Department, University of Hawaii, for their help with the thesis.

DIFFERENTIAL RESPONSE OF VEGETABLE SOYBEAN (GLYCINE MAX.) VARIETIES TO FERTILITY LEVELS AND SEASONS

INTRODUCTION

One of the problems confronting soybean growers in Hawaii is seasonal production. Soybeans are very sensitive to daylength. Early maturing varieties which have good eating qualities and which produce desirable plant size on the islands in the late spring and summer will be too short if planted in late fall and winter. On the other hand late maturing varieties, like the Seminole variety, will grow and attain a height acceptable for the fresh market during late fall and winter. However, Seminole may be late maturing and over vegetative during long daylength seasons. Seminole is now rarely planted in Hawaii and seed is no longer available locally. Furthermore, an attempt to ask farmers to use different varieties for different growing seasons has not succeeded. Thus, growers in Hawaii are particularly interested in any specific cultural practice which can minimize severe dwarfing effects of a shortened daylength on early maturing varieties during late fall and winter.

This problem is not only important from the economic standpoint, but it is also of physiological interest because dwarfing of the early maturing varieties during the short daylength seasons is closely associated with certain factors in the external environment of the plants. The most likely of these are: daylength, light intensity, temperature, soil moisture and nutrients available in the soil.

This study involves an attempt to use an early variety of soybean in the late fall and winter without the adverse severe dwarfing effects of the shortened daylength. Bansei is the most popular early vegetable type soybean variety in the Islands because of its excellent table qualities. However, dwarfing during the short daylength season is a serious problem with this variety. The purpose of the experiments reported here was to learn whether a fertilizer treatment could be found which will overcome the dwarfing effect of the short winter daylength. If so, this variety could be locally grown in all seasons for vegetable purposes.

REVIEW OF LITERATURE

The soybean plant is very sensitive to daylength. Garner and Allard (1920) reported that when daylengths were short, 12 hours or less, the date of the first bloom of early maturing varieties was reduced slightly as compared with later maturing varieties. Later reports by Garner and Allard (1930) indicated that daylengths of 9-1/2 to 12 hours showed no selective action on flowering of the different varieties. However, increasing daylength resulted in a distinct selection on varieties of soybeans. In the same report, Garner and Allard further indicated that when soybeans were exposed to warm temperatures and short days, all varieties responded as early maturing varieties. These conditions are prevalent in the Hawaiian Islands during late fall and early winter and the stature of the Bansei variety is too short for the fresh market.

Jacob and Uexkull (1960) in their text book reported that applications of phosphate accelerates ripening, but applications of nitrogenous fertilizer delays ripening of crops to some extent.

Camper and Smith (1958) reported that the maturing of soybeans is affected by daylength, temperature and moisture; however, season and date of planting had considerably more effect on plant height than any other factor. Weiss et al. (1950) emphasized that varieties respond differently to date of planting, but in general delayed planting in the spring produces less plant height.

Etheridge and Helm (1922) in testing soybean varieties on a wide range of soil types and fertility levels in Missouri found a differential response of varieties in different localities. In general the application of fertilizer, lime and manure to corn and wheat in the same rotation increased the yields of soybeans especially on soils of medium to low fertility.

Poehlman (1937) showed that season may have an important bearing on the comparative yields of soybeans and he suggests that soil fertility is probably one of the most important factors in determining the behavior of soybean varieties.

Ferguson and Albrecht (1941) emphasized that legumes are especially exacting in their requirement for calcium. This is well demonstrated by the fact that liming of soil low in calcium is an essential practice in order to insure healthy nodule formation. Ferguson et al. further showed that nitrogen fixation and nodule formation increased from the lowest to the highest level of potassium.

According to Fellers (1918), soybeans like most other legumes, draw heavily upon the stores of mineral plant food in the soil. Fertilizers, especially in the form of phosphorus containing materials, are quite essential to the production of maximum yields of soybeans. He also stated that the application of acid phosphate to soybeans gave increased yields if ample lime was present in the soil.

MATERIALS AND METHODS

Four experiments were conducted to study differential growth response of two soybean varieties, Bansei an early maturing Group II and Seminole a late maturing Group VIII (1927) to varied combinations of nitrogen, phosphorus and potassium fertilization during the short daylength period in Hawaii.

Soil samples of the experimental area were collected prior to the trials and sent to the Soils Science Department, University of Hawaii, for testing. The results are presented in Table 1.

The soil belongs to the Waimanalo family in the low humic latosols. The "A" horizon is dark gray silty clay, very hard when dry and fairly sticky when wet. The "B" horizon has poor internal drainage.

The area previously grew Pangola grass. Fertilizer (N-33 P-144 K-97) was applied at 400 pounds per acre at the beginning of the grass planting with no further fertilization for a period of five years. The whole field was considered as infertile before the soybean trials were initiated.

Bansei and Seminole varieties were sown on four planting dates in separate experiments at two-week intervals in Field R-1 at Waimanalo Branch Experiment Station, University of Hawaii.

Experiment No. 1 ... September 20, 1962

Experiment No. 2 ... October 4, 1962

Experiment No. 3 ... October 18, 1962

Experiment No. 4 ... November 1, 1962

Table 1. Results of Soil Tests, August 6, 1962.

Soil Samples	pH	Phosphorus (P) lbs/A	Potassium (K) lbs/A	Calcium (Ca) lbs/A
Experiment No. 1	6.2	Trace, Poor	Less than 40 Very poor	1000, Poor
Experiment No. 2	6.3	Trace, Poor	Less than 40 Very poor	1000, Poor
Experiment No. 3	6.4	Trace, Poor	Less than 40 Very poor	500, Very poor
Experiment No. 4	6.3	Trace, Poor	Less than 40 Very poor	500, Very poor

A randomized complete block design was used with a 2 x 3 x 3 x 3 factorial arrangement of treatments. The factors involved in the experiments are listed below:

Varieties ... Bansei (V_1) and Seminole (V_2).

Nitrogen ... 0 (N_0), 50 (N_1) and 100 (N_2) pounds per acre.

Phosphorus ... 0 (P_0), 50 (P_1) and 100 (P_2) pounds per acre.

Potassium ... 0 (K_0), 100 (K_1) and 200 (K_2) pounds per acre.

Each experiment was replicated three times and the treatments were rerandomized for each experiment.

Each plot was four and one-half feet wide, twelve feet long with a three-foot interspacing between plots within the same row. Only the center eight feet of the plot was harvested for sampling. The area of one block was 90 x 45 square feet.

Ammonium sulfate, ordinary superphosphate and muriate of potash were used as sources of N, P and K. The fertilizer was applied just prior to the sowing of the seeds in all experiments. The method of applying fertilizer was in a narrow band about two inches below and two inches to one side of the seeds on the inside of the bed. Figure 1 shows the position of fertilizers applied in the field.

Before sowing, the seeds were treated with Spergon to prevent damping off. Seeds were sown one and a half inches apart and thinned to three inches

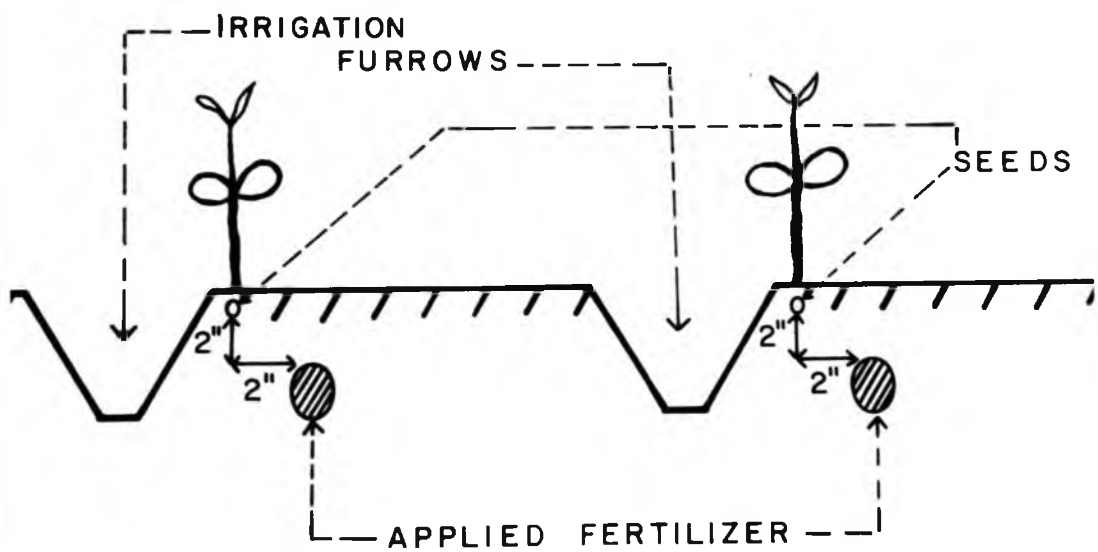

Figure 1. Diagram of the position of fertilizer applied in the field.

soon after emergence. Additional seeds were sown in jiffy pots at each planting to allow timely replacements in case of poor stands in the field.

After germination a bird banger was used during the first two weeks to keep birds from damaging the young seedling. A small garden tractor was used between the rows and hand hoeing was used between plants and furrows to keep the area free of competitive weeds. Damage from insects and pests was considerably decreased by using DDT and Diazinon sprays at weekly intervals. Dithane Z-78 was used occasionally as a fungicide when needed. Furrow irrigation was applied weekly at the early stages of growth. The irrigations were reduced to one every other week after the fourth week. By this time the plants had well developed root systems.

Observations were made throughout the growing season. All plots of the same variety within the same planting date were harvested when half of the leaves dropped and the pods turned brown but before any seed drop occurred in the field. The center eight feet of each row was harvested for sampling. Plants were tied in bunches and transported to the vegetable laboratory, Horticulture Department (Manoa campus), where the pods were removed and dried on the same day.

After harvesting, pods of each treatment were placed in paper bags and dried in the oven at 78 degrees Centigrade for 24 hours. After threshing all dry beans were exposed to the air for seven days before taking the weight of dry beans and weight of 100 seeds. Plant heights were measured from the first node to the growing point.

Plant height data, yield of dry beans and weight of 100 seeds were recorded. All the data were submitted to an analysis of variance according to Snedecor's Statistical Methods (1957) and Chang's Experimental Design (1958).

The air temperatures for the soybean plantings were recorded daily at a weather shelter nearby. Daily maximum and minimum temperatures and precipitation are presented in Figure 2. Annual average rainfall is about 50 inches at Waimanalo Experimental Farm.

Experiment No. 4 experienced unfavorable weather conditions. Gusty winds accompanied by heavy rain from December 14-19 flooded the area and deposited mud just when the young plants were starting to develop seeds in the pods. No data were obtained from Experiment No. 4.

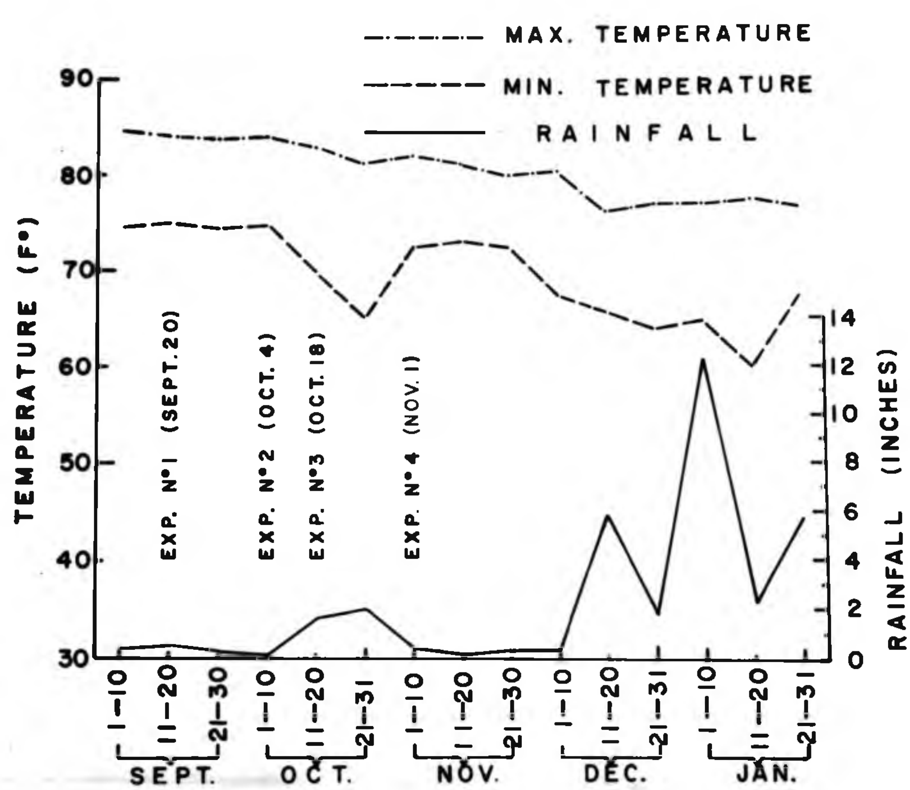

Figure 2. Maximum and minimum temperatures and rainfall at Waimanalo Branch Experiment Station (Sept. 1962 to June 1963).

RESULTS

The experimental results were divided into two parts. First, field observations were made throughout the growing season. Second, after harvest, measurements were taken of plant height, yield of dry beans and weight per 100 seeds.

The complete harvest records are presented in Appendix Tables II, IV and VI. Each of these data was subjected to an analysis of variance and presented in figures and graphs.

Field Observations

Field observations established that plants in all three experiments were strong and erect; no lodging was observed. The Seminole variety appeared taller than BANSEI in all plantings. This impression was not always consistent with the yield measurement, a discrepancy caused by the fact that Seminole had larger leaves with longer petioles than Bansei.

Visual observations indicated that plots of both varieties which received N_1 and N_2 were darker green than the plots receiving N_0. Color differences were particularly noticeable during the early stages of growth but became less obvious as the plants matured.

Bansei flowered 10 to 13 days earlier than Seminole in all three experiments. The flowering dates were determined by visual observations and are reported in Table 2. Appropriate harvest dates for the green beans were rather difficult to estimate. Bansei was estimated to be ready for green bean harvest 12 to 15 days before Seminole in the three experiments. This coincides approximately with the time intervals between flowering dates presented above. A similar differential was also observed in dry bean harvest. Bansei mature 16 days earlier than Seminole in Experiment No. 1, 13 days in Experiment No. 2 and 14 days in Experiment No. 3 (Table 2).

Table 2. Date of flowering, estimated date of green bean harvest and actual date of dry bean harvest for the soybean varieties.

	Experiment No. 1		Experiment No. 2		Experiment No. 3	
	Bansei	Seminole	Bansei	Seminole	Bansei	Seminole
Date of planting	September 20, 1962		October 4, 1962		October 18, 1962	
Flowering date	Oct. 14	Oct. 27	Oct. 27	Nov. 7	Nov. 10	Nov. 20
No. of days from sowing	24 days	37 days	23 days	33 days	22 days	32 days
Estimated date of harvest for green beans	Nov. 15	Nov. 30	Nov. 30	Dec. 3	Dec. 12	Dec. 24
No. of days from sowing	55 days	70 days	56 days	69 days	54 days	66 days
Dry bean harvest date	Dec. 19	Jan. 4, 1963	Jan. 4	Jan. 14	Jan. 14	Jan. 28
No. of days from sowing	89 days	108 days	89 days	108 days	86 days	100 days

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At the time of dry seed harvest, plots which had received nitrogen appeared to mature later than plots which had received no nitrogen. Phosphate and potash fertilized beans dried out more quickly than beans which received only nitrogen.

Harvest Data

A. The effect of treatments on plant height.

Harvested plants were stripped of leaves and pods and plant height was measured from the first node to the top of the growing point. All plant height data were subjected to analysis of variance. These data are presented in Appendix Table I.

The varietal difference in plant height was significant in Experiment No. 1. The treatment mean for Bansei was 26.0 cm. and Seminole 28.9 cm. Observation of these varieties during long days of the previous summer had indicated greater difference between Bansei and Seminole[a]. Bansei had attained a height of 29.9 cm. whereas Seminole had attained a height of 41.7 cm. (Appendix Figures I and II). Plants treated with nitrogen fertilizer showed marked increases in plant height in Experiment No. 1. Plant height differences among nitrogen treated plots are presented in Table 3 and Figure 3.

(a) Unpublished data from an experiment conducted at the University of Hawaii, H.A.E.S., Waimanalo Experimental Farm in June, 1962.

Table 3. The influence of nitrogen on the height of soybean plants in Experiment No. 1 (September 20, 1962).

	N_1	N_2
N_0	** 1.83 cm	** 1.37 cm
N_1	--	-0.46 cm

** 1% significance by $\bar{D}_{.01}$ test.

The first increment of nitrogen was associated with maximum plant height. The difference in plant height between the N_1 and N_2 levels was not significant. The NK interaction was significant. The means of plant height with minimum significant ranges of Duncanized multiple comparison are given in Table 4.

Mean values connected with bond bars are not significantly different. At the bottom of the table are minimum significant ranges (Rp) for the 5% and 1% probability levels. At K_0 plant heights were significantly increased from N_0 to N_2. But at K_1 and K_2 there was no significant difference in plant height among nitrogen levels.

In Experiment No. 2 differences in plant height between varieties which had occurred in Experiment No. 1 were not detected. The effect of nitrogen fertilization upon plant height was significant (Appendix Table I). Plant height differences among nitrogen treated plots are presented in Table 5.

Table 4. Duncanized ranges for NK multiple comparison of plant height, Experiment No. 1.

DUNCANIZED RANGES

Treatments	Means	Bars 5%		Bars 1%	
N_0K_0	25.49 cm	│		│	
N_2K_1	26.34	│	│	│	│
N_0K_1	26.68	│	│	│	│
N_0K_2	27.03	│	│	│	│
N_2K_2	27.36	│	│	│	│
N_1K_1	27.78	│	│	│	│
N_1K_2	28.34	│	│	│	│
N_1K_0	28.66		│	│	│
N_2K_0	29.41		│		│

Interval Means of		2	3	4	5	6	7	8	9
Rp values	1%	3.34	3.47	3.58	3.65	3.70	3.75	3.79	3.82
	5%	2.52	2.66	2.75	2.81	2.86	2.90	2.93	2.96

Table 5. Differences in plant height among nitrogen treated plots, Experiment No. 2 (Oct. 4).

	N_1	N_2
N_0	** 1.70 cm	0.92 cm
N_1	--	-0.78 cm

** 1% significance by $\bar{D}_{.01}$ test.

Plants treated with the first increment of nitrogen produced maximum plant height. Bansei and Seminole showed similar plant height curves in response to nitrogen levels (Figure 4).

No significant differences in varieties were seen in Experiment No. 3. However, significant differences in N and K main effects were measured. Plant height differences among nitrogen treated plots are presented in Table 6. The N_2 level of nitrogen had no effect on plant height.

Table 6. Differences in plant height among nitrogen treated plots, Experiment No. 3 (Oct. 18).

	N_1	N_2
N_0	* 0.48 cm	* 0.47 cm
N_1	--	-0.01 cm

* 5% significance by $\bar{D}_{.05}$ test.

The potassium fertilizer effect on plant height in Experiment No. 3 is presented in Table 7.

Table 7. Differences in plant height among potassium treated plots, Experiment No. 3.

	K_1	K_2
K_0	0.21 cm	-0.42 cm
K_1	--	-0.63 cm*

* 5% significance by $\bar{D}_{.05}$ test.

There were no significant differences in plant heights between K_0 and K_1 levels. K_2 significantly reduced plant height. The PK interaction was significant in Experiment No. 3 and the Duncanized multiple comparison is presented in Table 8. However, the PK interaction was inconsistent.

Table 8. Duncanized ranges for PK multiple comparison of plant height in centimeters, Experiment No. 3.

P_2K_1	P_2K_2	P_0K_0	P_1K_1	P_1K_0	P_0K_1	P_0K_2	P_2K_0	P_1K_2
22.60	22.68	23.08	23.18	23.38	23.39	23.44	23.44	24.06

Intervals Means of	2	3	4	5	6	7	8	9
Rp values 5%	1.23	1.30	1.34	1.37	1.40	1.42	1.43	1.45

The VN (variety x nitrogen) interaction was significant in this experiment. Comparisons between Bansei (V_1) and Seminole (V_2) in response to nitrogen levels are presented in Table 9 and Figure 5.

Table 9. Differences in plant height among nitrogen levels, Experiment No. 3.

	N_1	N_2
V_1N_0	0.12 cm	-0.08 cm
V_1N_1	--	-0.20 cm
V_2N_0	0.85** cm	1.02** cm
V_2N_1	--	0.17 cm

** 1% significance by $\bar{D}_{.01}$ test.

Nitrogen levels had a greater effect on Seminole than Bansei. There was a significant increase in height on Seminole between N_0 and N_1, whereas additional increments had no effect. There were no differences in height of Bansei at any level of N.

B. The effect of treatments on the yield of dry beans (seeds).

The yield of dry beans was obtained by harvesting at the stage of maturity when about half of the leaves dropped off, pods turned brown and before seed drop occurred. The results of the harvest of dry beans were presented in Appendix Table IV. All the data were subjected to an analysis of variance which is presented in Appendix Table III.

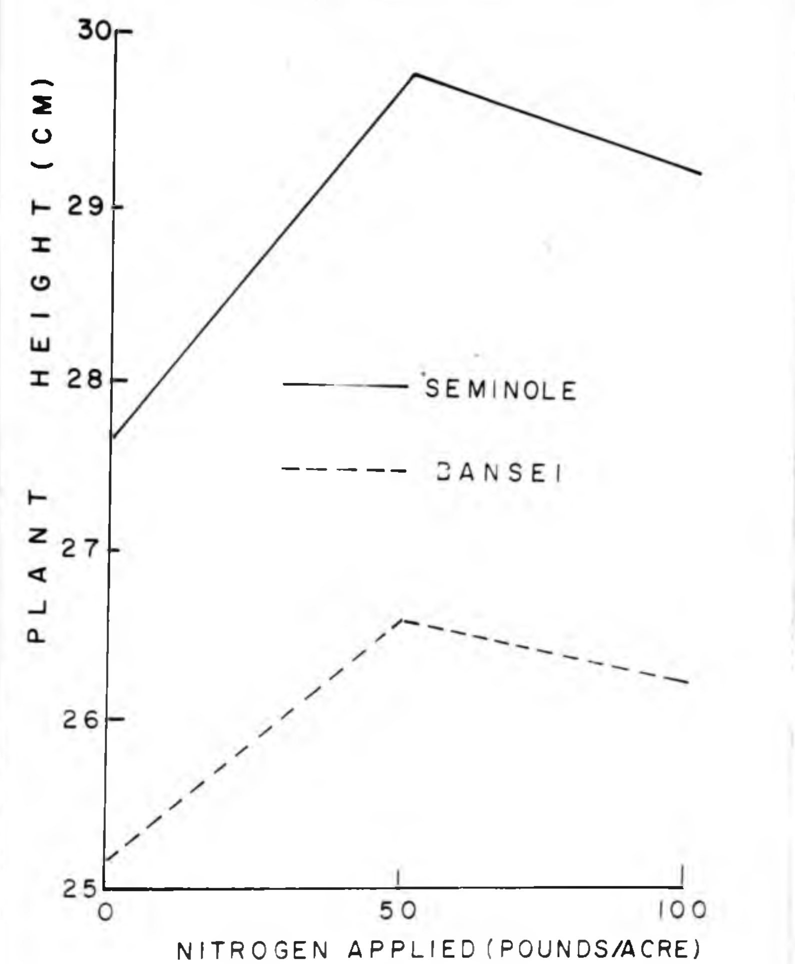

Figure 3. The influence of nitrogen on the height of soybean plants in Experiment No. 1 (September 20, 1962).

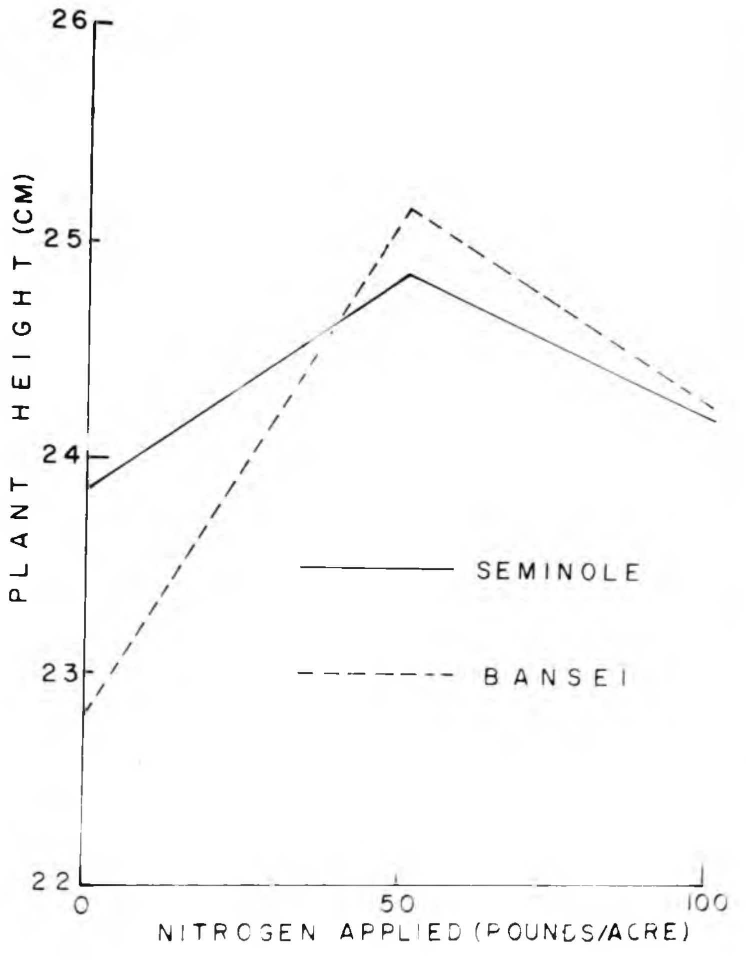

Figure 4. The influence of nitrogen fertilizer on the height of soybean plants in Experiment No. 2 (October 4, 1962).

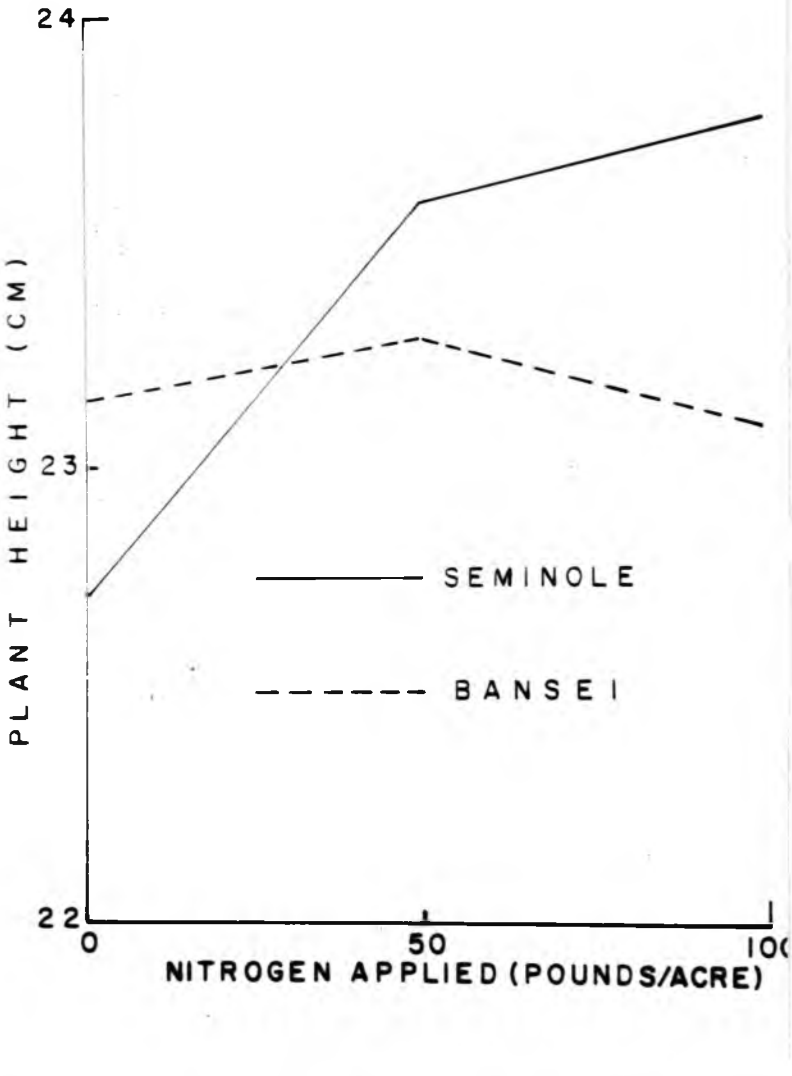

Figure 5. The influence of nitrogen on the height of soybean plants in Experiment No. 3 (October 18, 1962).

The analysis of variance shows that the varietal difference was significant in Experiment No. 1. The VN interaction was also significant and is presented in Table 10 and Figure 6.

Table 10. Differences in yields of dry beans among nitrogen levels, Experiment No. 1.

	N_1	N_2
V_1N_0	** 85.2 grams	** 104.6 grams
V_1N_1	--	** 20.4 grams
V_2N_0	** 56.8 grams	** 63.5 grams
V_2N_1	--	6.7 grams

** 1% significance by $\bar{D}_{.01}$ test.

Bansei and Seminole produced maximum yields of dry beans at the N_2 level. All differences were significant except Seminole at the N_1 to N_2 levels. The VP interaction was significant and is presented in Table 11 and Figure 7.

Table 11. Differences in yields of dry beans among phosphate levels, Experiment No. 1.

	P_1	P_2
V_1P_0	10.5 grams	22.3 grams**
V_1P_1	--	11.8 grams
V_2P_0	-30.5 grams**	-11.2 grams
V_2P_1	--	19.3 grams**

** 1% significance by $\bar{D}_{.01}$ test.

The Banasi variety produced the maximum yield of dry beans at the P_2 level. Whereas, Seminole produced maximum yields at the P_0 level and there was no significant increase in the yield of dry beans from P_0 to P_2.

The nitrogen main effect was significant in Experiment No. 1 and is presented in Table 12.

Table 12. Differences in yield of dry beans among nitrogen treated plots, Experiment No. 1.

	N_1	N_2
N_0	70.4 grams**	83.9 grams**
N_1	--	13.5 grams*

* 5% significance by $\bar{D}_{.05}$ test.

** 1% significance by $\bar{D}_{.01}$ test.

Yield of dry beans progressively increased as the amount of applied nitrogen increased.

The K treatment associated with significant differences in yield of dry beans are presented in Table 13.

Table 13. Differences in yield of dry beans for potassium treated plots, Experiment No. 1.

	K_1	K_2
K_0	-17.2 grams*	-9.0 grams
K_1	--	12.2 grams

* 5% significance by $\bar{D}_{.05}$ test.

The application of potassium reduced the yield of dry beans in Experiment No. 1. However, the data also indicated a significant difference in the NK interaction which is presented in Table 14.

Table 14. Duncanized ranges for NK multiple comparison of of yield of dry beans, Experiment No. 1.

N_0K_1	N_0K_0	N_0K_2	N_2K_1	N_1K_2	N_1K_1	N_1K_0	N_2K_2	N_2K_0	
297.6	305.0	316.4	371.8	372.6	378.6	378.8	383.2	415.7	grams

Intervals Means of	2	3	4	5	6	7	8	9
Rp values 5%	40.0	42.2	43.6	44.8	45.5	46.0	46.6	47.0

Potassium had less effect in this NK interaction. In fact, it clearly showed that the differences in yield of dry beans in this interaction was mainly because of the nitrogen effect.

There was no varietal difference in Experiment No. 2. However as in Experiment No. 1, the nitrogen effect was significant. Differences among yields of dry beans in variously nitrogen treated plots are contained in Table 15 and illustrated in Figure 8.

Table 15. Differences in yield of dry beans for nitrogen treated plots, Experiment No. 2.

	N_1	N_2
N_0	45.4 grams**	61.4 grams**
N_1	--	16.0 grams*

* 5% significance by $\bar{D}_{.05}$ test.

** 1% significance by $\bar{D}_{.01}$ test.

Yield of dry beans increased from N_0 to N_2. In addition phosphate fertilizer increased the yield of dry beans in Experiment No. 2. Table 16 and Figure 9 contain the yield differences among superphosphate treated plots.

Table 16. Differences in the yield of dry beans among superphosphate treated plots, Experiment No. 2.

	P_1	P_2
P_0	** 21.5 grams	11.1 grams
P_1	--	-10.4 grams

** 1% significance by $\bar{D}_{.01}$ test.

Bansei and Seminole produced maximum yields of dry beans at the P_1 level. The NPK interaction was significantly different at the 5% level.

In Experiment No. 3, Bansei and Seminole responded to the nitrogen treatments as in the two previous experiments but on a reduced scale. The data are summarized in Table 17 and Figure 10.

Table 17. Differences among the yield of dry beans among nitrogen treated plots, Experiment No. 3.

	N_1	N_2
N_0	** 23.2 grams	** 30.0 grams
N_1	--	6.9 grams

** 1% significance by $\bar{D}_{.01}$ test.

The first increment of nitrogen fertilization was related to a marked increase in the yield of dry beans. However, there was no significant increase in the yield of dry beans from the second increment of N. Here again the varietal difference was significant; Seminole did not respond as much as Bansei. The VP interaction was also significant. Yield differences between the Bansei and Seminole varieties in response to the phosphate fertilizer are presented in Figure 11 and Table 18.

Table 18. Differences in yield of dry beans among phosphate levels, Experiment No. 3.

	P_1	P_2
V_1P_0	9.7 grams	16.8** grams
V_1P_1	--	7.1 grams
V_2P_0	-1.8 grams	-3.9 grams
V_2P_1	--	-2.1 grams

** 1% significance by $\bar{D}_{.01}$ test.

Bansei responded with a significant increase in yield at the high level of P. The K main effect on the yield of dry beans were significant at the 5% level in Experiment No. 3. A summary of these data is presented in Table 19.

Table 19. Differences in the yield of dry beans among potassium treated plots, Experiment No. 3.

	K_1	K_2
K_0	4.0 grams	-7.2 grams
K_1	--	-11.2 grams*

* 5% significance by $\bar{D}_{.05}$ test.

There were no significant differences in yields between the K_0 and K_1 or K_2 treatments, but the K_2 level resulted in decreased yield when composed with K_1. The PK interaction was significant in Experiment No. 3. Duncanized ranges for the multiple comparisons in Table 20 show that the interaction was inconsistent.

C. The effect of treatments on the weight of 100 seeds.

The analysis of variance for seed weight is presented in Appendix Table V. Varietal differences were significant in all three experiments. However, the VN interaction was significant only in Experiment No. 1. A summary of seed weight data are presented in Table 21 and Figure 12.

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Table 20. Duncanized ranges for PK multiple comparison of yield of dry beans in Experiment No. 3.

DUNCANIZED RANGES

Treatments	Means	Bars 5%			Bars 1%		
P_2K_2	174.5 grams	│			│		
P_0K_0	181.8	│	│		│	│	
P_1K_2	182.6	│	│		│	│	
P_0K_1	183.2	│	│		│	│	
P_0K_2	188.1	│	│		│	│	
P_1K_1	189.0		│		│	│	│
P_2K_0	191.4		│		│	│	│
P_1K_0	193.3		│	│		│	│
P_2K_1	206.6			│			│

Intervals Means of		2	3	4	5	6	7	8	9
Rp values	1%	15.6	16.2	16.7	17.1	17.3	17.5	17.7	17.9
	5%	11.8	12.4	12.8	13.1	13.4	13.5	13.7	13.8

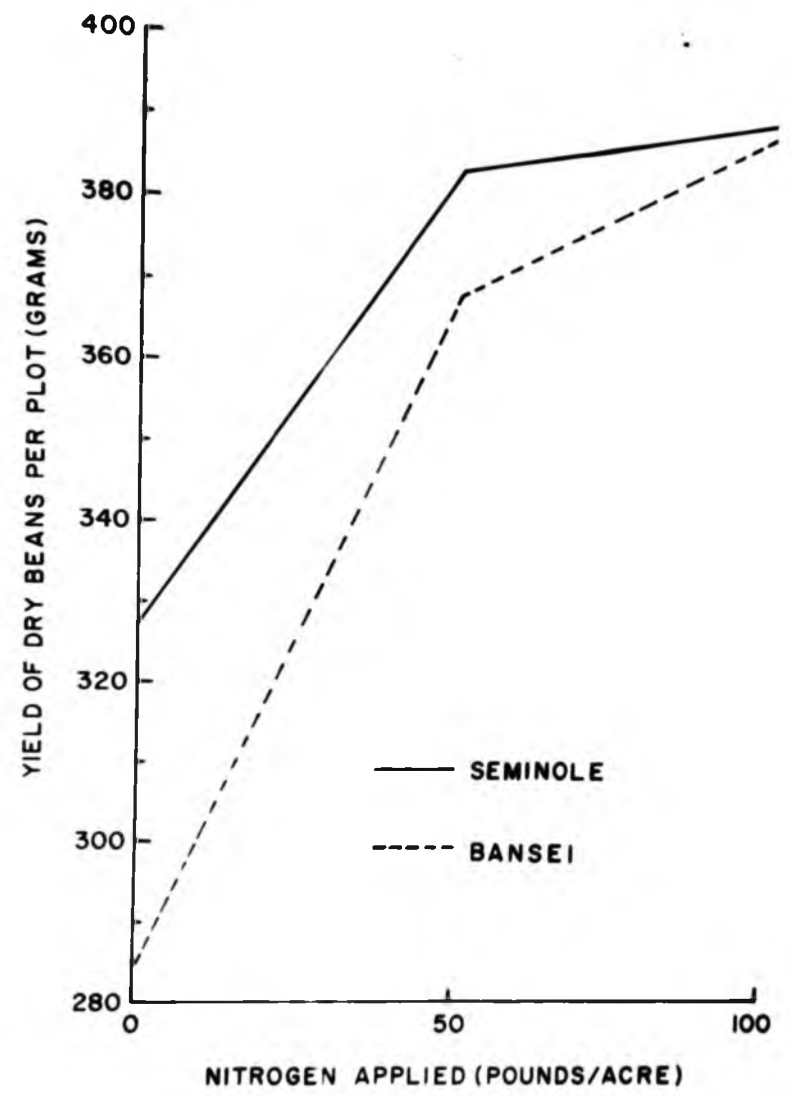

Figure 6. The influence of nitrogen fertilizer on the yield of dry beans, Experiment No. 1.

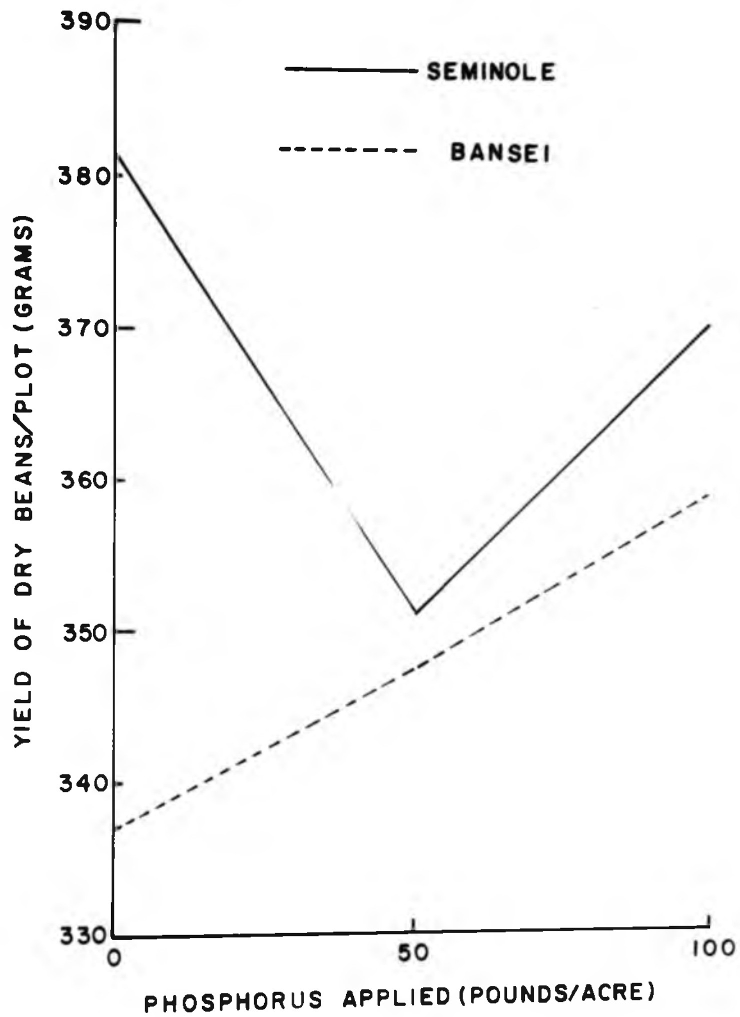

Figure 7. The influence of superphosphate fertilizer on the yield of dry bean, Experiment No. 1.

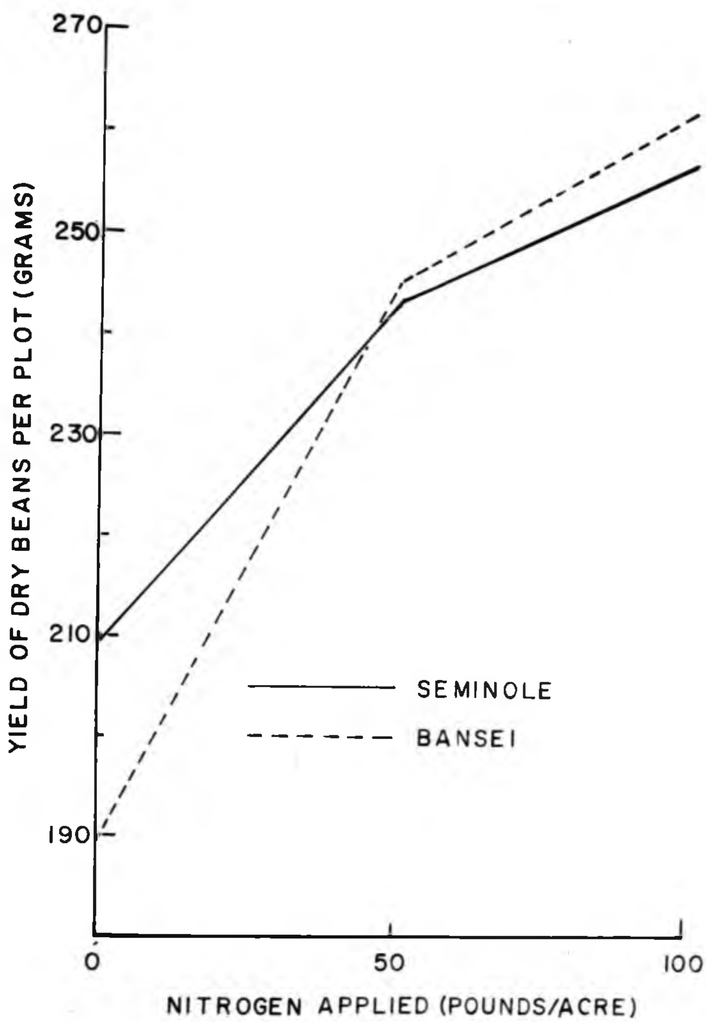

Figure 8. The influence of nitrogen fertilizer on the yield of dry beans, Experiment No. 2.

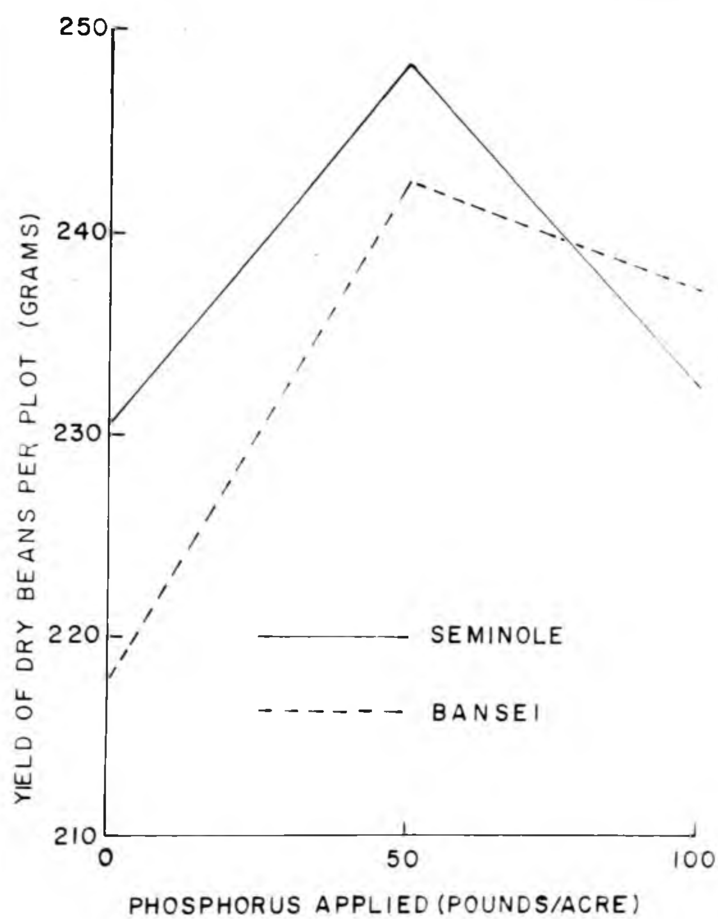

Figure 9. The influence of superphosphate fertilizer on the yield of dry beans, Experiment No. 2.

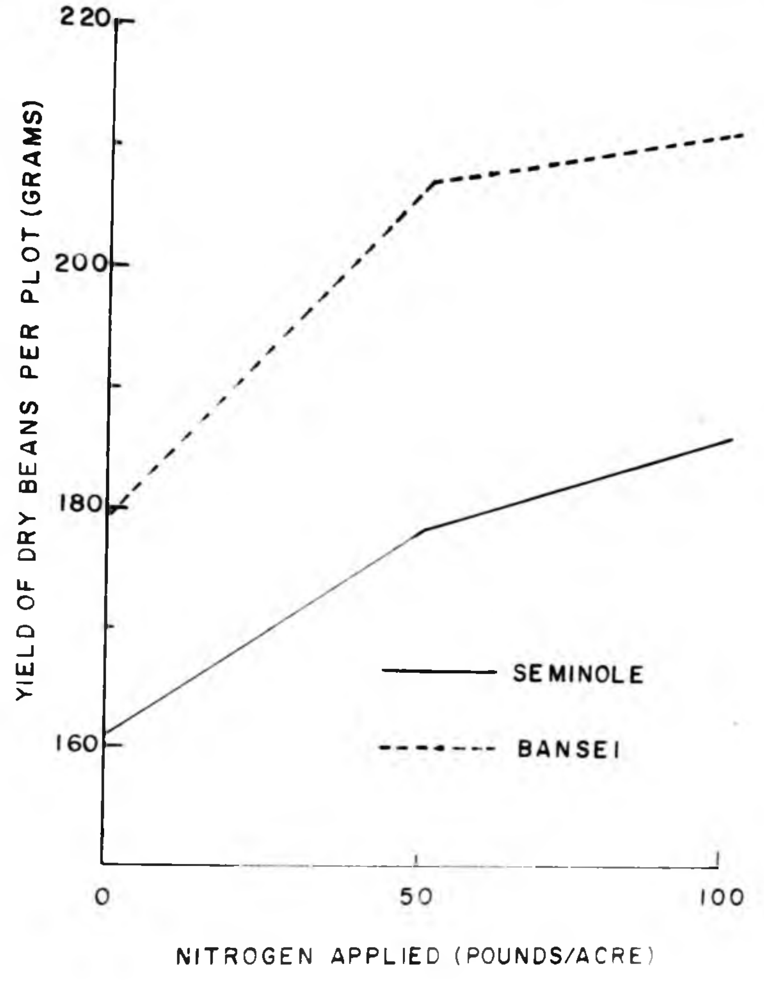

Figure 10. The influence of nitrogen fertilizer on the yield of dry beans, Experiment No. 3.

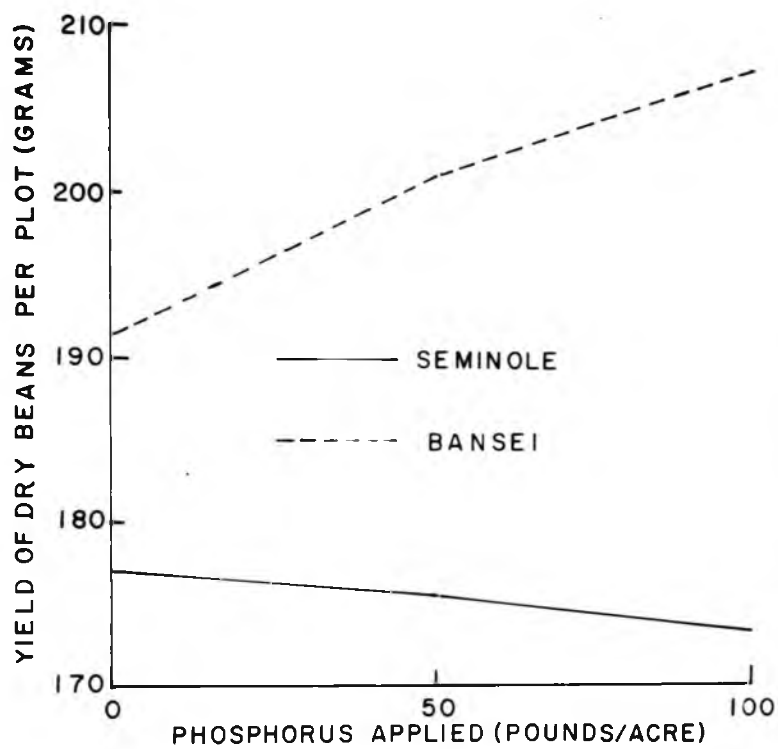

Figure 11. The influence of superphosphate fertilizer on the yield of dry beans, Experiment No. 3.

Table 21. Differences in weight per 100 seeds among nitrogen levels, Experiment No. 1.

	N_1	N_2
V_1N_0	** 4.34 grams	** 5.37 grams
V_1N_1	--	** 1.03 grams
V_2N_0	** 2.55 grams	** 2.97 grams
V_2N_1	--	0.45 grams

** 1% significance by $\bar{D}_{.01}$ test.

At each level of N there was a significant increase in the weight of 100 seeds with Bansei. Seminole produced a significant increase in weight to N_1 with additional increments of N having no effect. Duncanized multiple comparison are found in Table 22 for the NP interaction. It clearly shows that the effect of nitrogen had dominated the NP interaction.

Table 22. Duncanized ranges for NP multiple comparison of weight of 100 seeds, Experiment No. 1.

N_0P_2	N_0P_0	N_0P_1	N_1P_0	N_2P_0	N_1P_1	N_1P_2	N_2P_1	N_2P_2
30.33	31.44	31.56	33.87	34.52	34.74	35.05	35.51	35.80 grams

Intervals Means of	2	3	4	5	6	7	8	9
Rp values 5%	2.04	2.15	2.23	2.28	2.32	2.36	2.38	2.40

In Experiment No. 2 the nitrogen main effect was significant. The data are presented in Table 23 and Figure 13.

Table 23. Differences in the weight of 100 seeds among nitrogen treated plots, Experiment No. 2.

	N_1	N_2
N_0	2.36** grams	3.24** grams
N_1	--	0.88** grams

** 1% significance by $\bar{D}_{.01}$ test.

The weight of 100 seeds was progressively increased from N_0 to N_2. There was also a NP interaction in Experiment No. 2 (Table 24). The data in the table repeat the trend of the dominanting effect of nitrogen as in Experiment No. 1.

Table 24. Duncanized ranges for NP multiple comparison of the weight of 100 seeds, Experiment No. 2.

N_0P_2	N_0P_1	N_0P_0	N_1P_1	N_1P_0	N_1P_2	N_2P_0	N_2P_1	N_2P_2
30.71	30.81	30.92	32.93	33.21	33.37	33.39	34.27	34.28 grams

Intervals Means of		2	3	4	5	6	7	8	9
Rp values	1%	1.86	1.93	1.99	2.03	2.06	2.08	2.10	2.12

In Experiment No. 3 the main effect of nitrogen was significant as it was in Experiments 1 and 2. The data are presented in Table 25 and illustrated in Figure 14. The N_1 level resulted in a significant increase in the weight of 100 seeds over N_0, whereas additional increments of N had no effect.

Table 25. Differences in the weight of 100 seeds among nitrogen treated plots, Experiment No. 3.

	N_1	N_2
N_0	1.87** grams	2.03** grams
N_1	--	0.16 grams

** 1% significance by $\bar{D}_{.01}$ test.

The K main effect was significant at the 5% level in Experiment No. 3 and is presented in Table 26.

Table 26. Differences in the weight of 100 seeds among potassium treated plots, Experiment No. 3.

	K_1	K_2
K_0	-0.61* grams	-0.66* grams
K_1	--	-0.05 grams

* significance by $\bar{D}_{.05}$ test.

A significant decrease in the weight of 100 seeds was obtained from K_0 to K_2; however, no significant difference was found between K_1 and K_2.

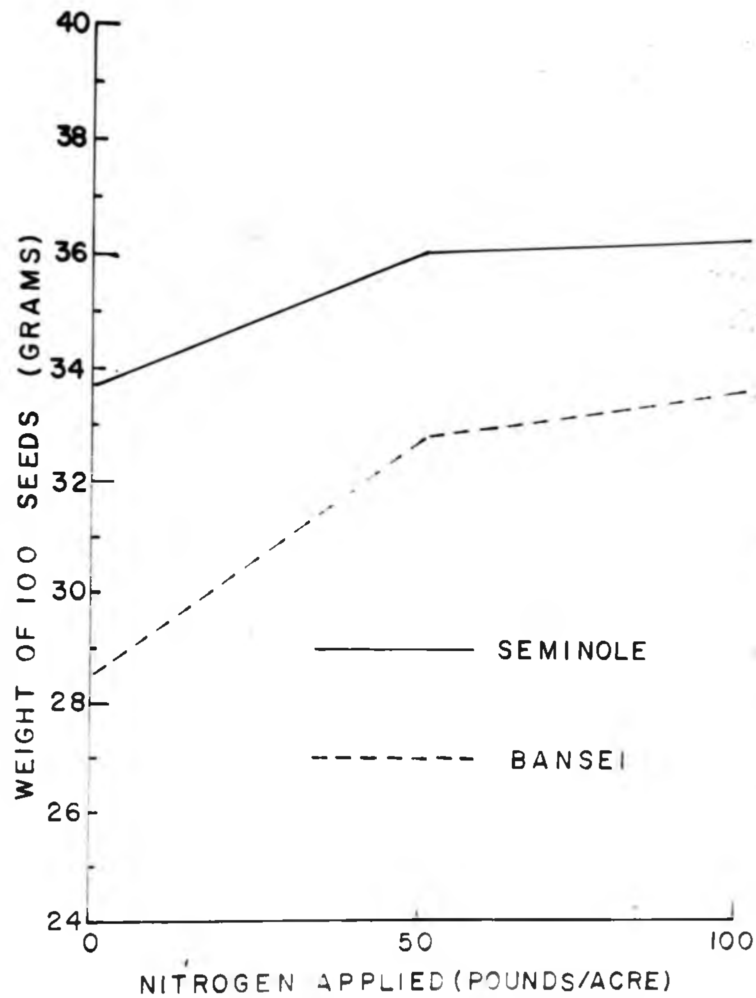

Figure 12. The influence of nitrogen fertilizer on the weight per 100 seeds, Experiment No. 1.

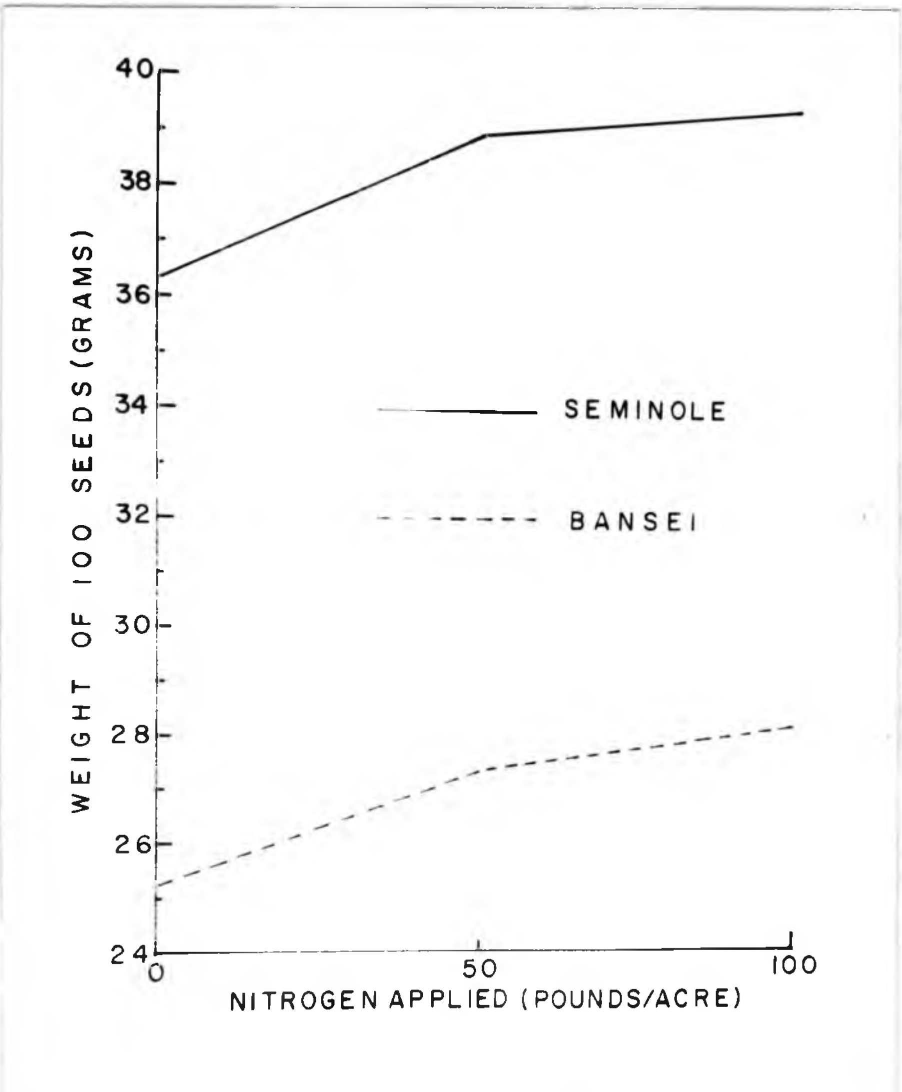

Figure 13. The influence of nitrogen fertilizer on the weight per 100 seeds, Experiment No. 2.

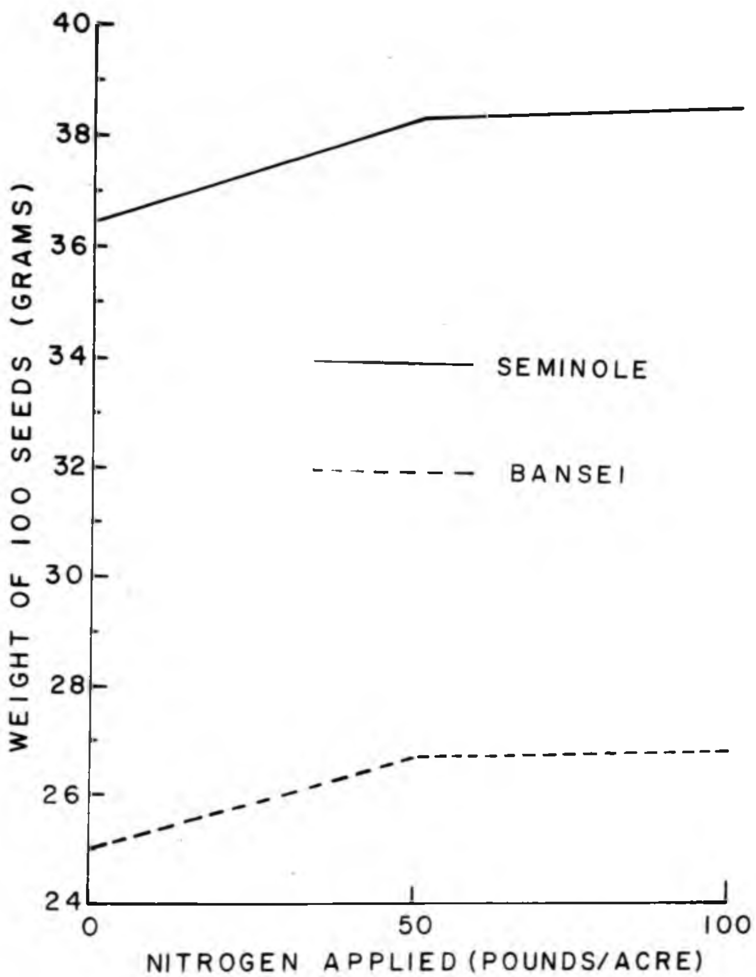

Figure 14. The influence of nitrogen fertilizer on the weight per 100 seeds, Experiment No. 3.

DISCUSSION

A. Plant height.

One of the most consistent observations of these studies was that the plant heights were responsive to the application of nitrogen fertilizer in all three experiments. The application of 50 pounds of nitrogen per acre resulted in maximum plant heights with Bansei and Seminole in Experiments No. 1 and No. 2. Only Seminole showed an increase in plant height at the 50 pounds per acre application in Experiment No. 3.

The application of 200 pounds of potassium per acre significantly reduced plant height in Experiment No. 3 and there were no significant differences between the 0 and 100 pound levels of potassium. The high amount of potassium applied may have stimulated early flower bud initiation. Consequently, the rate of vegetative growth cycle may have decreased because of an increase in the reproductive phase of growth. The NK interaction in Experiment No. 1 also showed that under the 0 level of potassium plant height increased with each increment of nitrogen applied, but under the 100 and 200 pound levels of potassium the nitrogen effect had been suppressed by the potassium. Here again, early flower bud initiation may have been responsible for or the result of the suppressed growth with potassium.

Seminole was taller than Bansei in Experiment No. 1. No varietal differences were found in Experiments No. 2 and No. 3. It is possible that Seminole, a late maturing variety, was more sensitive to a change in daylength with respect to flowering and date of maturity. Data in Table 2 show that Seminole flowered 5 days earlier in Experiment No. 3 than in Experiment No. 1. There was only a 2 day difference in flowering with the Bansei variety. This coincides with the report of Garner and Allard (1920). They reported that when the days are short, 12 hours or less, the number of days to the first bloom of early maturing varieties (for example Bansei) was reduced slightly as compared to a greater reduction with the late maturing varieties (for example Seminole). Furthermore, it took Seminole 128 days to mature dry seed in the summer months and a plant height of 41.7 cm. was attained, whereas only 100 days were required in Experiment No. 3 conducted in the winter months and the plant height was 23.4 cm. The Bansei variety in 95 days reached a height of 29.9 cm. in summer and in 86 days reached 23.2 cm. in the winter months.

B. Yield of dry beans

As with the plant height observations, the application of nitrogen fertilizer consistently showed an effect on the yield of dry beans in all three experiments. There was a significant increase in yield with Bansei at the 50 and 100 pound levels of nitrogen in Experiments No. 1 and No. 2, whereas maximum yields were obtained at the 50 pound level in Experiment No. 3. Seminole responded to the 50 and 100 pound levels in Experiment No. 2 and 50 pound level in Experiments No. 1 and No. 3. The increased yields may be due to the low soil fertility in a field which had not been fertilized for a period of five years. However, it is also important to note that the beans were not inoculated with nodule forming bacteria.

The application of phosphorus had an effect on the yield of dry beans. The application of 50 pounds of phosphorus gave both Bansei and Seminole maximum yields in Experiment No. 2. Only Bansei responded to increased yields at the 100 pound level of applied phosphorus in Experiments No. 1 and No. 3. According to Fellers (1918) phosphate fertilizers are essential to the production of maximum yields of soybeans. He also stated that the application of acid phosphate to soybeans resulted in increased yields if ample lime was present in the soil. This may be one of the reasons why Seminole showed only a limited response to phosphorus in that the field was not limed for a period of five years. However, another possibility is that phosphate fixation which is common in Hawaiian soils may have taken place (Chu and Sherman 1952).

The results showed that potassium, although an essential element to plant growth, did not increase the yield of dry beans. In Experiment No. 3 the 200 pound level of potassium significantly reduced the yield of dry beans. The 100 pound level in Experiment No. 1 also reduced the yield. However, it is important to note that the potassium treated plots matured earlier than those receiving nitrogen alone. Also, potassium had given well developed seeds but rather small in size. This may be one of the vital points that had caused the reduced bean yields with potassium fertilizer. It is also interesting to note that the NK interaction in Experiment No. 1 showed a dominating effect of nitrogen.

Seminole outyielded Bansei in Experiment No. 1, but there were no varietal differences in Experiment No. 2. However, Bansei outyielded Seminole in Experiment No. 3. This may demonstrate that Bansei was affected more by a change in nutritional conditions in the winter months than was the Seminole. In Experiment No. 1 Bansei progressively increased in the yield of dry beans as the nitrogen levels increased, whereas Seminole only responded to the 50 pound level. In the same experiment, the yield of Bansei increased at the 100 pound level of phosphorus applied while Seminole decreased in yield at the 50 and 100 pound levels. This tendency was again repeated in Experiment No. 3. The yield of Bansei had increased at the 100 pound level of phosphorus applied while Seminole had not responded to phosphorus. Weiss et al. (1950) emphasized that varieties responded differently to date of planting. This should be considered when interpreting the above results in that Bansei and Seminole may respond differently from one season to another. In other words, Bansei was affected more by a change in nutritional conditions in the winter months while Seminole may have been more sensitive to the change of daylength.

e. Weight of 100 seeds.

Application of phosphate and potash gave well-developed seeds. There was a tendency for seed coat to crack in plots which received 50 and 100 pounds of nitrogen with no supplemental phosphorus or potassium. This was especially noticeable with the Seminole variety and this may have been the result of a delay in maturity. On the other hand, nitrogen fertilizer showed a significant increase in the weight of 100 seeds in all three experiments. In Experiment No. 1 Bansei progressively increased in the weight of 100 seeds as the amounts of applied nitrogen increased, while Seminole responded only to the 50 pound level of nitrogen. However, in Experiment No. 2, Bansei and Seminole progressively increased in weight of 100 seeds as the amounts of nitrogen applied increased and in Experiment No. 3 both varieties responded to the 50 pound level. The NP interaction in Experiments No. 1 and No. 2 also reflected the dominating effect of nitrogen. Since nitrogen is a constituent of cell proteins, new cells cannot be formed without a supply of nitrogen. Therefore, it is very important to supply ample nitrogen in order to get large seeds since soybean seed is high in protein.

The application of potassium significantly reduced the weight of 100 seeds in Experiment No. 3. The 0 level of potassium resulted in the maximum weight of 100 seeds; subsequently the weight decreased as the amount of potassium increased. As discussed previously, this may have been a result of early maturity. However, Albrecht (1932) showed that legumes utilize large amounts of calcium and smaller amounts of potassium than some non-legumes.

When considering all of the experimental data, it appears that climatological factors may have been more important to varietal performance than the quantitative change in available nutrients. In other words, the short daylength accompanied by low light intensity and low temperature could have had a profound effect on the height and yield of the soybeans in the later plantings.

Camper and Smith (1958) stated that season and date of planting had considerably more effect on plant height than any other factor. However, to obtain maximum plant height, yield and seed size, it is very important to have sufficient moisture and nutrients available for a good start.

It is possible that the effect of short daylength periods may be intensified by other unfavorable growing conditions such as low soil fertility, unsuitable soil moisture, low temperature and low light intensity. An interaction of such factors with a shortened daylength period might accentuate the short day influence.

Why did the Seminole variety outyield Bansei in Experiment No. 1 and Bansei outyielded Seminole in Experiment No. 3? Can this be ascribed to a varietal response to differing climatic factors and soil conditions? It is recognized that the problem is complex and that conclusions made from the experiments conducted may not apply to other varieties and other localities. This may require a more extended and complete study of the various factors involved over a period of years.

SUMMARY

Experiments were conducted at the University of Hawaii, Waimanalo Experimental Farm (Field R-1) to study the differential growth response of Bansei and Seminole soybean varieties to varied combinations of nitrogen, phosphorus and potassium fertilizations during the fall and winter months when the daylength is short. (In Hawaii the shortest daylength in December is 10.42 hours, while the longest day in June is 13.58 hours.)

The field previously grew Pangola grass for five years with no supplemental fertilization after the initial application. The soil was considered low in fertility.

The responses of the soybean plants to daylength and accompanying seasonal changes were obvious. In general the plant height, yield of dry beans and weight of 100 seeds were considerably decreased during short day period. The favorable performance in plant height and yield of dry beans of Bansei when compared to Seminole was surprising during the fall and winter months. On the other hand, Seminole appeared to be more sensitive to daylength change as evidenced by date of flowering, time of maturity, height of plants and yield data. In the summer of 1962, it took the Seminole variety 128 days to mature dry seeds but only 100 days were required in Experiment No. 3 conducted in the winter months.

Nitrogen fertilizer produced positive effects on plant height, yield of dry beans and weight of 100 seeds. In Experiments No. 1 and No. 2 when nitrogen fertilizer was applied the yield of dry beans of Bansei and Seminole

showed less varietal difference. The NP interaction on weight of 100 seeds, still reflected the dominating effect of nitrogen. However, the NK interaction on plant height showed that the high amount of potassium suppressed the nitrogen effect.

Phosphorus fertilization resulted in a steady increase in the yield of dry beans with Bansei in Experiments No. 1 and No. 3. These results once again indicated the satisfactory performance of Bansei during the short day months under favorable nutritional conditions.

Potassium neither increased the yield of dry beans nor the weight of 100 seeds. On the contrary, the high application of potassium reduced the yield of dry beans, plant height and weight of 100 seeds. However, visual observations indicated that potassium had considerably accelerated the maturity of the soybeans in the field. It is generally assumed that legumes utilized larger amounts of calcium and less potassium than some non-legumes.

The varietal differences in plant height were significant in Experiment No. 1 but not in Experiments No. 2 and No. 3. In Experiment No. 3 Bansei outyielded Seminole in the yield of dry beans showing that Bansei performed well in the fall and winter months. From the results of these studies, it appears that the band application (at seeding time) of nitrogen and phosphorus fertilizer can stimulate early growth of the Bansei variety to a great enough extent to allow a fair production of vegetable soybeans for the Honolulu market in November and December without a shift to the Seminole variety.

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APPENDIX FIGURE 1

Soybean varietal differences in time of maturity for green beans receiving no fertilizer, June 1962, Waimanalo Branch Experiment Station, University of Hawaii. Bansei has many mature green pods while Seminole is just starting to flower.

APPENDIX FIGURE II

Soybean varietal differences in time of maturity for green beans receiving fertilizer, June 1962, Waimanalo Branch Experiment Station, University of Hawaii. Bansei has many mature green pods while Seminole is just starting to flower.

APPENDIX TABLE 1

ANALYSIS OF VARIANCE OF SOYBEAN PLANT HEIGHT IN RESPONSE TO FERTILIZER TREATMENTS

Sources	df	Mean Square		
		1st Experiment (Sept. 20)	2nd Experiment (Oct. 4)	3rd Experiment (Oct. 18)
Block	2	48.14**	8.35	0.50
Variety	1	352.78**	2.00	0.50
Treatment	53	14.33**	8.57	1.91*
N	2	48.72**	38.70**	4.05*
P	2	7.56	10.80	1.85
K	2	10.11	1.30	5.65*
NP	4	0.76	11.20	0.45
NK	4	22.19**	4.62	1.12
PK	4	5.95	3.40	3.32*
NPK	8	4.17	10.70	2.10
Varieties x N	2	2.01	6.90	4.60*
Varieties x P	2	11.17	5.15	0.40
Varieties x K	2	6.75	4.05	0.90
Varieties x NP	4	10.59	6.82	1.62
Varieties x NK	4	3.80	13.18	1.78
Varieties x PK	4	3.07	0.35	0.58
Varieties x NPK	8	3.24	9.28	1.78
Error	106	4.85	6.66	1.18

* 5% Significance.
** 1% Significance.

APPENDIX TABLE II

TREATMENT MEANS OF SOYBEAN PLANT HEIGHT IN RESPONSE TO FERTILIZER TREATMENTS

Treatments			1st Experiment (Sept. 20)		2nd Experiment (Oct. 4)		3rd Experiment (Oct. 18)	
			Sansei	Seminole	Sansei	Seminole	Sansei	Seminole
N_0	P_0	K_0	71 cm	83 cm	70 cm	71 cm	66 cm	67 cm
		K_1	73	79	64	71	71	71
		K_2	77	85	65	60	69	67
	P_1	K_0	74	76	70	71	71	68
		K_1	83	85	64	74	69	68
		K_2	78	77	74	79	70	64
	P_2	K_0	72	84	66	67	72	67
		K_1	75	86	73	70	71	72
		K_2	76	93	69	78	67	70
N_1	P_0	K_0	77	95	67	76	68	70
		K_1	73	90	79	70	70	69
		K_2	77	87	74	79	70	74
	P_1	K_0	80	91	80	80	70	68
		K_1	79	93	76	76	70	73
		K_2	82	85	76	82	69	69
	P_2	K_0	85	87	73	73	72	73
		K_1	77	88	78	72	70	75
		K_2	87	91	76	62	69	65
N_2	P_0	K_0	84	94	82	68	71	74
		K_1	70	89	70	78	70	69
		K_2	77	82	74	68	71	71
	P_1	K_0	87	89	69	70	69	75
		K_1	71	86	74	77	68	70
		K_2	81	88	72	69	64	70
	P_2	K_0	81	94	78	74	68	71
		K_1	78	83	69	79	74	71
		K_2	79	86	69	71	68	70

APPENDIX TABLE III

ANALYSIS OF VARIANCE OF SOYBEAN YIELD OF DRY SEEDS IN RESPONSE TO FERTILIZER TREATMENTS

Sources	df	Mean Square		
		1st Experiment (Sept. 20)	2nd Experiment (Oct. 4)	3rd Experiment (Oct. 18)
Block	2	3,932.10*	2,782.20	2,264.35**
Variety	1	15,941.10**	769.10	25,412.60**
Treatment	53	6,484.18**	3,874.59**	1,870.18**
N	2	109,581.30**	54,778.70**	13,257.35**
P	2	3,365.60	6,232.35**	576.50
K	2	3,973.40*	790.70	1,732.50*
NP	4	1,388.98	917.35	60.55
NK	4	3,590.70*	593.35	442.29
PK	4	1,507.12	639.25	1,806.72**
NPK	8	1,417.62	2,112.76*	435.35
Varieties x N	2	5,810.90*	2,662.10	408.95
Varieties x P	2	6,427.95**	1,032.90	1,447.45*
Varieties x K	2	574.50	3,050.15	232.70
Varieties x NP	4	2,612.58	530.85	366.02
Varieties x NK	4	851.35	1,018.32	366.02
Varieties x PK	4	2,311.40	823.96	513.22
Varieties x NPK	8	982.86	749.32	624.45
Error	106	1,238.58	1,024.48	461.62

* 5% Significance.
** 1% Significance.

APPENDIX TABLE IV

TREATMENT MEANS OF SOYBEAN YIELD OF DRY SEEDS IN RESPONSE TO FERTILIZER TREATMENTS

Treatments			1st Experiment (Sept. 20)		2nd Experiment (Oct. 4)		3rd Experiment (Oct. 18)	
			Bansei	Seminole	Bansei	Seminole	Bansei	Seminole
N_0	P_0	K_0	838 gr	1023 gr	544 gr	581 gr	452 gr	474 gr
		K_1	773	907	580	637	368	493
		K_2	907	1086	482	576	526	453
	P_1	K_0	862	908	684	780	601	505
		K_1	840	992	603	621	554	495
		K_2	915	864	526	661	485	449
	P_2	K_0	849	1010	567	529	580	446
		K_1	875	969	505	671	585	551
		K_2	839	1085	618	604	497	472
N_1	P_0	K_0	1099	1268	684	685	605	534
		K_1	1003	1229	690	709	596	533
		K_2	953	1113	630	815	579	585
	P_1	K_0	1052	1155	831	658	647	532
		K_1	1061	1111	810	801	617	538
		K_2	1151	1068	743	814	631	492
	P_2	K_0	1134	1110	799	764	672	509
		K_1	1270	1141	721	633	650	646
		K_2	1241	1184	724	738	619	451
N_2	P_0	K_0	1297	1295	829	777	632	576
		K_1	1022	1240	784	761	582	825
		K_2	1206	1142	661	709	631	611
	P_1	K_0	1290	1143	832	774	641	554
		K_1	1079	1119	786	808	622	576
		K_2	1129	1119	792	790	635	595
	P_2	K_0	1220	1237	828	745	653	586
		K_1	1147	1086	827	854	710	876
		K_2	1124	1178	830	748	659	443

To convert the above to pounds per acre, multiply by 0.89 (based on plot size 4-1/2 feet x 8 feet).

APPENDIX TABLE V

ANALYSIS OF VARIANCE OF SOYBEAN WEIGHT OF 100 SEEDS IN RESPONSE TO FERTILIZER TREATMENTS

Sources	df	Mean Square		
		1st Experiment (Sept. 20)	2nd Experiment (Oct. 4)	3rd Experiment (Oct. 18)
Block	2	14.80*	31.05**	19.15**
Variety	1	574.20**	8,179.30**	5,615.60**
Treatment	53	25.14**	105.09**	110.10**
N	2	267.90**	151.25**	69.10**
P	2	6.50	0.60	0.40
K	2	6.90	0.75	7.50*
NP	4	8.50*	5.72**	0.60
NK	4	1.02	1.40	0.83
PK	4	5.60	1.62	3.55
NPK	8	3.93	2.45	1.99
Varieties x N	2	18.75**	1.50	1.05
Varieties x P	2	2.30	0.35	0.30
Varieties x K	2	3.15	1.20	0.15
Varieties x NP	4	4.30	0.70	0.92
Varieties x NK	4	1.80	2.97	1.68
Varieties x PK	4	0.88	0.98	2.20
Varieties x NPK	8	3.25	0.78	0.94
Error	106	3.21	1.54	2.00

* 5% Significance.
** 1% Significance.

APPENDIX TABLE VI

TREATMENT MEANS OF SOYBEAN WEIGHT OF 100 SEEDS IN RESPONSE TO FERTILIZER TREATMENTS

Treatments			1st Experiment (Sept. 20)		2nd Experiment (Oct. 4)		3rd Experiment (Oct. 18)	
			Bansei	Seminole	Bansei	Seminole	Bansei	Seminole
N_0	P_0	K_0	86 gr	104 gr	77 gr	109 gr	78 gr	111 gr
		K_1	82	100	78	113	75	110
		K_2	89	106	74	106	72	109
	P_1	K_0	85	99	75	108	75	107
		K_1	86	106	75	105	76	109
		K_2	88	105	77	114	75	108
	P_2	K_0	85	99	75	109	78	115
		K_1	88	93	74	108	73	105
		K_2	82	99	76	110	74	112
N_1	P_0	K_0	99	110	82	118	83	117
		K_1	92	105	81	120	78	114
		K_2	94	109	82	115	78	116
	P_1	K_0	102	109	81	118	81	118
		K_1	100	102	83	116	80	118
		K_2	100	112	81	114	82	111
	P_2	K_0	96	111	84	120	80	118
		K_1	102	114	84	117	82	113
		K_2	101	106	80	116	80	114
N_2	P_0	K_0	101	106	88	118	82	116
		K_1	97	108	85	118	77	114
		K_2	101	112	82	113	83	116
	P_1	K_0	104	111	87	116	81	115
		K_1	104	109	82	121	81	120
		K_2	100	112	87	122	79	116
	P_2	K_0	105	110	87	116	82	118
		K_1	101	111	85	121	79	118
		K_2	103	114	86	122	80	116