THE EFFECT OF PLANTING DATE, NITROGEN LEVEL AND PLANT DENSITY ON SOYBEAN (*Glycine max* (Linn.) Merr.) SEED YIELD

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INTRODUCTION

Since soybean is most productive when grown as a summer crop when temperatures are high and the lengths of day are at their longest, it is cultivated most extensively as a summer crop in temperate areas between 35° to 45° latitude. It is the ranking grain legume crop of the world but is practically a non-entity in the tropics, as the tropics accounts for only around four percent of the world's acreage of 55 million acres devoted to soybean production.

As contrasted to the year-round cropping of most crops in the tropics, the limited acreage planted to soybean is grown largely as a summer crop because of its photosensitivity, yields dropping sharply particularly in winter plantings.

Actually, soybean can be grown throughout the year in the tropics but normally its yield is sharply pegged to the lengths of day during the growing period, yield being highest during periods of longest lengths of day and lowest during periods of shortest lengths of day. The low winter yields are closely correlated with earliness of floral initiation which sharply curtails plant growth.

Since it does not appear practical to augment the short daylengths of winter months by artificial supplementary lighting, modifications in cultural practices to counteract the adverse effects of short length of days might be effective in increasing winter production. Accordingly, two phases of cultural practices were studied. They were: (1) higher density of plant population to offset curtailed plant growth under short day conditions and (2) use of nitrogen fertilization to perhaps prolong the vegetative period and increase plant growth, assuming that resulting larger and taller plants will bear more pods.

Much research have already been conducted on plant density studies and effect of nitrogen fertilization on seed yield in temperate areas but their results have little application in the tropics because the objectives are different. In temperate areas the above lines of research were instituted to increase seed production of soybean grown under optimum climatic conditions of high temperatures and long days, whereas, in the tropics soybean can be produced year-round instead of the present single crop in the summer provided we are able to counteract the adverse effects of short days during winter months which induce early flowering and consequent low yields.

The present study was undertaken to ascertain whether denser plant population and stimulation of vegetative growth by nitrogen fertilization will be sufficiently large enough to offset the adverse effects of short days and their attendant lower temperatures. Furthermore, these two concurrent treatments were imposed on different dates of planting when days are short to observe the interaction between the planting dates and plant density nitrogen fertilization.

If any of the treatments prove to be effective in increasing production of soybean during winter months in the tropics, its production in the tropics may increase manyfold.

REVIEW OF LITERATURE

The review of literature pertinent to this work was based almost entirely on results of researches conducted in temperate areas because of the paucity of research on soybean in the tropics.

Garner and Allard (13) working on the photoperiodic response of soybeans in relation to temperature and other environmental factors observed that on months with 9½ to 12 hours daylength all varieties flowered in approximately 25 days after germination. They have noted further that when daylength began to exceed 12 hours, lengthening of vegetative period resulted. Results of similar studies by Osler and Cartter (10) and Hartvig (16) revealed that the vegetative period of soybean was shortened by shorter photoperiods. A more recent work by Abel (1) corroborated the preceding findings.

According to the report of soybean variety test in Hawaii (17), soybeans mature in less time in Hawaii than in the mainland United States. Biloxi, Laredo and Edward which mature in 140 to 170 days in Missouri mature in 110 to 130 days when planted as summer crop in Hawaii. Even when grown as a summer crop soybeans mature 20 to 25 percent earlier in Hawaii.

According to another report (18) winter planting of soybeans in Hawaii, both early and late varieties matured very early and all matured within two weeks of each other. It also reported that maximum height attained was 18 inches and that both yield and quality were poor due to unfavorable weather conditions.

In the mainland United States, soybean is usually planted around the middle of May. Planting made thereafter is often associated with substantial reduction in height. Garner et al (14) and other workers such as Weiss et al (42), Osler and Cartter (34) and Torrie and Briggs (39) found that delay in planting profoundly decreased height. According to report (18) from Hawaii of 14 varieties of soybeans tested under winter conditions, only O-too-tan exceeded 18 inches in height. Thipphavong (37), investigating the differential response of vegetable soybean varieties to fertility levels and seasons at the Waimanalo Experimental Farm of the University of Hawaii found that height gradually decreased as planting was delayed.

Highest soybean yields are generally obtained from early planting. Borthwick and Parker (3) studying the photoperiodic responses of several varieties of soybean, obtained results indicating reduction in yield due to delayed planting. Succeeding workers like Henson and Carr (19), Feaster (12), Dimmock and Warren (11), Hartwig (16), Cartter (10) and Thipphavong (37) also noted decrease in yield as a result of delay in planting. However, contrary to what was found in these foregoing experiments, Weiss et al (42), and Torrie and Briggs (39) observed no significant differences in yield of early varieties planted at different dates. Osler and Cartter (34) and Leffel (22) nevertheless, reported that early maturing varieties require later planting than varieties of late maturity.

The findings of different workers regarding the influence of planting time on seed size are not in agreement. Weiss et al (42), Osler and Cartter (34), and Torrie and Briggs (39) showed data which indicated that seed size was essentially unaffected by planting dates. Opposed to these were the findings of Abel (1) and Nelson and Roberts (30). They reported that seed size diminished with delayed plantings.

Spacings, both between and within rows vitally influence soybean yield. Several studies (2,4,8,15,20,25,26,41,43,44) showed that close spacings between and within the rows increased seed yield. Spacings affect seed size or weight of seeds but results regarding this are contradicting. Probst (35) stated that narrow within the row spacing produced slightly heavier seeds. But according to Nelson and Roberts (30) wider spacing in the row increased seed size. Lehman and Lambert (23) found that seeds were progressively lighter as population became denser and they also noted more pods and seeds per plant from wider spacing.

Plant height reportedly decreased with rate of seeding (9).

Soybeans perform decidedly better in the wet season than in the dry season where the wet season falls on months with relatively longer photoperiods. In the Philippines, the results of the studies of Layosa (21), Rodrigo and Urbanes (36) and Calma et al (7) bear out this information. Subsequent studies by Calma and Castelo (5), and Calma and Rosario (6) showed similar results.

Results from numerous experiments of Morse and Cartter (28) indicated that soybean do not respond to nitrogen fertilization. However, Norman (32), Norman et al (33) and Thornton (38) reported that to obtain high yields of soybean it may be necessary to use nitrogen fertilizer rather than to rely entirely on symbiotic nitrogen alone.

Lennox (24) stated that for the first 30 days from planting, application of nitrogen fertilizer is a necessity as nodulation within this period is not yet advanced. Mederski et al (27) presented data showing favorable yield responses from nitrogen application. Similar results were reported by Nelson (29). Lyons and Earley (25) also obtained increased yields from nitrogen fertilization. The findings of a more recent work by Nelson et al (31) indicated maximum seed yield at 160 pounds N per acre. Wagner (40) stated that nitrogen fertilization resulted in significant increases in non-nodulating soybeans. He further stated that seed weights were affected. In an experiment (37) conducted at the Waimanalo Experimental Farm of the University of Hawaii higher yields were obtained from plots treated with nitrogen at the rate of from 50 to 100 pounds per acre.

MATERIALS AND METHODS

Soybean variety Odgen was used in the experiment. It is a United States variety derived from hybridization of Tokyo x var. P.I. 54610. It is a grain type of soybean with olive yellow colored seed of medium size. This variety is grown chiefly in southern United States and is rated medium late in maturity, maturing in about 141 days in Mississippi.

The test was conducted in pots on a vacant lot at the back of the Agronomy Field Laboratory on the Manoa campus of the University of Hawaii. The pots used were five-gallon paint cans around 12 inches in diameter and 18 inches in height. Filled with soil up to approximately one inch below the brim, they were arranged close to one another in a square block of 8 pots, by 8 pots 64 treatment pots for each of four planting dates.

The soil, a low humic latosol with a silt loam texture and dark reddish brown color was pre-analyzed for pH and mineral contents.

Determinations for the mineral contents showed that they were present in trace amounts.

The pH determination indicated that it is fairly acid, the pH reading being 4.65. The titration curve analysis indicated some four tons of lime per acre was required to bring the pH level to six.

Lime (agricultural lime) at a four tons per acre rate (27 grams per pot) was worked in as thoroughly as possible into the soil for each pot by hand. Immediately after liming but before planting, the mixture of treble superphosphate, muriate of potash, sodium borate and ammonium molybdate were applied in each pot at the acre rate of 300, 200, 20 and 2 pounds of phosphorus, potassium, sodium borate and ammonium molybdate, respectively. This mixture was hand-mixed into the upper two inches of the soil.

The different levels of nitrogen in the form of ammonium sulfate were applied soon after planting in single bands on both sides of the sown seeds.

Sowing was made soon after the blanket application of mixed fertilizer. About double the number of seeds required for the different levels of stand were drilled in single row in each pot at a depth of about 1.5 inches. Approximately ten days after sowing the seedlings were thinned down to 2, 4, 6, and 8 per pot depending upon the density treatment.

From sowing up to maturity watering was done whenever necessary. All weeds were hand pulled. Other precautionary measures made were applications of chemicals to protect the plants against pests. At the seedling stage when they were liable to be damaged by African snails (Achatina fulica Bord.), which abound in the vicinity where the experiment was set up, a band of Ortho Bug-geta pellets was placed around the plots twice a week. Malathion was periodically sprayed to protect the plants from possible damage by insect pests.

The test, a factorial experiment, was carried in a split-split plot design. The split-split plot layout was as follows:

I Whole plots - 4 planting dates with 4 replications each.

II Sub-plots - 4 levels of nitrogen with 4 replications each.

III Sub-sub plots - 4 levels of density with 16 replications each.

To minimize border effects, the four sides of the field were lined with border pots.

The four dates of planting with their corresponding designations were the following: January 7, 1964-T_1; February 18, 1964-T_2; March 20, 1964-T_3 and June 1, 1964-T_4.

The nitrogen levels consisted of 0 (control), 60, 120 and 240 pounds per acre. On the per pot basis, the corresponding amounts were

0, 0.40, 0.82 and 1.60 grams. They were designated as N_0, N_1 and N_4, respectively.

The different plant densities used were the following with their corresponding approximate equivalents of number of plants per acre and rate of seeding per acre:

TREATMENT DESIGNATION	NUMBER OF PLANT/POT	APPROXIMATE NO. OF PLANTS/ACRE	APPROXIMATE SEEDING RATE/ACRE
D_2	2	100,000	40#
D_4	4	200,000	80#
D_6	6	300,000	120#
D_8	8	400,000	160#

The dates of planting, flowering and maturity were recorded.

The date of flowering was recorded as the date on which half of the plants in a plot were blooming.

The date of maturity was observed as the date on which 99 percent of the pods in a plot were dry.

Data for the following characters were also taken:

1. plant height
2. number of branches
3. length of branches
4. number of pods
5. number of aborted ovules
6. number of seeds
7. seed size (grams per 100 seeds)

Plant height was measured in centimeters from the base to the tip of the central stem at harvest time or maturity.

Simultaneous with the taking height measurement, the number of branches were counted and their lengths measured in centimeters. Measurement was made from its base to the tip.

For all plantings, the pods were counted just before they were detached from the plants for shelling except for the June planting where pod counts were made sometime after pod setting but long before maturity. Counts were made this early for the last planting because it was at this time when plants were showing signs of damage by drift of herbicide sprayed near the lot of the experiment.

Before shelling, the aborted ovules were counted.

Seed size was obtained by adjusting the oven-dry weight in grams of 100 seeds corrected to 12 percent moisture content.

Seed yield was obtained by multiplying the number of seeds by the weight in grams of 100 seeds.

All the data that required statistical treatment were subjected to analysis of variance of the split-split plot design with planting dates as the main plots, the levels of nitrogen as the sub plots and the plant densities as the sub-sub plots. Data with significant "F" values were further analyzed for comparison of means by utilizing the Duncan's New Multiple Range Test.

RESULTS AND DISCUSSION

The results of the study consisted of two parts. The first were visual observations made during the entire growing season, and the second were actual measurement data obtained before and after harvest.

Visual Field Observations:

Ocular observations were made on the general conditions of the plants during each growing period. It was noted that plants supplied with nitrogen fertilizer were darker green and relatively vigorous while those that received no nitrogen fertilizer appeared to be somewhat chlorotic or yellowish-green. However, plants fertilized with nitrogen but at different rates of application did not show any differential color response. Plants in each density treatment were observed to be uniform in growth except in the thickest density at eight plants. In this treatment a number of plants were spindly and stunted, especially in the lower levels of nitrogen treatments. Plants in the January planting were generally smaller than those of later plantings.

Actual Measurement Data:

Dates of planting, flowering and maturity and number of days from planting to flowering and maturity are presented in Table I.

The main effects of planting dates, nitrogen levels and plant densities and their important interactions for yield of seeds, percent aborted ovules, weight per 100 seeds, height of plants, number of branches and average length of branches are given in Tables II to IV.

TABLE I. DATES OF PLANTING, FLOWERING AND MATURITY; AND NUMBER OF DAYS FROM PLANTING TO FLOWERING AND MATURITY

Planting Date	January 17, 1964	February 18, 1964	March 20, 1964	June 1, 1964
Flowering Date	February 17, 1964	March 22, 1964	April 29, 1964	July 16, 1964
Number of Days to Flowering	32	34	41	46
Maturity Date	May 5, 1964	June 10, 1964[1]	July 14, 1964[1]	
		June 12, 1964[2]	July 17, 1964[2]	
Number of Days to Maturity	110	114[1]	117[1]	
		116[2]	120[2]	

[1] without nitrogen

[2] with nitrogen

TABLE II. MEAN SEED AND PLANT DATA ON SOYBEAN PLANTED ON DIFFERENT DATES AND FERTILIZED WITH VARYING LEVELS OF NITROGEN FERTILIZER

LEVEL OF NITROGEN	YIELD OF SEEDS/PLOT IN GRAMS				PERCENT ABORTED OVULES				WEIGHT OF 100 SEEDS IN GRAMS			
	T_1	T_2	T_3	MEAN	T_1	T_2	T_3	MEAN	T_1	T_2	T_3	MEAN
N_0 - 0	5.42	16.72	4.83	8.99	8.30	22.90	36.50	22.56	16.03	19.17	11.99	15.73
N_1 - 60	8.80	41.96	25.55	25.44	12.73	14.36	13.99	13.70	18.07	22.88	20.38	20.44
N_2 - 120	13.44	47.14	29.22	29.95	12.62	14.25	14.74	13.87	17.96	24.06	21.98	21.33
N_4 - 240	16.25	51.89	38.46	35.53	10.55	12.44	13.91	12.30	18.48	24.92	23.10	22.17
MEAN	10.99	39.43	24.52	24.98	11.05	15.99	19.78	15.61	17.64	22.76	19.36	19.92

LEVEL OF NITROGEN	HEIGHT OF PLANTS IN CM.				NUMBER OF BRANCHES PER PLOT				AVERAGE LENGTH OF BRANCHES (CM.)			
	T_1	T_2	T_3	MEAN	T_1	T_2	T_3	MEAN	T_1	T_2	T_3	MEAN
N_0 - 0	22.27	29.80	33.79	28.62	1.06	8.56	9.69	6.44	0.90	4.62	4.81	3.44
N_1 - 60	27.56	36.96	39.78	34.77	4.19	18.25	13.81	12.08	2.67	8.43	8.17	6.42
N_2 - 120	29.03	39.25	40.21	36.16	5.25	20.31	15.21	13.59	2.93	9.02	10.38	7.44
N_4 - 240	29.03	40.73	40.55	36.77	6.75	20.62	17.19	14.85	3.10	9.07	10.52	7.56
MEAN	26.97	36.68	38.58	34.08	4.31	16.94	13.98	11.74	2.40	7.78	8.47	6.22

TABLE III. MEAN SEED AND PLANT DATA ON SOYBEAN PLANTED ON DIFFERENT DATES AND AT DIFFERENT PLANT DENSITIES

PLANT DENSITY	YIELD OF SEEDS/PLOT IN GRAMS				PERCENT ABORTED OVULES				WEIGHT OF 100 SEEDS IN GRAMS			
	T_1	T_2	T_3	MEAN	T_1	T_2	T_3	MEAN	T_1	T_2	T_3	MEAN
D_2	7.04	29.83	18.97	18.61	13.94	14.74	18.26	15.65	18.07	22.85	19.47	20.13
D_4	9.80	40.46	23.43	24.56	11.80	14.73	20.12	15.54	17.12	21.96	18.96	19.35
D_6	12.49	47.77	30.10	30.12	7.90	15.60	19.32	14.28	17.89	23.19	19.40	20.16
D_8	14.64	39.66	25.56	26.62	10.55	18.89	21.44	16.96	17.46	23.01	19.62	20.03
MEAN	10.99	39.43	24.52	24.98	11.05	15.99	19.78	15.61	17.64	22.75	19.36	19.92

PLANT DENSITY	HEIGHT OF PLANTS IN CM.				NUMBER OF BRANCHES PER PLOT				AVERAGE LENGTH OF BRANCHES (CM.)			
	T_1	T_2	T_3	MEAN	T_1	T_2	T_3	MEAN	T_1	T_2	T_3	MEAN
D_2	23.66	34.25	36.53	31.48	3.12	12.12	8.88	8.04	3.05	10.53	9.68	7.75
D_4	26.28	36.28	38.94	33.83	4.38	16.38	14.56	11.77	3.02	8.82	9.31	7.05
D_6	29.56	38.88	39.57	36.00	5.06	19.12	16.25	13.48	1.89	6.97	8.55	5.80
D_8	28.39	37.34	39.28	35.00	4.69	20.12	16.12	13.64	1.62	4.81	6.34	4.26
MEAN	26.97	36.69	38.58	34.08	4.31	16.94	13.95	11.73	2.40	7.78	8.47	6.22

TABLE IV. MEAN SEED AND PLANT DATA ON SOYBEAN FERTILIZED WITH VARYING LEVELS OF NITROGEN AND PLANTED AT DIFFERENT PLANT DENSITIES

PLANT DENSITY	YIELD OF SEEDS PER PLOT IN GRAMS					PER CENT ABORTED OVULES					WEIGHT OF 100 SEED IN GRAMS				
	N_0	N_1	N_2	N_4	MEAN	N_0	N_1	N_2	N_4	MEAN	N_0	N_1	N_2	N_4	MEAN
D_2	6.28	16.87	21.93	29.37	18.61	21.64	15.98	13.97	11.00	15.65	15.91	20.46	21.12	23.03	20.12
D_4	7.60	26.49	30.45	33.71	24.56	22.52	12.13	13.78	13.75	15.54	14.22	20.54	21.15	21.48	19.35
D_6	10.08	30.60	36.00	43.80	30.12	21.88	12.94	11.86	10.43	14.28	16.15	20.54	21.37	22.59	20.16
D_8	12.02	27.79	31.43	35.24	26.62	24.22	13.73	15.87	14.01	16.96	16.63	20.23	21.69	21.56	20.03
MEAN	8.99	25.44	29.95	35.53	24.98	22.56	13.70	13.87	12.30	15.61	15.73	20.44	21.33	22.16	19.92

PLANT DENSITY	HEIGHT OF PLANTS IN CENTIMETERS					NUMBER OF BRANCHES PER PLOT					AVERAGE LENGTH OF BRANCHES IN CENTIMETERS				
	N_0	N_1	N_2	N_4	MEAN	N_0	N_1	N_2	N_4	MEAN	N_0	N_1	N_2	N_4	MEAN
D_2	26.21	32.00	33.75	33.96	31.48	4.08	7.75	10.17	10.17	8.04	4.89	6.62	9.54	9.96	7.75
D_4	28.71	34.24	35.73	36.66	33.84	6.25	12.75	13.92	14.17	11.17	4.26	7.94	8.05	7.95	7.05
D_6	30.02	36.88	38.24	38.89	36.01	7.75	14.75	14.25	17.17	13.48	2.70	6.33	7.36	6.82	5.80
D_8	29.54	35.95	36.94	37.38	35.00	7.67	13.08	15.92	17.92	13.65	1.92	4.79	4.81	5.51	4.26
MEAN	28.62	34.77	36.16	36.77	34.08	6.44	12.08	13.56	14.86	11.74	3.44	6.42	7.44	7.56	6.22

Their corresponding graphs are given in Figures 1 to 6. Their analyses of variance are appended (Appendix Tables 1 to 5). The Duncan's New Multiple Range Test are likewise appended (Appendix Tables 7 to 9).

The trends of response to the different treatments on the number of seeds, number of pods and number of aborted ovules either per plant or per plot were found to be essentially similar to that of yield of seeds. In view of this, it was deemed inconsequential to discuss them individually.

I. Response to Planting Dates:

A. Effect on Flowering and Maturity.

The differences in number of days to flowering and maturity in planting dates are relatively small. The differences between planting dates in these two measurements appear to be too small to account for the 2- to 3-fold increase in yield of later plantings over January planting. It is suspected that there maybe other contributing factors related to time of the year that exerted greater influence on seed yield than dates of flowering and maturity. One such factor might be cumulative number of sunlight hours during the entire period of growth. In this respect, the differences between January and the later two plantings were in the order of 100 to 200 hours. The percent differences between January and February plantings in number of days for flower and

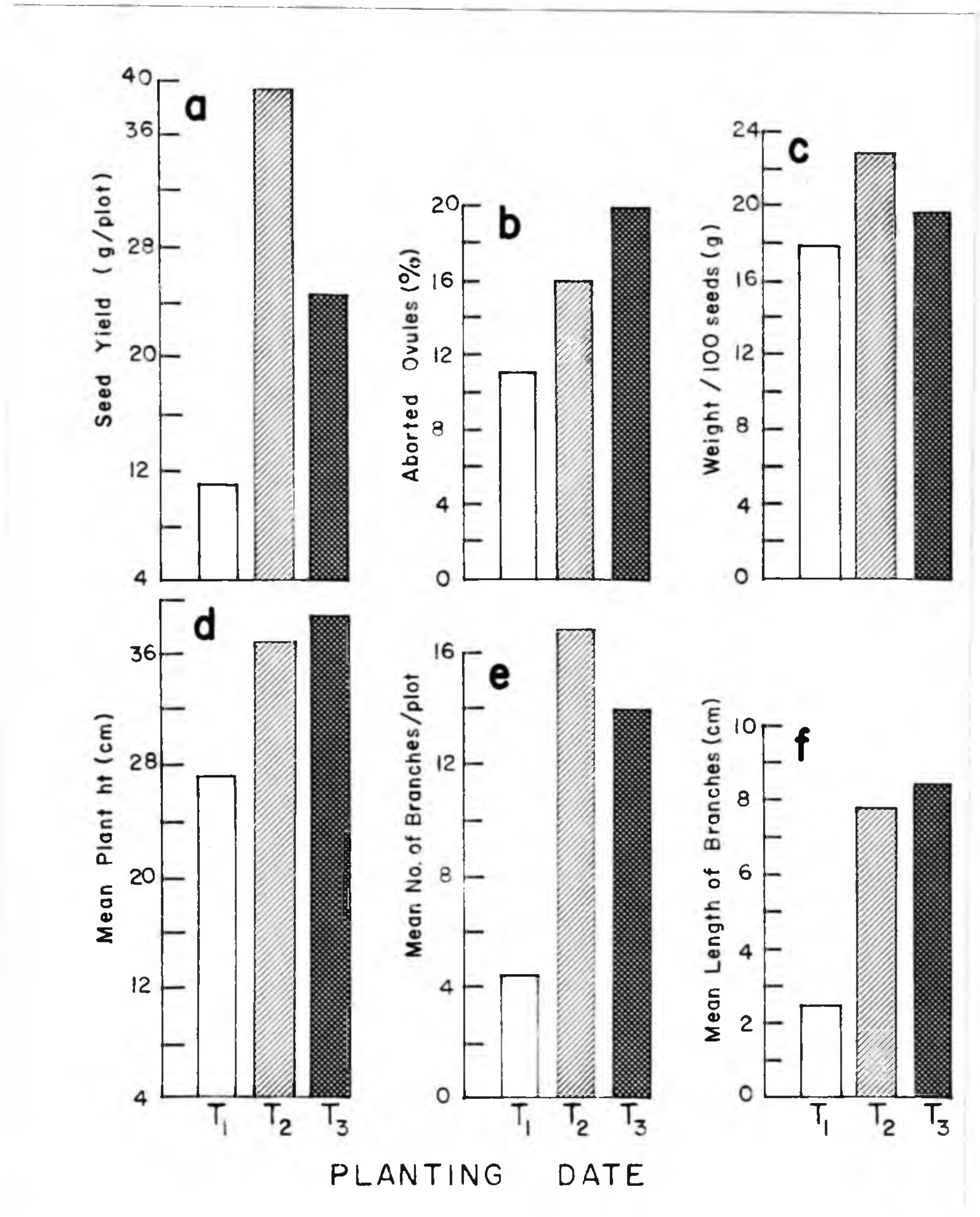

Figure 1. Effect of planting date on seed and plant characters.

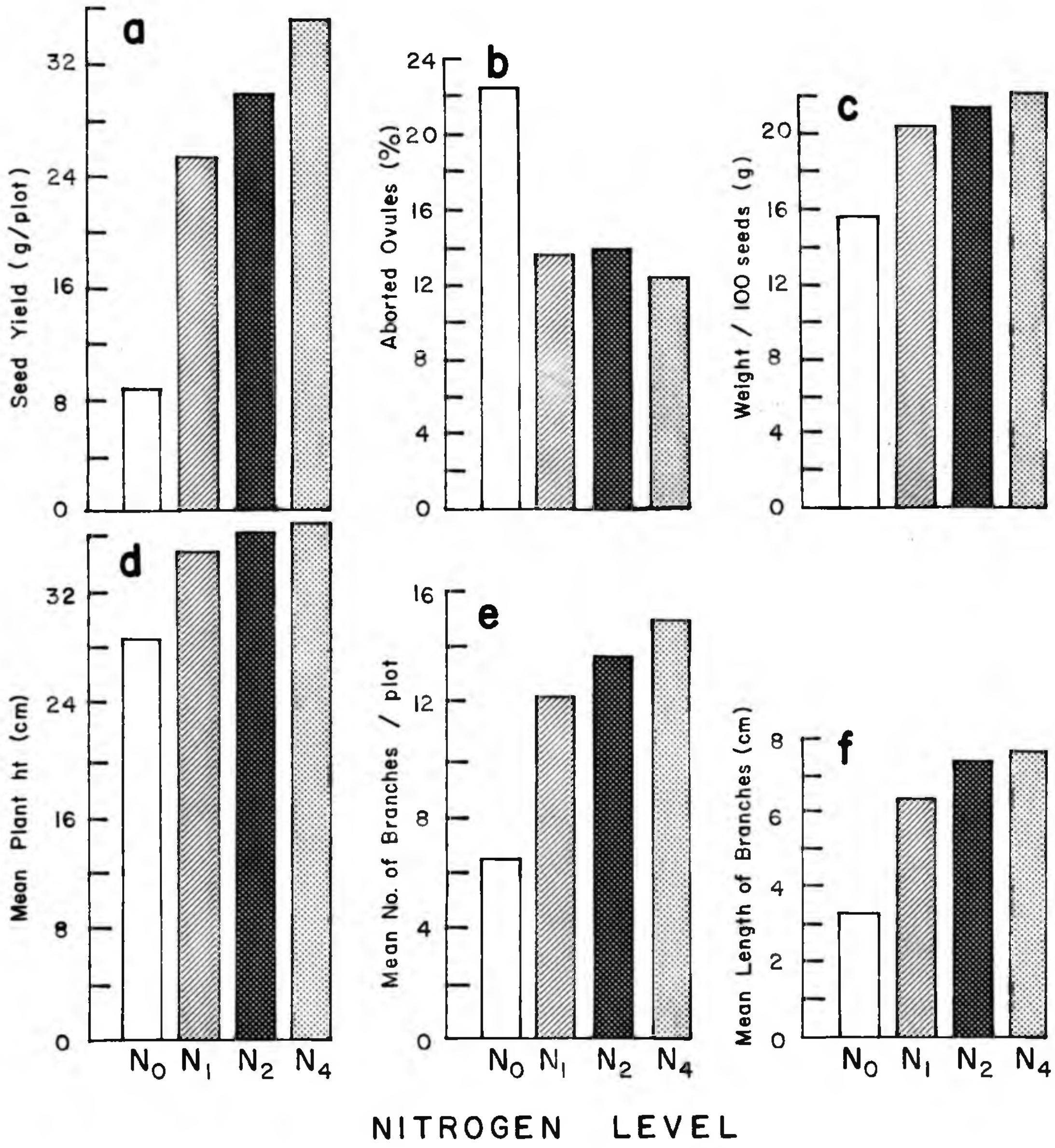

Figure 2. Effect of nitrogen level on seed and plant characters.

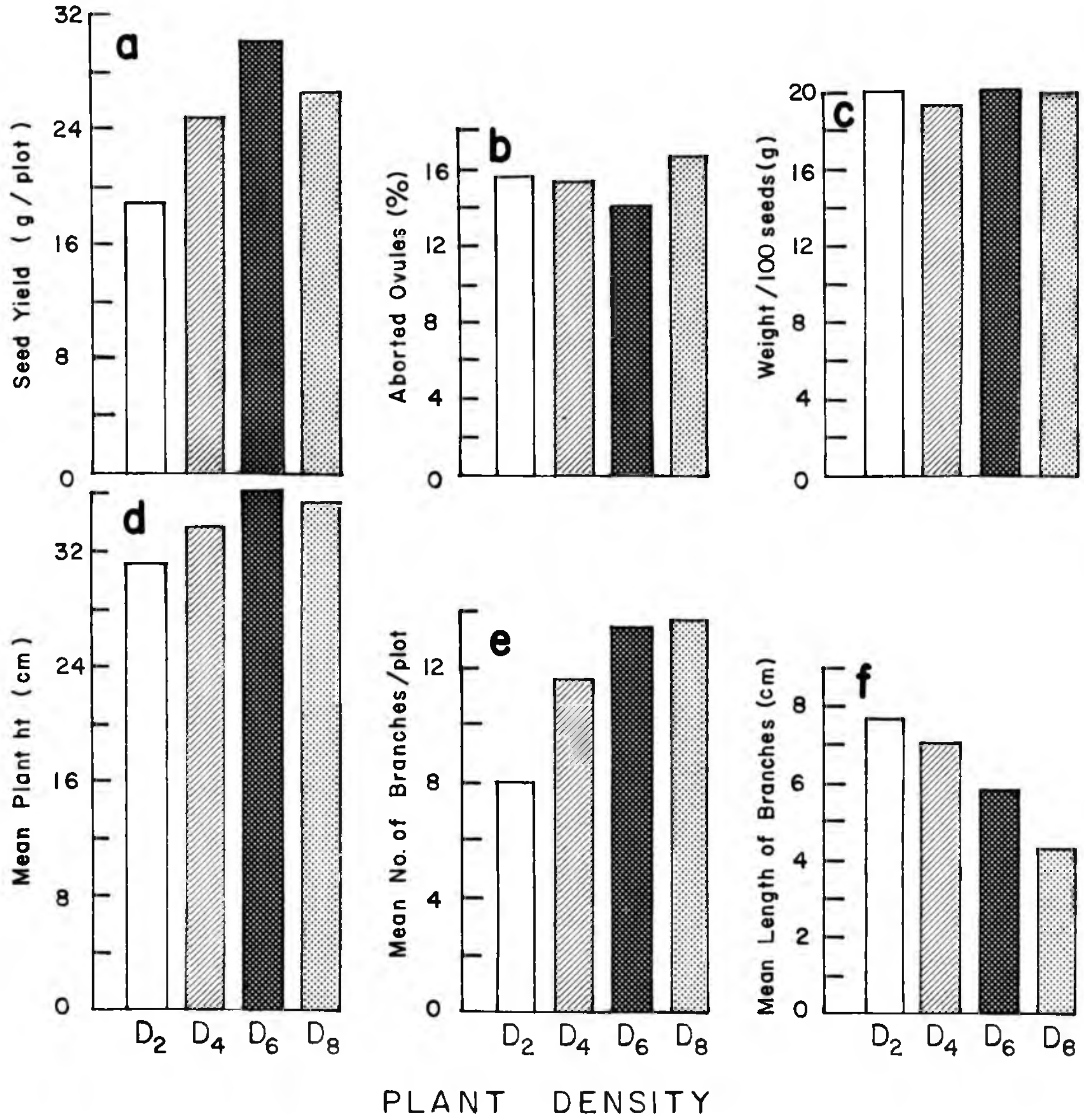

Figure 3. Effect of plant density on seed and plant characters.

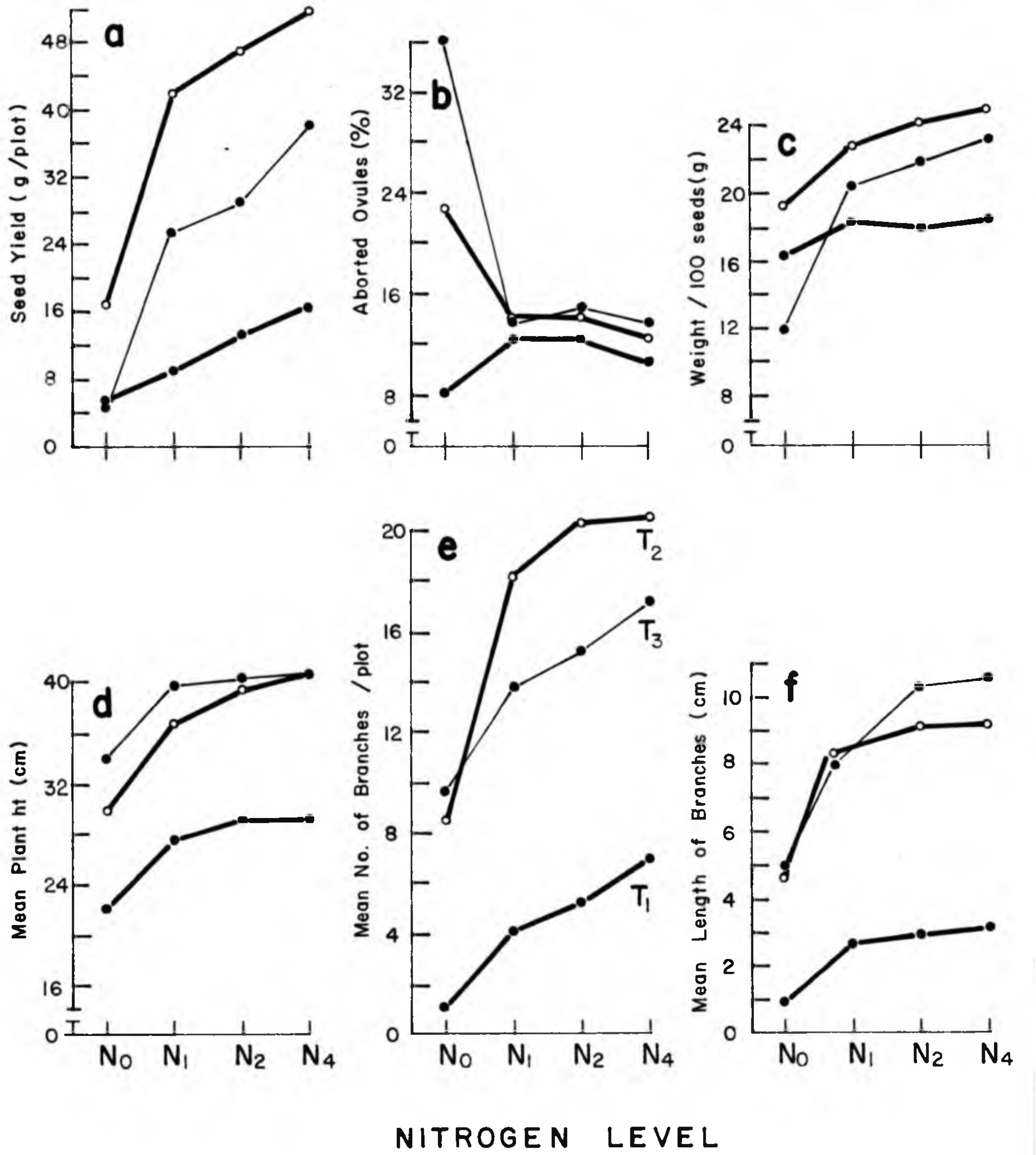

Figure 4. Effect of planting date and nitrogen level on seed and plant characters.

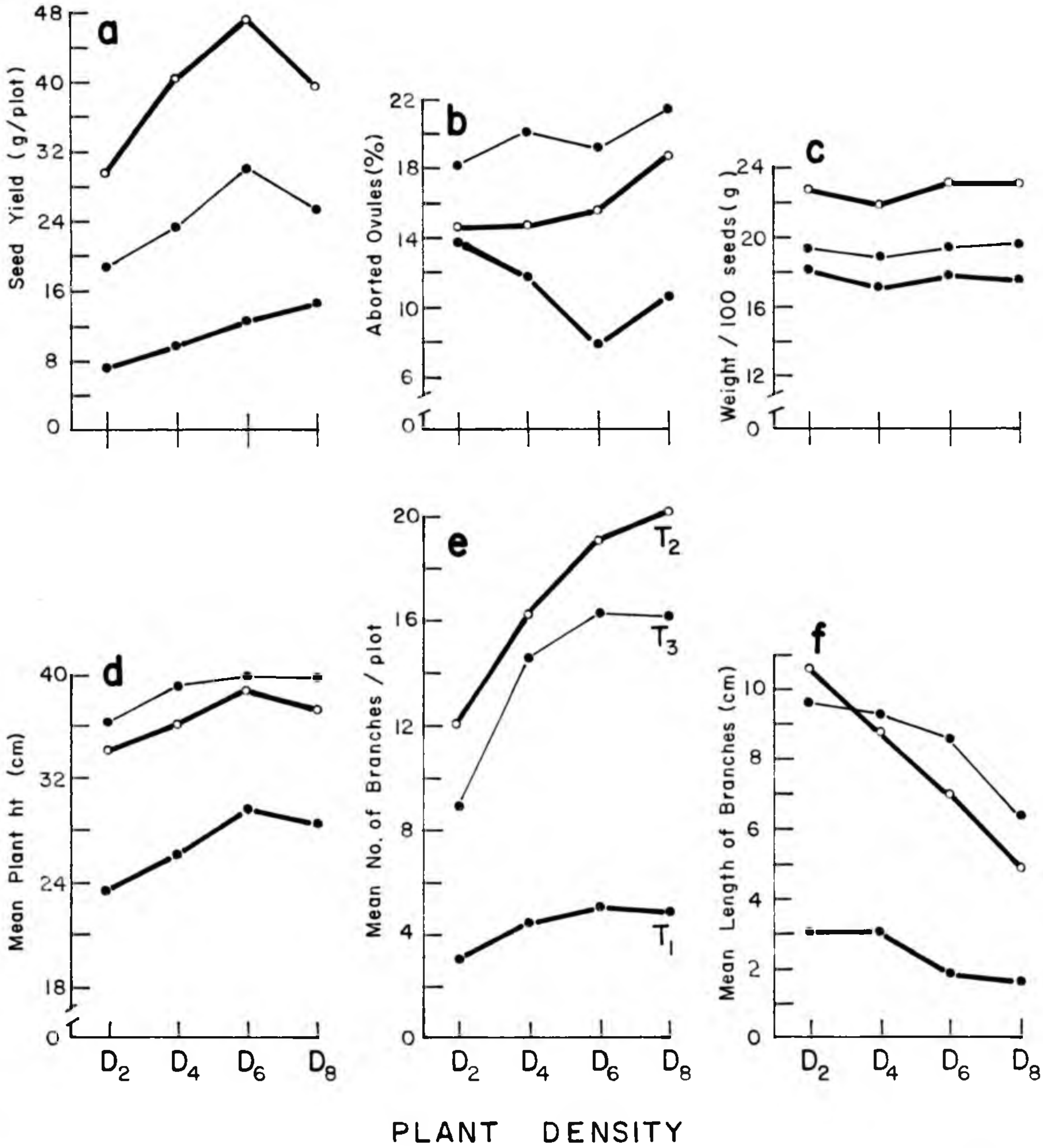

Figure 5. Effect of planting date and plant density on seed and plant characters.

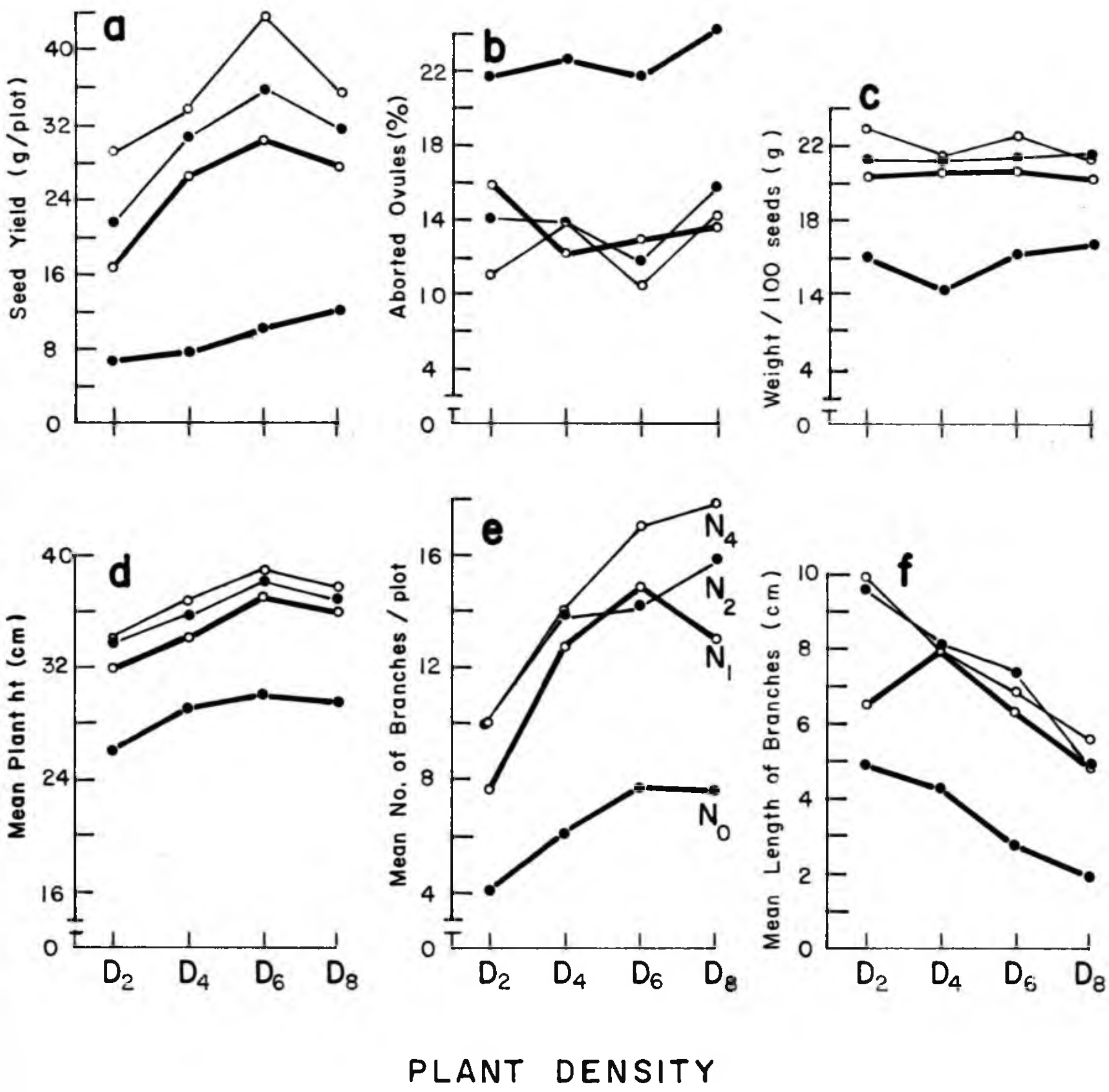

Figure 6. Effect of nitrogen level and plant density on seed and plants characters.

mature and cumulative sunlight hours were 6.2, 4.5 and 10.0 percent, respectively. Of the three measurements the biggest difference is in cumulative sunlight hours. Another factor could have been increasing temperatures from January onward but weather data (Appendix Table 10) indicate that February was colder than January so that temperature as a factor appears to have been a negligible factor.

The latest planting that reached maturity took 118 days to mature. But under mainland United States conditions the same variety when grown as a summer crop in Mississippi attains maturity in 141 days. They are actually not quite comparable because they were planted under different months of the year, but a study conducted in Hawaii (17) showed that Biloxi, Laredo and Edward which normally mature in 140 to 170 days on the mainland United States as a summer crop, mature in 110 to 130 days in Hawaii when planted also as a summer crop. It appears then that the maturity of Ogden is shortened considerably when grown in tropical Hawaii.

B. Effect on Production and Plant Growth.

As to be expected the first planting made in January had the lowest yield. February planting recorded a phenomenal increase in seed yield over the January planting, the rate of increase being 3.6 times. The yield of March planting was 40 percent lower than the high yield recorded in February planting but was still 2.4 times higher than that of January planting.

In view of the limited number of plantings made, there is no definite way of explaining the lack of linearity in increase of yield with presumably continuing improvements in weather conditions which ordinarily should result in increased production as weather conditions keep on improving.

In spite of the lack of linearity in yield increase, nevertheless, the yields of the two later plantings were so much higher than that of the earliest planting made in January so that it is reasonable to assume that yield of soybean even in the tropics is even more profoundly affected by the time of year of planting than in temperate areas. Previous study (18) conducted under Hawaiian conditions showed some differences in yield of seeds of plantings made during different months of the year. Lower yields were associated with plantings made on months with shorter daylengths. Thipphavong in his study (37) found differential seed yield response during different seasons of planting. In the mainland United States, results of similar investigations (3, 10, 12, 22, 34, 39, 42) indicated reduction in yield as influenced by delay in planting. Other studies (5, 6, 7, 36) also showed seed yield differences due to different seasons of planting.

There was a progressive increase in the percent aborted ovules from January through March. The percent abortion of February planting was 1.4 times higher than that of the January planting and March planting was 1.8 times higher than that of January planting.

Although the percentages of aborted ovules noted in the later two plantings were higher than that of the earliest planting, they were not high enough to adversely affect seed yields to any appreciable extent.

The weight per 100 seeds exhibited some significant differences among planting dates. However, differences were significant only between January and February, and between March and February. Seeds of February planting were 1.29 times heavier than those of January and 1.18 times heavier than those of March. These findings are not in agreement with those of Weiss *et al* (42), Osler and Cartter (34) and Torrie and Briggs (39). Their results indicated that seed size was essentially not influenced by planting dates. The results of the present test in this regard do not also completely conform with the reports of Abel (1) and Nelson and Roberts (30) that seed size diminished with delayed plantings because in this study seeds of February planting were statistically heavier than those of March.

With regard to plant growth, variations were also observed due to planting dates. It will be noted that plants in February and March planting dates were significantly taller than those planted in January. Those of February and March plantings were 1.37 and 1.44 times taller. Plants planted in March were taller than those planted in February. However, their differences were not statistically significant.

The probable reason for this non-significance might be that the daylength differences between these two plantings during the vegetative growth were not large enough to trigger a significant increase in height in the March planting. The daylength data (Appendix Table 11) indicate that the periods from planting to flowering of these two plantings had only about half an hour difference in daylength.

The progressive increase in plant height with planting in this experiment is closely related with reduction in height with delay in planting in previous tests (14, 18, 30, 39, 42) because this present experiment was made under conditions with increasing daylength whereas previous experiments were carried under decreasing daylength.

Under the present study, Ogden, the variety used attained below average height of about 12 inches compared with its height of 34 inches in mainland United States when grown in summer. In a previous experiment in Hawaii (18) out of the 14 varieties tested during the winter months only O-too-tan exceeded 18 inches in height.

As was the case in plant height, statistically significant differences in the average number and length of branches were noted between January and later two plantings. February and March plantings had more and longer branches than January planting. February had four times and March had three times more branches than January. Both February and March had branches four times longer than January.

II. Response to Nitrogen Fertilization and its Interaction with Planting Date.

A. Effect on Flowering and Maturity.

In spite of the large increase in yield resulting from nitrogen fertilization, levels of nitrogen fertilization had practically no effect on delaying of flowering and maturity. In all planting dates, all plots whether treated or untreated with nitrogen fertilizer flowered or matured at practically the same time. The number of days to maturity ranged from 110 to 120 days as compared to 141 days required to reach maturity when grown strictly as a summer crop in Mississippi. Despite nitrogen fertilization and increase in plant density, Ogden still matured 22 to 15 percent earlier in Hawaii. Previous study in Hawaii (18) showed that Biloxi, Laredo and Edward which take 140 to 170 days to mature when grown in the mainland United States, mature in 110-130 days in Hawaii even when grown at the peak of summer months. It appears that soybean matures much earlier in the tropics regardless of cultural practices because of the large differential in length of days. In the tropics the longest days range from 12½ to 13½ hours whereas in temperate areas the longest days range from 14 to 17 hours.

B. Effect on Production and Plant Growth.

Seed yield data clearly indicate that seed yields are influenced by levels of nitrogen fertilization. All nitrogen treated plots yielded significantly higher than the no nitrogen control plots. There was a remarkably large increase in yield from the first nitrogen increment at the rate of 60 pounds per acre, the increase being almost triple. Further increments from this rate did not give proportional increase in the yield of seeds. The treatment receiving 120 pounds N per acre, was a little more than three times that of the control, whereas that of the highest rate, 240 pounds N per acre was almost four times higher than that of the control.

The large yield response from treatment receiving 60 pounds N per acre over the no nitrogen plot was due to the low content of native nitrogen in the soil used in this test or the inadequacy of nitrogen elaborated by nodulation. Lennox (24) reported positive response to nitrogen in Hawaiian soils. More recently Thipphavong (37) reported that soybean responded to nitrogen fertilization. Earlier workers (25, 27, 29, 32, 33, 38, 40) also reported favorable yield responses to nitrogen fertilization.

Data show that maximum seed yield was obtained when nitrogen was applied at the rate of 240 pounds per acre, the highest rate in this experiment. But Nelson and his co-workers (31) reported that yield increased with nitrogen levels up to 160 pounds per acre only. Thipphavong (37) noted response when nitrogen was applied at 50 to 100 pounds per acre. This discrepancy may be primarily due to differences in the amounts of nitrogen originally present in the soil. Aside from the nitrogen fertility differences of the soil and probable differences in other environmental factors, differential response of different varieties to nitrogen fertilization may also have contributed a lot to these conflicting results.

The limited number of tests on N fertilization of soybean in Hawaii clearly indicate high response to nitrogen fertilizer.

In contrast, in the mainland United States, conflicting response has been obtained from N fertilization. The conditions under which N fertilization trials were conducted in the United States are quite different from the few that have been conducted in Hawaii. In the United States trials, N was applied to soybean crops making the best of growth under the best climatis conditions of optimum temperatures and lengths of day. Also, temperate soils are generally more fertile than tropical soils, so that they are less likely to show high response to N. On the contrary, N fertilizer tests in Hawaii have been conducted during the season of the year when productivity is at its lowest ebb due to adverse conditions of short length of days and lower temperatures.

The high nitrogen level x planting date interaction bears out the fact that nitrogen showed differential effect on seed yield at different planting dates. This high interaction was accounted for by the slight yield increases due to nitrogen treatments in January planting and the large increases obtained both in February and March plantings. It will be observed that the January planting receiving no nitrogen, seed yield was only trifle higher than the corresponding check plots of March planting but the response to levels of nitrogen fertilization was over twice as high.

Large differences in percent aborted seeds were observed between the control and those that received nitrogen fertilizers. In the no nitrogen treatment the percent aborted seeds for the three planting dates was 22.56 percent, almost twice greater than those at 60, 120 and 240 pound N per acre, which were 13.70, 13.87 and 12.30 percent, respectively. The high percentage of seed abortion in the no nitrogen treatment may have contributed partly to the depression of yield in this treatment. Data however, show that at 0 level of nitrogen the lowest percentage aborted ovule was recorded in the January planting while at the same level the two highest percentages were recorded for February and March plantings.

Seed size (weight per 100 seeds) was materially influenced by nitrogen fertilization. It progressively increased with N levels. However, statistically significant differences were only noted between the control and those that received either 60, 120 or 240 pounds N per acre. Seeds of plots treated with nitrogen were on the average 1.3 times heavier than those of the no nitrogen plots.

Previous experiments also showed increases in seed weight as one of the responses to nitrogen fertilization. Wagner (40) reported increased seed size resulting from nitrogen treatment. In another report (37) it is indicated that seed size showed positive response to nitrogen.

There was a significant nitrogen level x planting date interaction on seed weights. This was primarily due to the extremely low seed weight of the control in March planting, which was considerably lower than that recorded in January planting.

Nitrogen fertilization showed some appreciable influence on plant growth. Plants fertilized with nitrogen at the rate of 60, 120 and 240 pounds per acre were significantly taller than plants receiving no nitrogen. However, plants supplied with nitrogen fertilizer at either 60, 120 or 240 pounds per acre did not significantly differ in height.

There was a significant nitrogen level x planting date interaction which resulted from the occurrence of taller plants in February than in March when fertilized with nitrogen at the rate of 240 pounds per acre.

Perusal on the data will show that more nitrogen is necessary to boost its growth when soybeans is planted on months with shortest daylength and that the need for it becomes lesser as daylength becomes longer. It will be noted that in January as well as in February plantings nitrogen at the rate of from 120 to 240 pounds per acre was required in order to attain its maximum height. In the latest planting made in March, plants were already able to make maximum growth even when rate of nitrogen was only at 60 pounds per acre.

Thipphavong (37) also observed response in plant height to nitrogen fertilization of soybean planted in fall.

Nitrogen fertilization has favorably influenced the number and average length of branches. There were more branches and these were longer when plants were supplied with nitrogen. At the first nitrogen increment at 60 pounds per acre the number and average length of branches were twice those of the control. There were also statistically significant increases in the number and average length of branches at the next two increments of nitrogen but they were not proportional to increments. The number of branches was only a little more than double that of 0 nitrogen. Likewise, the average length of branches was only little more than twice as long as those that received no nitrogen.

The nitrogen level x planting date interactions were significant for both the number and average length of branches. The former was due to more branching in February than in March when plots received nitrogen and the lesser branching in February than in March when plots were not fertilized with nitrogen. The latter was accounted for by longer branches in February than in March when plots were supplied with nitrogen at the rate of 60 pounds per acre.

Generally, the trends of response in the weight per 100 seeds and in all the vegetative characters discussed closely paralleled that manifested by yield of seeds. Each one of them progressively increased with nitrogen level. On the contrary, percent aborted ovule more or less decreased as nitrogen level increased.

III. Response to Plant Density and its Interaction with Planting Date and Nitrogen Level.

A. Effect on Flowering and Maturity.

As might be expected, plant density had no effect on dates of flowering and maturity. Of the three series of treatments it appears that only planting time has exercised some amount of influence in delaying flowering and maturity.

B. Effect on Production and Plant Growth.

Of the three factors under study, levels of density treatments showed the least effect on seed yield. However, the fact that D_4 treatment did show moderate increase, and D_6 a significant increase in yield over the D_2, which is about the usual planting density, indicate that winter plantings should be seeded much more heavily than summer plantings.

Numerous earlier studies (2, 4, 8, 15, 20, 26, 41, 43, 44) showed that close spacings both between and within the row increased seed yield. Although these and the present test are not quite comparable because they were made under different growing conditions, but in view of the substantial differences among densities it seems logical to assume that different density treatments resulted in differential response in yield.

The plant density x planting date interactions was highly significant. This significance was caused by D_8 treatment yielding the most in January but decidedly lower than D_6 in February and March. There was also a high plant density x nitrogen level interaction. Its significance was primarily due to the progressive increase in yield with density at the 0 pound level of nitrogen and its reduction at the highest density when nitrogen was applied either at 60, 120 or 240 pounds per acre.

The interaction data between plant density vs. planting date indicate that in January plantings soybean can probably be benefited by heavier seeding than D_8 because growth is at its lowest ebb due to shortest days of the year. It is further shown that plantings made later than January maybe seeded only up to D_6 for increase in seed yield.

Based on the plant density x nitrogen interaction data it seems that at 0 nitrogen level plant density can be increase higher than D_8 and that with nitrogen fertilizer especially at higher levels positive response to density treatment can be obtained when level is only as high as D_6.

Percent aborted ovule did not show any response to density treatments.

Likewise, the weight per 100 seeds was essentially unaffected, contrary to previous findings. Probst (35) reported that narrow within the row spacing produced slightly heavier seeds. But according to another report (30) wider spacing in the row increased seed size. Other workers such as Lehman and Lambert (23) found that seeds were progressively lighter when population became denser.

Response in plant height was practically the same as that in seed yield. Maximum height was attained only when density was as high as D_6. Beyond D_6, there was reduction in height probably due to overcrowding. These results more or less conform with the findings of Camper and Smith (9).

Height significantly reacted to density treatments at different planting dates. It will be noted that height differences in March at D_4, D_6 and D_8 treatments were small compared to those occurring in January and February. This seems to indicate that as daylength increases and perhaps as other attendant factors become more favorable seeding should be made less heavily.

The number of branches per plot, likewise increase with density. There were significantly more branches at the three higher densities than at the lowest density.

There was differential response in number of branches to plant density during different dates of planting. Differences between D_2 and D_4 were much greater in February and March than in January. This accounted for the significant interaction.

Contrary to the respondes in plant height and number of branches, the average length of branches tended to decrease as density became thicker. However, significant difference was found only between D_2 and D_8.

Both the plant density x planting date and plant density x nitrogen interactions were significant. The first was due to shorter branches at D_2 in March than in February while the second was caused by shorter branches both at D_4 and D_8 when nitrogen fertilizer was applied at the rate of 240 pounds per acre than when the rate of application was 120 pounds per acre.

As shown by the data on both seed yield and average length of branches, it is clearly indicated that in spite of the shorter branches at the higher density treatments yield was not adversely affected. Apparently, if there was any adverse effect at all it was cancelled out by the larger number of branches at higher densities.

The results on plant density studies indicate off season production of soybean in the tropics can be increased by adjusting the plant density according to the time of planting, being highest at the dead of winter months of December and January and decreasing thereafter in either direction with decrease or increase in growing climatic conditions.

SUMMARY AND CONCLUSIONS

The investigations on the effect of planting date, nitrogen fertilization and plant density on the yield of seed of soybean grown during cooler and shorter days of the year in tropical Hawaii showed highly significant responses to all three treatments. Yield of seed of planting made in February was 3.6 times greater than that of January planting, and that of March planting was 2.2 times greater than that of January planting. All levels of nitrogen recorded higher seed production than that receiving no nitrogen. The yield differential was particularly marked between no nitrogen plots and those that received the lowest increment of nitrogen at the rate of 60 pounds of nitrogen per acre. Increase in plant density up to treatments with six plants per pot showed increase in yield but the increase was relatively small compared to other treatment series.

Responses were noted in seed size and percent aborted seeds but the differences were only a fraction of those noted in seed yield.

Responses in plant characters to treatments were even more pronounced than in yield of seeds. Contrary to expectation, however, the increased stimulation in growth by treatments was not reflected in proportional increase in seed yield.

The results of this test indicate that soybean planted in the tropics during the coller and shorter days flower and mature earlier and is shorter in height in spite of nitrogen fertilizer and plant density treatments but it does show that considerable increase in seed yield can be obtained by a combination of nitrogen fertilization and an increase in plant density.

The results have turned out to be statistically highly significant but before any definite conclusions can be drawn, the test must be repeated under field conditions and preferably over the entire year. Moreover, results in Hawaii obtained under the fringe of the tropical zone may not be necessarily applicable to wet equatorial belt, 10° on either side of the equator where the length of days are even shorter, without some modifications in treatment combinations or in nitrogen fertilization and plant density. Another stumbling block may be excessive rains during curing. Despite the many drawbacks to soybean production in the tropics, it appears that it is not impossible that the adverse effects of short daylength can be offset by appropriate fertilization and planting density, thus widening the latitude of cropping instead of the usual single crop in summer.

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APPENDIX TABLE 1

ANALYSIS OF VARIANCE OF SEED YIELD AS INFLUENCED BY PLANTING DATE, NITROGEN LEVEL AND PLANT DENSITY

SOURCE OF VARIATION	DF	SS	MS	F-COMP.
Replication (R)	3	100.00	33.46	2.08$^{n.s.}$
Planting date (T)	2	25,897.24	12,948.62	803.76**
Error (a)	6	96.65	16.11	
Nitrogen level (N)	3	18,809.22	6,269.74	225.21**
T X N	6	3,773.58	628.93	22.59**
Error (b)	27	751.63	27.84	
Plant Density (D)	3	3,352.48	1,117.49	47.01**
T X D	6	803.09	133.85	5.63**
N X D	9	721.64	80.18	3.37**
T X N X D	18	476.05	26.45	1.11$^{n.s.}$
Error (c)	108	2,566.88	23.77	

APPENDIX TABLE 2

ANALYSIS OF VARIANCE OF SEED SIZE(WEIGHT IN GRAMS PER 100 SEEDS) AS INFLUENCED BY PLANTING DATE, NITROGEN LEVEL AND PLANT DENSITY

SOURCE OF VARIATION	DF	SS	MS	F-COMP.
Replication (R)	3	15.45	5.11	2.10 n.s.
Planting date (T)	2	868.96	434.48	177.34**
Error (a)	6	14.71	2.45	
Nitrogen level (N)	3	1,194.63	398.21	87.71**
T X N	6	390.05	65.01	14.32**
Error (b)	27	122.68	4.54	
Plant density (D)	3	21.25	7.08	2.14**
T X D	6	5.79	0.96	0.29
T X N X D	18	80.15	4.45	1.43 n.s.
Error (c)	108	357.53	3.31	

APPENDIX TABLE 3

ANALYSIS OF VARIANCE OF PLANT HEIGHT AS INFLUENCED BY PLANTING DATE, NITROGEN LEVEL AND PLANT DENSITY

SOURCE OF VARIATION	DF	SS	MS	F-COMP.
Replication (R)	3	20.98	6.99	0.75 n.s.
Planting date (T)	2	4,965.24	2,482.62	265.52**
Error (a)	6	56.12	9.35	
Nitrogen level (N)	3	2,010.62	670.21	102.95**
T X N	6	107.20	17.87	2.74**
Error (b)	27	175.71	6.51	
Plant density (D)	3	546.07	182.02	119.75**
T X D	6	50.93	8.49	5.59**
N X D	9	10.35	1.15	0.76 n.s.
T X N X D	18	32.77	1.82	1.20 n.s.
Error (c)	108	163.76	1.52	

APPENDIX TABLE 4

ANALYSIS OF VARIANCE OF NUMBER OF BRANCHES PER PLOT AS INFLUENCED BY PLANTING DATE, NITROGEN LEVEL AND PLANT DENSITY

SOURCE OF VARIATION	DF	SS	MS	F-COMP.
Replication (R)	3	25.38	8.46	1.43$^{n.s.}$
Planting date (T)	2	5,573.09	2,786.54	470.70**
Error (a)	6	35.54	5.92	
Nitrogen level (N)	3	1,980.18	660.06	74.92**
T X D	6	328.62	54.77	6.22**
Error (b)	27	237.89	8.81	
Plant density (D)	3	976.10	325.37	28.97**
T X D	6	250.95	41.82	3.72**
N X D	9	115.75	12.86	1.15$^{n.s.}$
T X N X D	18	163.01	9.06	0.81$^{n.s.}$
Error (c)	108	1,212.94	11.23	

APPENDIX TABLE 5

ANALYSIS OF VARIANCE OF AVERAGE LENGTH OF BRANCHES AS INFLUENCED BY PLANTING DATE, NITROGEN LEVEL AND PLANT DENSITY

SOURCE OF VARIATION	DF	SS	MS	F-COMP.
Replication (R)	3	25.67	8.56	2.99$^{n.s.}$
Planting date (T)	2	1,414.91	707.46	247.36**
Error (a)	6	17.15	2.86	
Nitrogen level (N)	3	530.66	176.89	58.96**
T X N	6	77.92	12.99	4.33**
Error (b)	27	80.90	3.00	
Plant density (D)	3	338.81	112.94	57.62**
T X D	6	84.99	14.16	7.22**
N X D	9	57.17	6.35	3.24**
T X N X D	18	30.22	1.68	0.86**
Error (c)	108	211.64	1.96	

APPENDIX TABLE 6a

TABULAR F VALUES

SOURCE OF VARIATION	DF	F 0.05	F 0.01
Relication (R)	3	4.76	9.78
Planting date (T)	2	5.14	10.92
Error (a)	6		
Nitrogen level (N)	3	2.96	4.60
T X N	6	2.46	3.56
Error (b)	27		
Plant density (D)	3	2.69	3.97
T X D	6	2.18	2.98
N X D	9	1.96	2.58
T X N X D	18	1.73	2.17
Error (c)	108		
Total	191		

APPENDIX TABLE 6b

TABULAR F VALUES

SOURCE OF VARIATION	DF	F 0.05	F 0.01
Replication (R)	3	3.86	6.99
Planting date (T)	3	3.86	6.99
Error (a)	9		
Nitrogen level (N)	3	2.86	4.38
T X N	9	2.15	2.94
Error (b)	36		
Plant density (D)	3	2.67	3.92
T X D	9	1.94	2.54
N X D	9	1.94	2.54
T X N X D	27	1.57	1.88
Error (c)	144		
Total	255		

APPENDIX TABLE 7a

MULTIPLE COMPARISON OF SEED YIELD AS INFLUENCED BY PLANTING DATE WITH THE USE OF DUNCAN'S NEW MULTIPLE RANGE TEST

PLANTING DATE		$\bar{x}$	$\bar{x}$-10.99	$\bar{x}$-24.52
T_2		39.43	28.44**	14.91**
T_3		24.52	13.53	
T_1		10.99		
p		2	3	
Rp values	5%	6.95	7.20	
	1%	10.52	10.92	

APPENDIX TABLE 7b

MULTIPLE COMPARISON OF SEED SIZE (GRAMS PER 100 SEEDS) AS INFLUENCED BY PLANTING DATE WITH THE USE OF DUNCAN'S NEW MULTIPLE RANGE TEST

PLANTING DATE		$\bar{x}$	$\bar{x}$-17.64	$\bar{x}$-19.36
T_2		22.76	5.12**	3.40
T_3		19.36	1.72	
T_1		17.64		
p		2	3	
Rp values	5%	2.71	2.81	
	1%	4.11	4.26	

APPENDIX TABLE 7c

MULTIPLE COMPARISON OF NUMBER OF BRANCHES PER PLOT AS INFLUENCED BY PLANTING DATE WITH THE USE OF DUNCAN'S NEW MULTIPLE RANGE TEST

PLANTING DATE		$\bar{x}$	$\bar{x}$- 4.31	$\bar{x}$-13.95
T_2		16.94	12.63**	2.99
T_3		13.95	9.64	
T_1		4.31		
p		2	3	
Rp values	5%	4.21	4.36	
	1%	6.38	6.61	

APPENDIX TABLE 7d

MULTIPLE COMPARISON OF AVERAGE LENGTH OF BRANCHES AS INFLUENCED BY PLANTING DATE WITH THE USE OF DUNCAN'S NEW MULTIPLE RANGE TEST

PLANTING DATE		$\bar{x}$	$\bar{x}$- 2.40	$\bar{x}$- 7.78
T_3		8.47	6.07**	0.69
T_2		7.78	5.38**	
T_1		2.40		
p		2	3	
Rp values	5%	2.92	3.03	
	1%	4.43	4.60	

APPENDIX TABLE 7e

MULTIPLE COMPARISON OF PLANT HEIGHT AS INFLUENCED BY PLANTING DATE WITH THE USE OF DUNCAN'S NEW MULTIPLE RANGE TEST

PLANTING DATE		$\bar{x}$	$\bar{x}$-26.97	$\bar{x}$-36.69
T		38.58	11.61**	1.89
T		36.69	9.72	
T		26.97		
p		2	3	
Rp values	5%	5.29	5.48	
	1%	8.01	8.31	

APPENDIX TABLE 8a

MULTIPLE COMPARISON OF YIELD AS INFLUENCED BY NITROGEN LEVEL WITH THE USE OF DUNCAN'S NEW MULTIPLE RANGE TEST

NITROGEN LEVEL	$\bar{x}$	$\bar{x}$- 8.99	$\bar{x}$-25.44	$\bar{x}$-29.95
N_4	35.53	26.54**	10.09	5.58
N_2	29.95	20.96**	4.51	
N_1	25.44	16.45**		
N_0	8.99			
P	2	3	4	
Rp values 5%	7.65	8.04	8.30	
1%	10.32	10.77	11.08	

APPENDIX TABLE 8b

MULTIPLE COMPARISON OF SEED SIZE (GRAMS PER 100 SEEDS) AS INFLUENCED BY NITROGEN LEVEL WITH THE USE OF DUNCAN'S NEW MULTIPLE RANGE TEST

NITROGEN LEVEL	$\bar{x}$	$\bar{x}$-15.73	$\bar{x}$-20.44	$\bar{x}$-21.33
N_4	22.17	6.44**	1.73	0.84
N_2	21.33	5.60**	0.89	
N_1	20.44	4.71**		
N_0	15.73			
P	2	3	4	
Rp values 5%	3.09	3.25	3.35	
1%	4.17	4.35	4.47	

APPENDIX TABLE 8c

MULTIPLE COMPARISON OF NUMBER OF BRANCHES PER PLOT AS INFLUENCED BY NITROGEN LEVEL WITH THE USE OF DUNCAN'S NEW MULTIPLE RANGE TEST

NITROGEN LEVEL	$\bar{x}$	$\bar{x}$- 6.44	$\bar{x}$-12.08	$\bar{x}$-1356
N_4	14.85	8.41**	2.77	1.29
N_2	13.56	7.12**	1.48	
N_1	12.08	5.64*		
N_0	6.44			
p	2	3	4	
Rp values 5%	4.30	4.52	4.67	
1%	5.81	6.06	6.23	

APPENDIX TABLE 8d

MULTIPLE COMPARISON OF AVERAGE LENGTH OF BRANCHES AS INFLUENCED BY NITROGEN LEVEL WITH THE USE OF DUNCAN'S NEW MULTIPLE RANGE TEST

NITROGEN LEVEL	$\bar{x}$	$\bar{x}$- 3.44	$\bar{x}$- 6.42	$\bar{x}$- 7.44
N_4	7.56	4.13**	1.14	0.12
N_2	7.44	4.00**	1.02	
N_1	6.42	2.98		
N_0	3.44			
p	2	3	4	
Rp values 5%	2.51	2.64	2.72	
1%	3.39	3.54	3.64	

APPENDIX TABLE 8e

MULTIPLE COMPARISON OF PLANT HEIGHT AS INFLUENCED BY NITROGEN LEVEL WITH THE USE OF DUNCAN'S NEW MULTIPLE RANGE TEST

NITROGEN LEVEL	$\bar{x}$	$\bar{x}$-28.62	$\bar{x}$-34.77	$\bar{x}$-36.16
N_4	36.77	8.15**	2.00	0.61
N_2	36.16	7.54**	1.39	
N_1	34.77	6.15**		
N_0	28.62			
p	2	3	4	
Rp values 5%	3.70	3.89	4.01	
1%	5.00	5.21	5.36	

APPENDIX TABLE 9a

MULTIPLE COMPARISON OF SEED YIELD AS INFLUENCED BY PLANT DENSITY WITH THE USE OF DUNCAN'S NEW MULTIPLE RANGE TEST

PLANT DENSITY	$\bar{x}$	$\bar{x}$-18.61	$\bar{x}$-24.56	$\bar{x}$-26.62
D_6	30.12	11.51**	5.56	3.50
D_8	26.62	8.01	2.06	
D_4	24.56	5.95		
D_2	18.61			
p	2	3	4	
Rp values 5%	6.85	7.19	7.43	
1%	9.03	9.41	9.68	

APPENDIX TABLE 9b

MULTIPLE COMPARISON OF NUMBER OF BRANCHES PER PLOT AS INFLUENCED BY PLANT DENSITY WITH THE USE OF DUNCAN'S NEW MULTIPLE RANGE TEST

PLANT DENSITY	$\bar{x}$	$\bar{x}$- 8.04	$\bar{x}$-11.77	$\bar{x}$-13.48
D_8	13.65	5.61**	1.88	0.17
D_6	13.48	5.44*	1.71	
D_4	11.77	3.73		
D_2	8.04			
p	2	3	4	
Rp values 5%	4.70	4.94	5.11	
1%	6.21	6.47	6.65	

APPENDIX TABLE 9c

MULTIPLE COMPARISON OF AVERAGE LENGTH OF BRANCHES AS INFLUENCED BY PLANT DENSITY WITH THE USE OF DUNCAN'S NEW MULTIPLE RANGE TEST

PLANT DENSITY	$\bar{x}$	$\bar{x}$- 4.26	$\bar{x}$- 5.80	$\bar{x}$- 7.05
D_2	7.75	3.49**	1.95	0.70
D_4	7.05	2.79**	1.25	
D_6	5.80	1.54		
D_8	4.26			
P	2	3	4	
Rp values 5%	1.97	2.06	2.13	
1%	2.59	2.70	2.78	

APPENDIX TABLE 9d

MULTIPLE COMPARISON OF PLANT HEIGHT AS INFLUENCED BY PLANT DENSITY WITH THE USE OF DUNCAN'S NEW MULTIPLE RANGE TEST

PLANT DENSITY	$\bar{x}$	$\bar{x}$-31.48	$\bar{x}$-33.84	$\bar{x}$-35.00
D_6	36.00	4.52**	2.16**	1.00
D_8	35.00	3.52**	1.16	
D_4	33.84	2.36**		
D_2	31.48			
P	2	3	4	
Rp values 5%	1.73	1.82	1.88	
1%	2.28	2.38	2.44	

APPENDIX TABLE 10

MAXIMUM AND MINIMUM TEMPERATURES AND RAINFALL ON MANOA CAMPUS[1]

JANUARY				FEBRUARY				MARCH			
	TEMPERATURE		RAIN-		TEMPERATURE		RAIN-		TEMPERATURE		RAIN-
DAY	Max.	Min.	FALL	DAY	Max.	Min.	FALL	DAY	Max.	Min.	FALL
1				1				1			
2	80	69	0.62	2				2	79	61	0.28
3	81	65	0.37	3	84	63	0.06	3	79	64	0.01
4	--	--		4	82	65	T	4	81	64	0.01
5	--	--		5	81	64	0	5	82	65	0.01
6	80	69	1.69	6	81	64	0.05	6	81	66	T
7	76	67	0.68	7	81	66	0.03	7	--	--	
8	81	69	0.22	8	--	--		8	--	--	
9	81	69	0.10	9	--	--		9	82	65	0.22
10	78	68	0.09	10	80	60	0.18	10	79	63	0.02
11	--	--		11	77	64	0.02	11	77	64	T
12	--	--		12	78	66	0.08	12	80	63	0.01
13	81	71	0.01	13	79	65	0.13	13	81	66	0.10
14	82	72	0	14	73	61	0.11	14	--	--	
15	82	72	0.08	15	--	--		15	--	--	
16	80	69	0.21	16	--	--		16	81	62	T
17	79	72	T	17	80	63	0.11	17	81	65	0.01
18	--	--		18	81	64	0.01	18	83	65	0.0
19	--	--		19	79	64	0.04	19	81	64	0.07
20	80	68	0.12	20	80	62	0	20	83	60	0.76
21	79	69	0.17	21	--	--		21	--	--	
22	79	66	0.01	22	--	--		22	--	--	
23	80	65	0.04	23	--	--		23	83	62	0.50
24	82	67	T	24	81	63	0.02	24	81	65	2.10
25	--	--		25	78	63	0.09	25	69	62	0.79
26	--	--		26	75	62	0.45	26	--	--	
27	80	68	T	27	77	62	0.11	27	--	--	
28	79	71	T	28	77	62	T	28	--	--	
29	82	71	0	29	--	--		29	--	--	
30	82	71	T	30	--	--		30	80	62	0.76
31	82	68		31	--	--		31	80	64	0.04
TOTAL	1766	1516	4.41		1504	1203	1.49		1603	1210	5.69
AVERAGE	80	69			79	63			80	61	

[1]Data recorded by the Meteorology Department of the University of Hawaii.

APPENDIX TABLE 10 (Continued)

MAXIMUM AND MINIMUM TEMPERATURES AND RAINFALL ON MANOA CAMPUS[1]

APRIL				MAY				JUNE			
	TEMPERATURE:		RAIN-		TEMPERATURE:		RAIN-		TEMPERATURE:		RAIN-
DAY	Max.	Min.	FALL	DAY	Max.	Min.	FALL	DAY	Max.	Min.	FALL
1	80	65	T	1	79	79	0.01	1	86	63	0
2	82	66	0.26	2	--	--		2	84	66	0.05
3	81	67	0.65	3	--	--		3	85	68	0
4	--	--		4	80	65	0.12	4	86	67	0
5	--	--		5	81	65	0.01	5	86	67	0
6	81	65	0.36	6	80	65	0	6	--	--	
7	80	64	T	7	80	64	0	7	--	--	
8	80	65	0.10	8	80	65	0.01	8	85	68	0.03
9	78	64	0.06	9	--	--		9	84	69	T
10	78	65	0.01	10	--	--		10	84	68	0
11	--	--		11	81	65	0.06	11	--	--	
12	--	--		12	80	64	0	12	86	66	0
13	80	64	0.01	13	79	64	T	13	--	--	
14	82	66	0	14	79	64	0.01	14	--	--	
15	82	65	0	15	79	65	0.12	15	84	68	T
16	83	65	0	16	--	--		16	80	69	0.02
17	82	67	T	17	--	--		17	83	69	T
18	--	--		18	82	64	0	18	82	69	0
19	--	--		19	82	65	0	19	83	71	0
20	82	64	0.12	20	81	67	0.05	20	--	--	
21	83	66	0.25	21	80	68	0.16	21	--	--	
22	79	66	0.47	22	80	68	0.54	22	85	70	0.12
23	79	65	0.11	23	--	--		23	82	68	0.03
24	78	64	1.00	24	--	--		24	80	68	0.02
25	--	--		25	79	67	0.50	25	83	69	0.10
26	--	--		26	76	66	0.10	26	84	69	0.07
27	79	62	0.44	27	79	66	0.06	27	--	--	
28	78	64	0.01	28	80	64	T	28	--	--	
29	76	66	0.18	29	--	--		29	82	67	0.16
30	76	65	0.06	30	--	--		30	82	68	0.13
31	--	--		31	--	--		31	--	--	
Total	1759	1430	4.08		1597	1315	1.75		1756	1427	0.73
Average	80	65			80	66			84	68	

[1] Data recorded by the Meterorology Department of the University of Hawaii.

APPENDIX TABLE 11

DAYLENGTH IN HONOLULU[1]

MONTHS	DATES		
	1	16	31
January	10.8	11.0	11.2
February	11.2	11.5	11.7
March	11.7	12.0	12.3
April	12.4	12.6	12.9
May	12.9	13.2	13.4
June	13.4	13.4	13.4
July	13.4	13.3	13.1
August	12.1	12.8	12.6
September	12.5	12.2	12.0
October	12.0	11.6	11.4
November	11.4	11.1	10.9
December	10.9	10.8	10.8

[1]U.S. Weather. Local Climatological Data. Honolulu. 1949.