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Effect of Planting Time, Plant Population and Row Spacing on Yield and Other Characteristics of Pigeonpeas, *Cajanus cajan* (L.) Millsp.[1]

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INTRODUCTION

The value of pigeonpeas, *Cajanus cajan* (L.) Millsp., increased rapidly in Puerto Rico during the last decade, from $15.14 per hundredweight in 1961–62 to $40.00 in 1970–71. The value of the 1970–71 crop was estimated at more than $3 million. In spite of this increase, total production decreased from 116,000 hundredweights of green peas in 1961 to 75,000 in 1971.

Increased production costs, especially the high cost of harvesting, accounted partially for this decrease. The major areas of production in the southern part of the island are in poor soils which are not adapted to mechanized farm operations. These two factors, plus inadequate production practices followed in these areas, have resulted in lower yields per acre.

It will be possible in the future, however, to grow pigeonpeas commercially on farms adapted to mechanical operations in the lowlands of Puerto Rico.

The present investigation was undertaken because of the paucity of information pertaining to the response of pigeonpeas to time of planting, and the best combination of population and row spacing, with special reference to mechanized production. The major objectives were to obtain basic data furnishing information as to the effects of these factors and others on yield and other agronomic characteristics.

MATERIALS AND METHODS

The experiments were conducted during 1970–71 on a Coto clay at the Isabela Agricultural Experiment Substation, Isabela, P.R.

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Pigeonpea cultivar Kaki was selected for the purpose of this study. Seedings at the rates of 9,075, 18,150 and 36,350 plants per hectare were made in each of the following three row spacings: 91.4 cm. (3 feet), 121.9 cm. (4 feet), and 182.8 cm. (6 feet). Uniform stands were obtained by thick planting and subsequent hand thinning to the spacings shown in table 1. Prometryne was applied as a pre-emergent herbicide at the rate of 3.33 kg./ha. (3 lbs./A) and Paraquat was applied as a post-emergent herbicide at the rate of 1.18 liter/ha. (1 lb./A) when the plants were about 45 cm. (18 inches) tall. The experiments were planted during 1970 in April, May, June, July, August, September and October.

The two center rows of a 4-row plot were harvested at the mature-green pod stage. The number of plants harvested per plot varied from 10 to 80. Data collected were converted to an equal-land area basis for analysis. The following attributes were evaluated:

1. Green pod yield—ql.[3]/ha. of green mature pods. (Pods picked by hand, three pickings per plot).

TABLE 1.—*Plant population, plant and row spacings used*

Population		Distance between rows (cm.)		
Code	Plants/ha.	91.4	121.9	182.8
		Distance between plants within rows		
	Number	*Centimeters*	*Centimeters*	*Centimeters*
P_1	9,075	121.9	91.4	60.9
P_2	18,150	60.9	45.7	30.5
P_3	36,350	30.5	20.3	15.2

2. Date of flowering—number of days from planting until 50 percent of the plants in a plot were in bloom.

3. Plant height—centimeters from ground level to top of stem at harvest.

4. Seed size—weight in grams per 100 seeds from a randomly selected sample of green whole seed.

5. Protein percent—determined on a dry-weight basis.

The average number of seeds per pod (Y) was from 100 pods picked at random in each plot. The mean seed weight (Z) was obtained by weighing 100 green seeds from a randomly selected sample in each plot. The number of pods per plant (X) was estimated from the equation W (yield) $= XYZ$, as defined in field beans by Adams (1), in soybeans by Anand and Torrie (2), and in peas by Johnson (4).

The design was a split-plot with four replications, having row spacings as whole plots and populations as subplots. Analyses of variance were made for green-pod yield, plant height, number of days to flower, and

[3] A quintal = 100 kg.

protein percentage. Treatments for row spacings and populations were constant across planting dates and that portion of the analyses was combined over planting dates.

RESULTS

Analyses of variance for green-pod yield, plant height, number of days to flower, and protein percent combined across planting dates are presented in table 2. Means for these characters for the various population arrangements for each planting date are presented in table 3.

TABLE 2.—*Analyses of variance for mature green pod yield (ql./ha), plant height, days to flower, and protein percent of the dry seed for combined 7-month planting date data*

Source of variation	D.F.	Yield	Height	Flowering	Protein
Planting dates (P.D.)	6	5,952.6**[1]	127.5**	46,224.10**	15.00**
Spacing between rows (R.W.)	2	135.9**	.05	2.55	.05
P.D. × R.W.	12	52.7**	.22	2.51	.77
Replications (R.) in P. D.	21	17.9	.52**	24.89**	.90
R. in P.D. × R.W.	42	18.1	.17	2.53	.67
Population (P.) in R.W.	6	336.2**	.25	1.37	.43
P. in 91.4 cm.	2	361.1**	.05	1.75	.20
P. in 121.9 cm.	2	88.5**	.15	1.75	.15
P. in 182.8 cm	2	559.1**	.15	.60	.95
P.D. × P. in R.W.	36	37.1**	.08	1.37	.57
P.D. × P. in 91.4 cm.	12	52.0**	.06	1.72	.60
P.D. × P. in 121.9 cm.	12	26.3**	.06	1.79	.20
P.D. × P. in 182.8 cm.	12	91.9**	.12	.58	.57
R. in P.D. × P. in R.W.	126	7.6	.11	2.40	.87
C. V. (percent)		13.0	5.4	0.95	4.7

[1] ** = Significant at 1-percent level.

YIELD

The effects of planting date were highly significant for green-pod yield. The highest yields were obtained in the early planting dates, i.e., April, May and June, with a mean green-pod yield of 83.0 ql./ha. (68.6 cwt./A), 62.8 ql./ha. (51.9 cwt./A), and 68.5 ql./ha. (56.6 cwt./A), respectively. Yields were much lower after June, especially during the last two planting dates (September and October), with a mean green-pod yield of 13.2 ql./ha. (10.9 cwt./A) and 7.09 ql./ha. (5.8 cwt./A), respectively. Significant interactions were between planting date × row spacing and planting date × population in row spacing.

The effect of row spacing was highly significant for green-pod yield.

TABLE 3.—*Mean agronomic and protein-percent performance obtained for the three populations at seven planting dates at Isabela, Puerto Rico in 1970–71*

Planting date	Population code	Time to flower	Height	Seed weight	Pod yield	Protein
		Days	*Cm.*	*G./100*	*Ql./ha.*	*Percent*
April	P_1	225	235	33.0	76.1	20.4
	P_2	225	247	33.1	80.8	20.1
	P_3	225	241	33.5	92.2	20.4
	Mean	225	241	33.2	83.0	20.3
May	P_1	187	241	32.4	51.2	20.1
	P_2	187	244	33.2	60.4	20.1
	P_3	187	244	31.4	76.6	20.0
	Mean	187	243	32.3	62.8	20.1
June	P_1	175	229	32.9	52.0	19.3
	P_2	175	226	32.4	71.6	19.0
	P_3	175	232	31.7	82.4	18.8
	Mean	175	229	32.3	68.5	19.0
July	P_1	154	192	32.8	41.3	19.5
	P_2	154	186	32.6	42.1	19.9
	P_3	154	189	32.4	47.4	21.1
	Mean	154	189	32.6	43.7	19.6
August	P_1	133	146	32.2	38.0	18.8
	P_2	133	149	32.1	40.8	19.4
	P_3	133	152	32.4	46.9	19.1
	Mean	133	149	32.2	42.0	19.1
September	P_1	129	131	31.8	11.0	18.6
	P_2	129	134	31.7	12.5	18.8
	P_3	129	134	32.0	16.2	18.4
	Mean	129	133	31.8	13.2	18.6
October	P_1	131	101	31.9	5.1	20.2
	P_2	131	98	32.5	6.5	20.2
	P_3	131	104	31.5	10.0	20.1
	Mean	131	101	32.0	7.0	20.1

Within each row spacing, green-pod yield increased with each increase in population. The mean pod yield for 91.4 cm. and 121.9 cm. row spacings were 45.4 ql./ha. (40.5 cwt./A), 41.1 ql./ha. (36.7 cwt./A) and 40.7 ql./ha. (36.3 cwt./A), respectively, across planting dates, indicating that yield was maximized when plants were grown in 91.4 cm. rows. There was no significant increase in yield between 121.9 cm. and 182.8 cm. row spacings, although the data tends to indicate a linear relationship across row spacings.

The differences in population between the various row spacings were highly significant for green yield; in specific row spacings they were significantly different at the 1-percent level (table 2). In general, it is evident that differences between populations became more marked with decreasing row spacings. Average yield across all row spacings was always highest at the 14,520-plant level per acre (P_3). The planting date × population in row spacing was significant at the 1-percent level for green-pod yield in all tried row spacings.

The effect of time of planting and plant population on the green-pod yield of pigeonpeas is shown in figure 1.

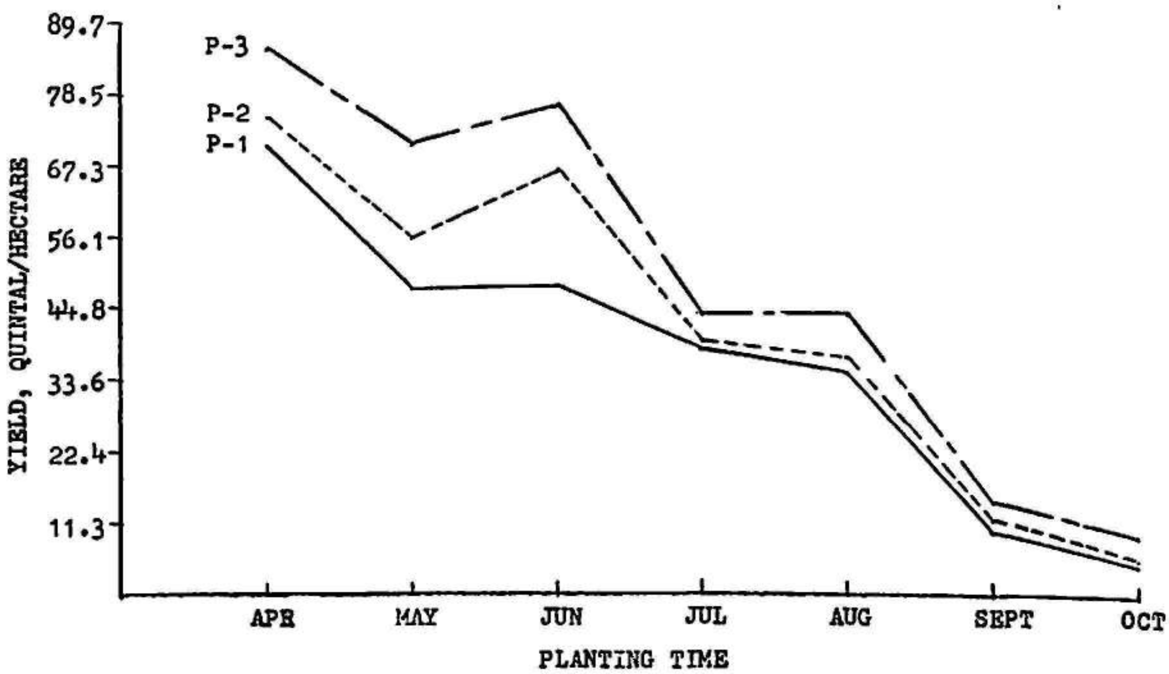

FIG. 1.—Effect of planting time and plant population on the mean green-pod yield of pigeonpea cultivar Kaki.

PLANT HEIGHT

Date of planting had a significant effect on plant height. Maximum plant height was attained in the first two planting dates (April and May) with a progressive decrease with delayed plantings. The mean plant height ranged from 243 cm. in the first planting to 101 cm. in the last planting (October) as shown in figure 2.

Plant height was not affected either by row spacing or plant population. The findings in plant height are similar to previous results obtained with soybeans by Osler et al. (6), Weiss et al. (8), and Webber et al. (7).

DATE OF FLOWERING

The number of days to flower followed a pattern similar to plant height; i.e., this factor was significantly affected by date of planting but not by either row spacing or plant population. It is quite clear from the data in table 3 that delayed planting reduced the number of days to flower as well as the size of plant. Pigeonpeas planted in April required 225 days from germination to flowering date while late planting (October) required only 131 days. Figure 3 shows the effect of planting date on the number of days to flower.

PROTEIN

Percent protein decreased slightly but significantly with late planting dates, indicating influence by this factor. However, as in the instances of

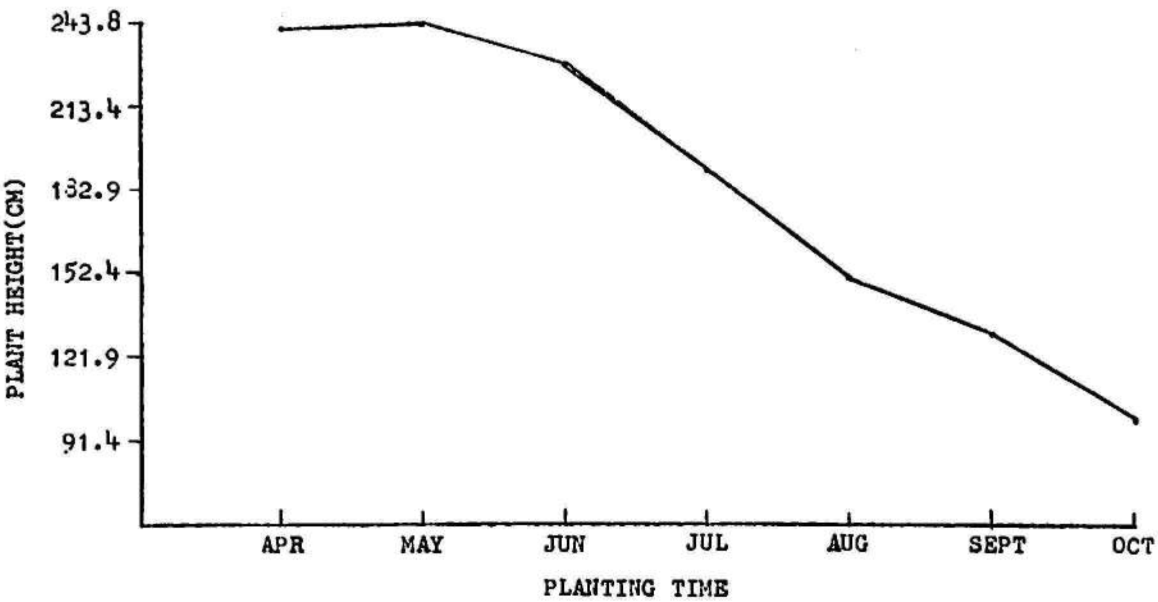

FIG. 2.—Mean plant height of pigeonpea cultivar Kaki as affected by planting date.

plant height and date of flowering, there was no effect either from row spacing or plant population on seed protein content.

YIELD COMPONENTS

NUMBER OF PODS PER PLANT

The number of pods per plant dropped significantly by both delayed planting and plant population, and decreased consistently with increased plant population (table 4). These findings are similar to those previously reported for soybeans by Osler et al. (6) and Weiss et al. (8), and for peas (*Pisium sativum* L.) by Gritton and Eastin (3).

NUMBER OF SEEDS PER POD

Delayed planting (September and October) slightly influenced the number of seeds per pod. Usually, pod borer infestations are considerably more intense late in the season. This may account at least in part for reduction of seeds per pod in September and October plantings.

SEED WEIGHT

Seed of almost equal size was harvested from all planting dates and populations as shown in table 4. The weight of 100 seeds was the plant character least affected by planting date, row spacing, or plant population.

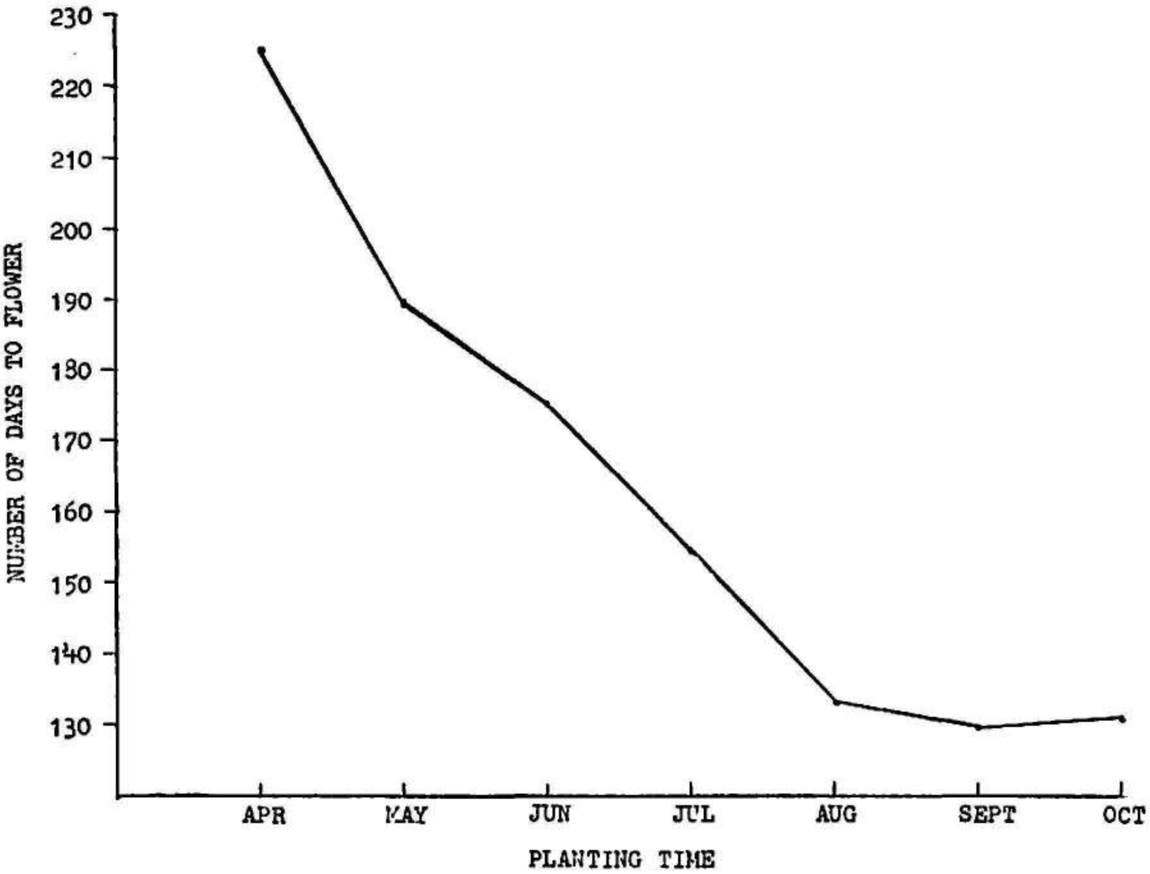

FIG. 3.—Mean number of days to flower of pigeonpea cultivar Kaki as affected by planting date.

DISCUSSION

Yield and chemical composition of the seed are among the attributes of primary importance in the commercial production of pigeonpeas. The Station breeding program is presently focused for that reason on the development of pigeonpea varieties that will fulfill both requirements. Future expansion and survival of the commercial pigeonpea industry in Puerto Rico will be limited, however, if field operations, including harvesting at the mature green-pod stage, are not fully mechanized. To accomplish these goals, the crop must be planted in the lowlands. Varieties must be developed purposely adapted or modified for mechanical harvesting. The time of

TABLE 4.—*Mean number of pods per plant, seeds per pod and seed weight obtained for the three populations at seven planting dates at Isabela, Puerto Rico, in 1970–71*

Planting date	Population code	Pods per plant	Seeds per plant	Seed weight
		Number	*Number*	*G./100*
April	P_1	574	4.0	33.0
	P_2	328	3.9	33.1
	P_3	188	4.1	33.5
	Mean	363	4.0	33.2
May	P_1	401	4.2	32.5
	P_2	259	4.1	33.5
	P_3	163	4.0	31.4
	Mean	274	4.1	32.4
June	P_1	429	3.9	32.9
	P_2	295	4.1	32.4
	P_3	180	3.9	31.7
	Mean	301	4.0	32.3
July	P_1	321	4.1	32.8
	P_2	171	4.3	32.8
	P_3	102	4.3	32.4
	Mean	198	4.3	32.7
August	P_1	317	4.1	32.2
	P_2	173	4.0	32.4
	P_3	105	3.9	32.4
	Mean	198	4.0	32.3
September	P_1	104	3.6	31.8
	P_2	59	3.8	31.7
	P_3	40	3.7	32.0
	Mean	68	3.7	31.8
October	P_1	50	3.6	31.9
	P_2	35	3.4	32.5
	P_3	24	3.7	31.5
	Mean	36	3.6	32.0

planting by determining the length and period of the growing season, and the desirable plant height for mechanical harvesting, create environmental conditions largely under the control of the farmer.

The data presented herein show that delayed planting of pigeonpeas has a definite influence upon yield, plant height, date of flowering, and protein content. Highest yields occurred in April, May, and June, intermediate yields in July and August, and sharply reduced yields in September and October.

The pigeonpea cultivar Kaki selected for this study is an indeterminate, well adapted, heavy yielder, intermediate in maturity under Puerto Rican conditions. It is possible that employment of early flowering cultivars, late planting and higher-population levels might produce results different from those reported herein. Williams and Spence in Trinidad and the authors in Puerto Rico (unpublished data), working with semi-dwarf, determinate-type of flowering lines, with pods maturing more or less at the same time, and with high plant populations (40 to 50,000 plants/acre), have obtained good commercial yields by late planting (October, November and December in Puerto Rico; December and January in Trinidad). Plant breeders may be able through such experiments to reduce environmental effects brought about by delayed planting in photoperiodic crops as pigeonpeas in the Tropics.

It is interesting to note the contrasting effect of date of planting upon plant height and number of days to flower (figs. 2 and 3). There are similarities between the date of flowering curve and the curve for plant height, with the most dramatic change occurring after the August planting. These two factors are of particular interest from the mechanization point of view. The taller plants of early planting (April, May, June) present mechanical harvesting problems. These early planting dates produce the highest yields, however, and where hand labor is available, the earlier dates compensate for the higher cost of production.

These experiments show, however, that it is possible to plant selected indeterminate cultivars at high population levels late in the season to compensate in part for the reduction in yield. By so doing, the season of production can be prolonged as it is apparent that the population response in this study is linear.

Delayed planting, as compared to early planting, tended to reduce the protein content of the seed. The decrease was in the order of 1.7 percent between the highest and lowest protein means for the 7-month planting season. The most significant effect however, was the lower total protein production per acre due to lower yields in later plantings.

One of the primary purposes of this investigation was to determine the relative importance of the three yield components and their influence on yield as affected by plant population and row spacing. The data (table 4) indicates that an increase in plant population consistently resulted in a decreased number of pods per plant. The same effect also was caused by delayed planting. This confirms results reported by Lehman and Lambert (5) in soybeans and Gritton and Eastin (3) in peas for processing.

Reduction in yield, resulting from delayed planting and small plant population, was not accompanied by a corresponding reduction in the weight of 100 seeds. Seeds of almost equal size were harvested from all plantings including the late one in October.

The number of seeds per pod was not substantially affected by changes in row spacing and planting date. A regular insecticide spraying program should be established for control of pod borer populations to minimize losses resulting from reduced numbers of seeds per pod.

The data show that reduced yield due to late planting and row spacing resulted from a reduction in the number of pods per plant rather than from a reduction in the number of seeds per pod and size of the seed.

SUMMARY

Pigeonpea cultivar Kaki was grown during 1970–71 to determine the effect of planting date, plant population and row spacing on green-pod yield, date of flowering, plant height, protein content of the seed and yield components.

Green-pod yields were significantly higher in plantings made during early April, May and June than during late September and October. Yield also tended to be higher at lower spacing between rows, and at highest populations, regardless of row spacing.

Plant height, number of days to flower and protein percent of the dry seed were unaffected by row spacing and plant population, but these factors were affected significantly by date of planting.

Pods per plant increased markedly as spacing was increased and with early plantings. Date of planting, row spacing and plant population had no affect on seed size or number of seeds per pod.

RESUMEN

La variedad comercial de gandur Kaki se sembró en 1970–71 para estudiar el efecto de la época de siembra, distancia entre hileras y población de plantas en el rendimiento de vainas verdes, fecha de la florescencia, altura de las plantas, contenido de proteína de la semilla y componentes del rendimiento.

El rendimiento de vainas verdes fue significativamente mayor en las siembras tempranas de abril, mayo y junio, que en las siembras tardías de septiembre y octubre. También se obtuvieron los mayores rendimientos sembrando a la menor distancia entre hileras con poblaciones altas.

La altura de las plantas, fecha de la florescencia y contenido de proteína del grano no fueron afectados por la distancia entre hileras ni la población de plantas, aunque sí lo fueron significativamente por la época de siembra.

El número de vainas por planta aumentó considerablemente con las épocas tempranas de siembra, según aumentó la distancia entre hileras. La época de siembra, distancia entre hileras y población de plantas no afectaron en nada el tamaño de la semilla y el número de semillas por vaina.

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