GUAR:

Seed, Plant And Population Studies

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GUAR:

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by

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Guar—*Cyamopsis tetragonoloba* (L.) Taub.—is a drought-tolerant, annual legume grown primarily in the Indo-Pakistan subcontinent. In India it is cultivated mainly in Rajesthan, Punjab, and Gujerat; while in West Pakistan, it is grown in Punjab and Sind. In these areas guar is cultivated as forage for cattle, as a green manure, and as a shade plant for ginger. It is also grown as a vegetable for human consumption and as a medicinal plant for both humans and livestock (5, 14, 15).

In the United States guar is presently being grown for industrial use. The beans of the crop are processed to make guar flour, which is a source of galactomannan gum. The gum is currently being used by paper, tobacco, petroleum, mining, textile, food, cosmetic, and pharmaceutical industries.

This bulletin reports results of recent investigations conducted on guar at the Oklahoma Agricultural Experiment Station. With the purpose of distinguishing types which are potentially adaptable to Oklahoma, the investigations included a survey of natural variability in the plant introductions; studies of seedcoat color and its effects on germination and plant growth; and studies of the effects of competition on plant performance.

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Survey of Genetic Diversity In Plant Introductions Of The Genus *Cyamopsis*

Methods and Materials

From 1959 to 1961 all available plant introductions of the genus (Table 1) were planted in dryland observation plots on the Agronomy Farm near Stillwater (6, 7, 9). In 1960, a duplicate nursery was grown at the Sandy Land Agronomy Research Station near Mangum. Each row was 16 feet long with a 3-foot alley between plots. The rows were spaced 40 inches apart. Approximately 100 scarified seed pretreated with Arasan were planted in each plot row.

A numerical code system was modified from the investigations of Patel *et al.* (11) by which plant introductions were classified according to the following three morphological characters:

A. Biramose hairs on leaves and pods.
   1. Absent (glabrous)
   2. Present
   3. Both characters

B. Pod length. Introduction produced:
   1. Small (average length of pod less than 4.0 cm. long)
   2. Medium (average length of pod is between 4.0 and 7.0 cm. long)
   3. Large (average length of pod is greater than 7.0 cm. long)
   4. Small and medium length pods
   5. Small and large pods
   6. Medium and large pods
   7. Small, medium and large pods

C. Branching habit. Introduction produced:
   1. Erect (plant produces a single primary axis)
   2. Upper branching (plant produces one or more branches on the upper portion of the primary axis)
   3. Branching (plant produces branches throughout the primary axis)
   4. Basal branching (plant produces branches at the base of the primary axis)

Table 1. Plant introductions of the genus *Cyamopsis*, origin, year introduced and morphological code*

P.I.**	Origin	Year Introduced	Biramose Hairs	Pod Length	Branching Habit
116034	Jaipur, India	1936	2	2	7
158116	New Delhi, India	1947	2	2	7
158118	Sirsa, India	1947	2	2	3
158119	Sirsa, India	1947	2	2	8
158120	Sirsa, India	1947	2	2	3
158121	Sirsa, India	1947	3	2	10
158123	Poona, India	1947	2	2	8
158124	Poona, India	1947	2	2	8
158125	Poona, India	1947	2	2	8
158126	Poona, India	1947	3	2	3
158129	Poona, India	1947	2	2	12
163103	New Delhi, India	1947	2	2	13
163104	Jubbulpore, India	1947	2	2	6
164170	Nagpur, India	1948	2	2	13
164299	Coimbatore, India	1948	3	2	3
164353	Jubbulpore, India	1947	2	2	13
164386	Jakhal, India	1948	2	2	3
164420	Loharu, India	1948	2	2	8
164429	Jaipur, India	1948	2	2	3
164446	Chatsu, India	1948	2	2	8
164476	Jaipur, India	1948	2	2	11
164477	Jaipur, India	1948	2	2	12
164485	Jaipur, India	1948	3	2	3
164486	Jaipur, India	1948	2	2	3
164592	Coimbatore, India	1948	3	3	5
164765	Belgaum, India	1948	2	2	3
164799	Poona, India	1948	2	2	14
164801	Poona, India	1948	2	2	3
165511	Lucknow, India	1948	2	2	6
165527	Malasa, India	1949	3	2	13
176373	New Delhi, India	1949	2	2	14
176374	New Delhi, India	1949	2	2	3
176375	New Delhi, India	1949	2	2	3
176377	New Delhi, India	1949	2	2	10
176378	New Delhi, India	1949	2	2	3
179682	Phulera, Jaipur, India	1948	2	2	3
179683	Pokaran, Jodhpur, India	1948	2	1	3
179684	Marwar, India	1948	2	2	3
179685	Jodhpur, India	1948	2	2	10
179686	Ahmedabad, India	1949	2	2	14
179926	Sakaranpur, India	1948	2	2	10
179928	Barmer, India	1949	2	2	11
179929	Sirohi, India	1948	2	2	10
179930	Posalia, India	1948	3	2	10
179931	Sihor, India	1949	3	2	8
180285	Manadir, India	1948	2	2	10
180287	Mount Abu, India	1949	2	2	11
180288	Bhavnagar, India	1949	3	2	10
180432	Sidhpur, India	1949	1	2	3
180433	Ahmedabad, India	1949	2	2	10
180434	Rajkot, India	1949	2	2	3
182968	Veraval, India	1949	1	2	5
182969	Bhuj, India	1949	2	2	7

* See preceding explanation.

** Plant introduction number.

Table 1. (Continued)

P.I.	Origin	Year Introduced	Biramose Hairs	Pod Length	Branching Habit
183315	Jamnagar, India	1949	3	2	13
183400	Surat, India	1949	3	2	3
186477	Coimbatore, India	1950	3	2	11
198296	New Delhi, India	1951	2	2	3
198297	New Delhi, India	1951	2	2	5
214041	Mysore, India	1954	2	2	14
214319	Ferozepur, India	1954	2	2	8
214320	Sirsa, India	1954	2	2	8
215590	Hansi, India	1954	2	2	10
215591	Moga, India	1954	2	2	3
217923	New Delhi, India	1954	2	2	7
217924	New Delhi, India	1954	2	6	14
217925	New Delhi, India	1954	3	2	11
223685	Anand, India	1955	2	2	6
223686	Anand, India	1955	3	2	6
236478	New Delhi, India	1957	3	2	13
236479	New Delhi, India	1957	2	2	4
250211	Gujrat, Pakistan	1958	2	2	10
250212	Gujrat, Pakistan	1958	2	2	3
250213	Gujrat, Pakistan	1958	2	2	10
250214	Gujrat, Pakistan	1958	2	2	7
250357	Lahore, Pakistan	1958	2	2	10
250358	Lahore, Pakistan	1958	2	2	3
250359	Lahore, Pakistan	1958	2	2	6
250360	Lahore, Pakistan	1958	2	2	10
253182	Glenn Dale, Maryland	1958	2	2	7
253183	Glenn Dale, Maryland	1958	2	2	7
253184	Glenn Dale, Maryland	1958	2	2	7
253185	Glenn Dale, Maryland	1958	2	2	13
253186	Glenn Dale, Maryland	1958	2	2	7
253187	Glenn Dale, Maryland	1958	3	2	10
254367	New Delhi, India	1958	3	2	3
254368	New Delhi, India	1958	2	2	3
262149	Lyallpur, Pakistan	1960	2	2	4
262151	Lyallpur, Pakistan	1960	2	2	3
262153	Lyallpur, Pakistan	1960	2	2	3
262154	Lyallpur, Pakistan	1960	3	2	6
262155	Lyallpur, Pakistan	1960	2	2	3
262156	Lyallpur, Pakistan	1960	2	2	13
262157	Lyallpur, Pakistan	1960	2	2	3
263406	Yangambi, Congo	1960	1	2	6
263525†	Bambey, Senegal	1960	2	1	3
263698	Khartoum, Sudan	1960	2	2	10
263874	New Delhi, India	1960	2	2	3
263875	New Delhi, India	1960	2	2	3
263876	New Delhi, India	1960	2	2	3
263877	New Delhi, India	1960	2	2	3
263878	New Delhi, India	1960	2	2	12
263879	New Delhi, India	1960	3	2	11
263880	New Delhi, India	1960	2	2	14
263881	New Delhi, India	1960	2	2	7
263882	New Delhi, India	1960	2	2	3
263883	New Delhi, India	1960	1	3	5
263884	New Delhi, India	1960	3	6	11
263885	New Delhi, India	1960	3	2	10
263886	New Delhi, India	1960	2	2	11
263887	New Delhi, India	1960	2	2	1

Table 1. (Continued)

P.I.	Origin	Year Introduced	Biramose Hairs	Pod Length	Branching Habit
263888	New Delhi, India	1960	1	3	15
263889	New Delhi, India	1960	2	2	7
263890	New Delhi, India	1960	3	2	10
263891	New Delhi, India	1960	2	2	3
263892	New Delhi, India	1960	2	2	3
263893	New Delhi, India	1960	2	2	8
263894	New Delhi, India	1960	2	2	8
263895	New Delhi, India	1960	2	2	3
263896	New Delhi, India	1960	2	2	14
263897	New Delhi, India	1960	2	2	3
263898	New Delhi, India	1960	2	2	3
263899	New Delhi, India	1960	2	2	3
263900	New Delhi, India	1960	2	6	13
263901	New Delhi, India	1960	3	2	7
268228	Bahawalpur, Pakistan	1960	2	2	3
268229	Bahawalpur, Pakistan	1960	2	2	3
271025†	Bambey, Senegal	1961	2	1	3
279564†	Kimberly, South Africa	1962	2	1	3

† All introductions are *Cyamopsis tetragonoloba* (L.) Taub. except 263525 and 271025 which are *C. senegalensis* Guill. and Perr. and 279564 which is *C. serrata* Schinz.

5. Erect and upper branching plants
6. Erect and branching plants
7. Erect and basal branching plants
8. Upper branching and branching plants
9. Upper branching and basal branching plants
10. Branching and basal branching plants
11. Erect, upper branching, and branching plants
12. Erect, upper branching, and basal branching plants
13. Erect, branching, and basal branching plants
14. Upper branching, branching, and basal branching plants
15. Erect, upper branching, branching, and basal branching plants

Discussion

Plant introduction 116034 is the only one of 47 accessions available from the pre-World War II introductions (4). Prior to 1946, plant introductions were evaluated at a few federal and state experiment stations. Many of the guar introductions were tested in areas unsuitable for proper growth; therefore, the seed were discarded. The Research and Marketing

Act of 1946 made funds available for the establishment of a national cooperative program for screening and testing of plant material which might be of commercial use. From 1947 through 1962, 156 plant introductions of *Cyamopsis* spp. were introduced into this country. Of these, 127 (Table 1) or 81 percent of the plant introductions have been maintained at the Oklahoma Agricultural Experiment Station, the Texas Agricultural Experiment Station and/or the Southern Regional Plant Introduction Station.

Many of the recent introductions from India appear to be duplicates of previous accessions. Furthermore, descriptions of introductions obtained from Brazil, Palestine, Australia, and the United States appear to be identical with accessions from India and Pakistan (3).

Biramose hairs on pods and leaves appeared in 96.1 percent of all the introductions, while 21.9 percent of the introductions contained glabrous plants (Table 2).

Table 2. Summary of data on biramose hairs in the plant introductions of the genus *Cyamopsis*.

Biramose Hairs	Number of Introductions Containing Character
Absent	5
Present	100
Mixed	23
TOTAL	128

In northern India and in Pakistan, where most of the introductions come from, farmers prefer pubescent type plants over glabrous types. This selection pressure creates an extreme bias towards this morphological character.

Roesler (12) evaluated certain plant introductions for edibility of the green pods. She reported that guar was by no means unacceptable to those who tasted it. "There was evidence of curiosity toward a new product and in general it was accepted as a new food stuff. The potential use of guar on the table is anticipated by those who became acquainted with it."

The frequency of medium-, large-, and small-sized pods present in the introductions was 94.5, 4.7, and 3.1 percent, respectively (Table 3).

Table 3. Summary of data on pod size in plant introductions of the genus *Cyamopsis*.

Pod Size	Number of Introductions Containing Character(s)
Small	4
Medium	118
Large	3
Small and medium	0
Small and large	0
Medium and large	3
Small, medium and large	0
TOTAL	128

Cyamopsis senegalensis (P.I.263525 and P.I.271025) and *C. serrata* (P.I.279564) had smaller pods in the observation plots than those of the *C. tetragonoloba* introductions. This finding is not too difficult to reconcile, since both *C. senegalensis* and *C. serrata* are wild species native to Africa, while *C. tetragonoloba* is found at present only in cultivated fields. Mutation and/or recombinations, coupled with selection pressure by farmers over the years, probably account for the increase in the average pod size of *C. tetragonoloba*. In fact, in India, most of the vegetable varieties are in the large pod category. However, in field trial experiments, Matlock (9) has shown that, in general, large podded plants in Oklahoma are poorer yielders and also later in fruiting than plants with medium-sized pods.

Branching plants appeared in 82.8 percent of the plant introductions evaluated, while the frequency of basal branching, erect, and upper branching plants was 40.6, 35.2, and 26.6 percent, respectively (Table 4).

The erect type of plant is favored in Kaira District, Gujerat, India. Here the Sotia variety is used as a shade plant for ginger and grows to a height of 10-12 feet. The young pods are stripped off the plant and eaten like string beans. Any excess foliage is reincorporated into the soil as a green manure. Elsewhere, the farmers of India and Pakistan favor the branching type plants.

A composite picture of the cultivar *C. tetragonoloba* reveals that it is a pubescent, branching plant with medium-sized pods. This composite is in reality a reflection on the areas from which the plant introductions originated. Examination by the senior author of the *Cyamopsis* folders at the Royal Botanical Gardens, Kew; Indian Botanical Gardens, Calcutta; and St. Xaviers College, Bombay, confirms the plant introduction composite of *C. tetragonoloba*.

Table 4. Summary on branching habit in plant introductions of the genus *Cyamopsis*.

Branching Habit	Number of Introductions Containing Character(s)
E*	1
Ub**	0
B†	45
Bb††	2
E and Ub	4
E and B	7
E and Bb	12
Ub and B	11
Ub and Bb	0
B and Bb	18
E, Ub and B	8
E, Ub and Bb	3
E, B and Bb	9
Ub, B and Bb	7
E, Ub, B and Bb	1
TOTAL	128

* E = Erect
** Ub = Upper Branching
† B = Branching
†† Bb = Basal Branching

At present, the best types for seed production in Oklahoma appear to be either the pubescent or glabrous medium-sized podded plants with branching, basal, or upper-branching type of growth habit. The erect types, i.e. Texsel variety, are excellent yielding plants under the most favorable conditions. However, under unfavorable conditions, if the primary growing point is destroyed by frost or by some organism, the growth of the plant is limited. However, in a branched type of plant, the destruction of the primary growing point does not mean that the plant is a total loss, for the side branches could partially compensate for this loss. Another important factor is that a branching type plant shades out potential weeds between the rows, while an erect type of plant offers little shading for late season weed control.

The upper-branched plants appear to be the ideal types for the future varieties of guar. These types have all the advantages of the completely-branched plants and the extra advantage of having pod formation initiated 4 to 12 inches from the ground. This is high enough to permit a combine to harvest the pods with very little seed loss.

C. senegalensis and *C. serrata* might someday serve as raw material for resistance to pests and organisms in guar breeding programs. However, at present their procumbent growth habit and shattering of mature seed from the pods eliminate them as potential agronomic crops.

Seedcoat Color And Germination Studies

Variations In Seedcoat Color Of Groehler Guar – Genetic Or Environmental?

In establishing guar as a cash crop, several important agronomic problems arise. A major problem is the gradations in seedcoat color of mature seed. The colors range from deep black to dull white. Musil (10) noted that the proportion of black seed varies from year to year and was believed to be due to frost. Guar gum processing companies prefer seed with light-colored seedcoats. They believe that in the manufacturing process, the dark seedcoats tend to discolor the pure white gum.

The object of this study was to establish whether variations in seedcoat color of Groehler variety of guar was due to an environmental or genetic phenomenon.

Methods and Materials

In the fall of 1959, part of a border row of Groehler variety of guar, surrounding the guar variety test at the Sandy Land Agronomy Research Station near Mangum, was harvested. The bulk sample was divided into two lots. One lot was retained by the experimenters and labeled "mixed seed." The second lot of seed, consisting of approximately 1,000 grams, was separated into four groups based on the light reflectance of the seedcoat[2] (Table 5).

A single row of each group plus a row of mixed seed were planted in June, 1960, at the Agronomy Research Station near Stillwater. The rows were 36 feet long with 40 inches between the rows. Unfortunately, the seed with more than 75 percent light reflectance had to be omitted because of an inadequate amount of seed.

The second generation plants were harvested in November, 1960. Approximately 750 grams of seed from each row were individually separated into the four original seedcoat reflectant categories.

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[2]The seed were separated by the Electric Sorting Machine Company, Houston, Texas.

Results and Discussion

As shown in Table 5, there was little difference between the second generation progeny seedcoats when they were sorted out into the various light reflectance components. That is, the black, grey, light grey, and mixed seed categories produced seedcoat colors in similar proportions to one another. However, the proportion of each light reflectance category varied between 1959 and 1960, indicating an environmental cause rather than a heritable one.

The senior author observed, that in India as one proceeds northward from the Kutch area of Gujerat, through Rajesthan and into the Punjab, the predominant seedcoat color of guar changes from dull white to grey-black. This change in seedcoat color tends to follow an increasing rainfall pattern. In Oklahoma, the brightest seed are produced in the southwestern counties where the average rainfall is between 20 and 30 inches. The Agronomy Farm near Stillwater, which averages about 35 inches of rainfall annually, consistently produces darker and poorer quality seed especially during seasons when excess rainfall occurs during September and October.

Table 5. Percentage and color of guar seed separated by light reflectance of the seedcoat in 1959 and percentage of each group in progeny grown from original seed separates in 1960.

Components By % Light Reflectance	Original Seed Percent	Original Seed Color	Mixed Seed %	Reflectance of 2nd Generation Progeny Seedcoats: Below 35%	35-55%	55-75%
Below 35%	34.44	Black	31.7	27.6	25.4	23.0
35 — 55%	30.69	Grey	33.7	36.7	34.7	38.2
55 — 75%	33.62	Light Grey	32.5	33.7	34.2	37.3
Over 75%	1.25	Dull White	2.0	2.0	5.7	1.4

Effect Of Temperature And Light Reflectance Of The Seedcoat, On Germination Of Groehler Guar

Another problem in establishing guar as a cash crop concerns the proper soil temperature for sowing the seed. Musil (10) reported that a constant 86 degrees F. was the most satisfactory temperature for germinating guar. However, she did not separate the dark seedcoats from the light-colored ones, but rather, germinated samples of unseparated lots.

This study was designed to investigate the effect of temperature, the light reflectance of the seedcoat, and the interaction between the two factors on the germination of Groehler guar seed.

Methods and Materials

The plant materials used in this experiment were similar to those used in the seedcoat color study. A refrigerator equipped with a Sargent temperature control unit served as the germination incubator. Each treatment contained 100 seed replicated four times. The seed were placed between two sheets of moistened absorbent paper which were rolled and surrounded by a sheet of waxed paper in order to maintain the moisture content. The rolls were kept intact by rubber bands. Germination tests were conducted at 60, 70, 80, and 90 degrees F.

Germination counts were made after one week of incubation. The ungerminated seed were returned to the incubator for another week of incubation. At the end of the second week, a final count was recorded. The analysis of variance (13) and Duncan's new multiple range test (2) are presented in Tables 6, 7, and 8.

Table 6. Analysis of variance of the effect of temperature and light reflectance of the seedcoat on germination of Groehler guar.

Source of Variation	D.F.	Sum of Squares	Mean Squares	F
Replications	3	142	47	
Temperature	3	54,072	18,024	643.71**
Error (a)	9	249	28	
Seedcoat Categories	3	2,252	751	27.81**
Temp. x S.C.	9	4,266	474	17.56**
Error (b)	36	959	27	
Total	63	61,940		

** Indicates significance at the one percent level of probability.

Table 7. Multiple range test of the effect of temperature on the percent germination of Groehler guar.

Temperature in ° F.	60	70	80	90
Mean* (in percent)	23.4	80.8	89.3	97.3

Table 8. Multiple range test of the effect of light reflectance of the seedcoat on the percent germination of Groehler guar.

Seed Category	55-75%	Mixed Seed	35-55%	Below-35%
Mean (in percent)*	62.9	73.9	74.9	78.9

* Any two means underscored by the same line are not significantly different.

Results and Discussion

At the one percent confidence level, the analysis of variance indicated that the mean percentages of germination for temperature, seedcoat reflectance categories, and the interaction between temperature and the seedcoat reflectance categories were each significantly different. Interaction between temperature and the seedcoat reflectance categories was mainly due to the fact that the germination slopes of the four seedcoat categories changed independently with changing temperatures.

As measured by Duncan's new multiple range test, there was a significant difference in germination at the one percent level of significance among percent germination at the various levels. Moreover, $\frac{dG}{dT}$ is maximum at 60 to 70 degrees F.[3] When temperature is plotted against the average germination means, the equation fits a quadratic curve.

At both the five and one percent levels of probability, the 55-75 percent light reflectant seed was significantly inferior in germination to the other seedcoat categories.

A separate study was conducted to determine the effect of scarification on light grey seed (55-75% light reflectance) when germinated at 70 degrees F. Seed were scarified for five minutes using a modified Hamilton Beach mixer with a rheostat setting on 40. The results were as follows:

[3] G = germination T = temperature

	Germinated Seed Percent	Hard Seed Percent
Unscarified Seed	75.5	24.5
Scarified Seed	92.8	7.2

Mechanically scarifying the seedcoat increased the mean germination percentage by 17.3 percent and reduced hard seed to 7.2 percent. Musil (10) using dilute sulfuric acid as the scarifying agent, obtained similar results.

In order to obtain good stands of guar, the data indicate that the crop should be planted in the field when the soil temperature is at least 70 degrees F. The dark seedcoat is discriminated against by farmers and seedmen in the belief that it lowers the germination, ultimately resulting in poor stands. Experimental evidence indicates that in the laboratory studies, dark-colored seed germinated equally as well as the light-colored seed.

Dark-colored seed appear to be scarified by nature, while light-colored seed retain the hard seedcoat. In the event of a cool season, scarification of guar seed may insure a farmer against poor stands.

Influence Of Light Reflectance Of The Seedcoat On Seedling Emergence And On Rate Of Growth Of Groehler Guar

The previous two studies reported the results of laboratory experiments involving the interaction of environment with the amount of light reflectance of the seedcoat. This study was designed to investigate the influence of light reflectance of the seedcoat on seedling emergence and on the rate of growth during the growing season in a field experiment.

Methods and Materials

The Groehler seed used in this experiment included those separated into three groups by light reflectance of the seedcoat, the mixed lot, and the scarified 55-75 percent reflectant group used in previous experiments.

The five classes of seed were planted June 9, 1960, on the Agronomy Farm near Stillwater, in single rows in a randomized block design with three replications. Each row was 20 feet long and contained 100 seed.

The rows were 40 inches apart. Emergence counts were taken each day from June 13 to June 26 and once again on July 10.

Rate of growth, as measured by centimeters of height of 10 randomly chosen plants in each row, was taken on June 19 and continued weekly until September 11.

Results and Discussion

As shown in Table 9, the 55 to 75 percent light reflectant, scarified seed emerged more rapidly than the other classes. However, within a week after emergence each of the other classes except the below 35 percent light reflectant seed increased their germination percentages to approximately that of the scarified seed and remained fairly constant for the duration of the test. An interesting result was the relatively poor germination percentage of each seed category. The highest count (69.0 percent) was on June 16 in the scarified seed treatment. The below 35

Table 9. Influence of light reflectance of the seedcoat on percent germination.

		Category of light Reflectant Seedcoats			
Date	Mixed Seed	Below 35%	35-55 %	55-75 %	Scarified 55-75%
		Percent Germination			
June 13	53.3	43.3	56.6	43.0	64.3
14	54.0	45.6	58.3	50.6	66.6
15	55.6	45.6	58.6	52.3	67.6
16	58.6	45.6	60.3	57.6	69.0
17	58.0	56.6	60.3	59.3	67.0
18	60.0	47.3	61.0	61.0	66.0
19	60.0	47.3	61.0	61.0	65.6
20	58.3	45.6	60.3	61.0	63.3
21	58.3	45.6	60.3	61.6	63.0
22	58.3	45.6	60.3	61.6	63.0
23	61.3	45.0	60.0	66.3	64.0
24	61.3	45.0	60.0	66.3	64.0
25	61.3	45.0	60.0	66.3	64.0
26	60.3	45.0	59.3	64.6	64.0
July 10	62.0	46.0	58.3	63.3	61.6

percent light reflectant seed had a relatively low germination percentage. These results are diametrically opposed to those obtained in the previous experiments.

This apparent dichotomy is difficult to explain. Perhaps, in a germinator the dark-colored seed are buffered against such variations as micro-temperature, water content, wind velocity, and soil organisms, and therefore appear to be superior in germination to the light-colored seeds. However, in the field the selection processes favor the grey to dull white hard seedcoat over the dark-colored wrinkled seedcoat.

As presented in Table 10, there were no significant differences among mean plant heights of each class on a given date during the growing season. The crop reached its peak height during the weeks of September 14 and 21. The subsequent loss in height was due to the buckling of the stem at the base of the plant. The growth equation for guar, as measured by plant height during the growing season, followed the standard sigmoid curve.

Table 10. Mean plant height of each category of light reflectant seedcoats during the growing season.

Date		Mixed Seed	Category of light Reflectant Seedcoats			
			Below 35%	35-55 %	55-75 %	Scarified 55-75%
			Plant Height in Centimeters			
June	19	2.4	2.4	2.4	2.5	2.6
	26	5.8	5.8	5.8	5.2	6.2
July	3	9.7	10.2	10.2	9.5	9.8
	10	16.6	17.2	19.2	18.4	18.1
	17	30.5	31.4	32.2	31.4	31.0
	24	45.7	46.3	47.7	46.3	46.0
	31	67.3	70.1	66.4	68.9	69.0
Sept.	7	82.2	83.0	83.4	83.8	82.9
	14	89.7	89.7	91.0	91.5	89.8
	21	88.5	89.3	90.3	90.3	89.8
	28	81.3	83.7	84.2	83.9	84.3
Oct.	4	82.6	82.0	84.0	84.2	82.9
	11	77.1	78.3	81.7	76.6	79.6

Competition Studies On Guar

The performance of a plant is the result of the interaction of its genotype with an environment. The environment of an economic plant is usually thought of as its spatial arrangement or competition stress in a field of similar plants. The variability of expression of certain plant characters is an important consideration in the initiation of a successful breeding and testing program. If the parameters of the expressivity of certain characters were understood, then considerable progress could be made in selecting heritable differences rather than environmental effects.

Brooks and Harvey (1) found that guar plants have the ability to adapt themselves to a wide range of spacings. Matlock, Aepli, and Streets (8) reported that higher mean yields for Mesa variety of guar were obtained from 7-inch and 12-inch row spacings than from 24- or 36-inch row spacings. Investigations by Williams (16) suggested that the mean seed yield of Groehler and Plant Introduction 164801 were greatest at a seeding rate of three plants per foot. Furthermore, plants grown at 20-inch row spacings produced higher mean seed yields than 30- or 40-inch spacings. Williams also found no differences in stem diameter and branch length among the various treatments.

The purpose of this investigation was to study the effect of competition on certain plant and fruiting characters and to determine the relationships between weight of pod, weight of seed in the pod, pod length, and number of seed in the pod.

Methods and Materials

In the spring of 1960, three varieties of guar were planted in three row-spacings and in three planting rates on Norge fine sandy loam at the Paradise Agronomy Research Station, northeast of Coyle. The plots were arranged in a factorial design with three replications. Each replication consisted of three ranges and each range was divided into nine four-row plots. The plots were 19 feet long with 3 feet of alley.

The varieties used were Texsel, Groehler, and P.I. 164801. Each of these varieties differs in habit of growth. Texsel has an erect growth habit, but occasionally will have one side branch that arises near the base of the main axis. Groehler has branches arising from the bases of the primary axis, suggesting the shape of an upside down umbrella.

P.I. 164801 has branches arising from the base to the apex of the primary axis. The row spacings were three, six, and nine viable seed per foot of row (Table 11).

During the last week of October and the first week of November, three healthy plants were selected from each plot. The plants were measured for height and number of branches. The pods were stripped from each of the 243 plants and were stored in individual paper bags for further study. The total number of pods, number of mature pods, and number of immature pods for each plant were counted. Using a subsample of 10 pods from each bag, determinations were made for weight of pod, weight of seed in the pod, pod length, and number of seed in the pod. The remaining pods in the bags were threshed and weighed.

Table 11. Varieties, spacings, and population rates used in guar competition study.

Variety	Spacing Inches Between Rows	Population Rate Viable Seed Per Foot of Row
Groehler	20	3
		6
		9
	30	3
		6
		9
	40	3
		6
		9
Texsel	20	3
		6
		9
	30	3
		6
		9
	40	3
		6
		9
P. I. 164801	20	3
		6
		9
	30	3
		6
	40	9
		3
		6
		9

A program was designed[4] using the IBM 650 to compute on one output card the competition code, plant height, number of branches, total number of pods, number of mature pods, number of immature pods, weight of mature pods including subsample, weight of seed including subsample, and threshing percent, that is, the ratio of seed weight divided by pod weight and multiplied by 100.

The analyses of variance and mean for plant treatments were obtained by using the North Carolina IBM 650 programs 81 and 92. The subsampled pods were analyzed by using the IBM 650 Beaton Correlation Routine and the Pooled Beaton Routine.

The linear and quadratic responses for the significant treatment main effects were evaluated as presented by Snedecor's orthogonal comparisions (13). The means of each significant treatment main effects were analyzed according to Duncan's new multiple range test (2).

Results and Discussion

Mean squares of the eight characters measured are presented in Tables 12, 21, and 31. Highly significant replication effects were obtained for seven out of eight characters studied. This apparently indicates that: 1) the test plots were on heterogeneous soils, or 2) perhaps the number of replications and/or subsamples should have been increased.

Plant Height: Varieties and spacings affected plant height (Table 12). The spacing treatment exhibited a linear response and was significant at the one percent confidence level.[5] On the average, plant height decreased as the distance between rows decreased. The standard deviation and the coefficient of variation were 11.75 centimeters and 11.79 percent, respectively.

The mean plant height for Texsel was significantly taller than for P.I. 164801 or Groehler. There were no significant differences between P.I. 164801 and Groehler (Table 13).

The mean heights for plants grown at 20-, 30-, and 40-inch row spacings were 94.57, 101.63, and 102.65 centimeters, respectively. The plants grown at the 20-inch spacing were significantly shorter in height than those grown at the 30- or 40-inch spacings (Table 14).

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[4]Program was designed by William Gurley, a graduate student in the Statistics Department, Oklahoma State University.

[5]Probability levels will be expressed at the one percent confidence level unless otherwise stated.

Table 12. Mean squares for plant height, number of branches, and total number of pods for the guar competition study, 1960.

Source of Variation	D.F.	Mean Squares: Plant Height (cm.)	Number of Branches	Total Number of Pods
Total	242			
P.W.E.U.†	162	42	1.22	2,715
Replications	2	2,578**	6.50	46,923**
Treatments	26	1,478**	197.88**	31,616**
Varieties (V)	2	16,322**	2512.50**	41,101**
Spacing (S)	2	1,570**	13.00**	88,190**
Linear (L)	1	2,644**	25.28**	176,293**
Quadratic (Q)	1	492	.06	94
Population (P)	2	158	16.00**	157,394**
Linear	1		21.00**	262,955**
Quadratic	1		9.98*	61,750**
V. × S.	4	36	6.00*	11,892*
V. × S.L.	2		10.64**	9,313
V. × S.Q.	2		1.94	14,536*
V. × P.	4	183	3.00	6,087
S. × P.	4	174	1.50	15,104*
S.L. × P.L.	1			23,856*
S.L. × P.Q.	1			691
S.Q. × P.L.	1			35,783**
S.Q. × P.Q.	1			92
V. × S. × P.	8	93	2.50	13,203**
Error	52	138	2.10	4,240
Standard Deviation		11.75	1.45	65.12
C.V.%		11.79	32.08	52.11

†P.W.E.U = Plants within experimental units.
*Indicates significance at the five percent level.
**Indicates significance at the one percent level.

Table 13. Multiple range test for effect of competition on mean plant heights of three varieties of guar.

Variety	P.I. 164801	Groehler	Texsel
Mean Plant Height* (in cm.)	90.26	92.64	115.95

Table 14. Multiple range test for effect of competition on mean plant height of three spacings of guar.

Spacing Between Rows (in inches)	20	30	40
Mean Plant Height* (in cm.)	94.57	101.63	102.65

*Any two means underscored by the same line are not significantly different.

Number of Branches: As noted in Table 12, variety, spacing, and population rate affected the number of branches. The spacing treatments exhibited a linear response, while the population treatments displayed both linear and quadratic responses. The standard deviation and coefficient of variation were 1.45 branches and 32.08 percent, respectively.

The mean numbers of branches for plants of Texsel, Groehler, and P.I. 164801 were significantly different from one another. This was expected since the varieties used in this study had different growth habits (Table 15).

Table 15. Multiple range test for effect of competition on number of branches of three varieties of guar.

Variety	Texsel	Groehler	P.I. 164801
Mean Number of Branches*	0.28	2.44	10.83

The mean numbers of branches for plants grown at 20-, 30-, and 40-inch row spacings were 4.11, 4.54, and 4.90, respectively. There were no differences between the 20- and 30-inch spacings and between the 30- and 40-inch spacings. The numbers of branches for plants grown in the 20- and 40-inch rows were significantly different (Table 16).

Table 16. Multiple range test for effect of competition on number of branches of three spacings of guar.

Spacing Between Rows (in inches)	20	30	40
Mean Number of Branches*	4.11	4.54	4.90

(Underscores: 4.11–4.54 share one line; 4.54–4.90 share one line.)

As presented in Table 17, plants grown at the three-seed-per-foot population rate had more branches than those plants grown at the six- or nine-seed-per-foot population rates.

Table 17. Multiple range test for effect of competition on number of branches of three populations of guar.

Population in Seed per Foot	6	9	3
Mean Number of Branches*	4.23	4.30	5.02

(Underscores: 4.23–4.30 share one line; 5.02 separate.)

*Any two means underscored by the same line are not significantly different.

Total Number of Pods: The total number of pods was affected by variety, spacing, and population rate. The spacing treatments indicated a linear response, while the population rate treatments displayed significant linear and quadratic responses. The variety × spacing interaction was significant at the five percent level and was due to a quadratic response. The first order interaction of spacing × population was significant at the five percent confidence level. This was due to a spacing linear × population linear and spacing quadratic × population linear response. By size of variance, population seems to account for the greatest effect, followed by spacing. The standard deviation and the coefficient of variation were 62.49 pods and 53.21 percent, respectively.

The mean numbers of total pods per plant of P.I. 164801 and Groehler were significantly higher than the plants of Texsel. There was no difference between the mean numbers of total pods of plants from P.I. 164801 and Groehler (Table 18).

Table 18. Multiple range test for effect of competition on total number of pods of three varieties of guar.

Variety	Texsel	P.I. 164801	Groehler
Mean Number of Pods*	99.75	132.05	143.09

The mean numbers of total pods from plants grown at 20-, 30-, and 40-inch row spacings were 91.53, 125.83, and 157.51, respectively (Table 19). The three treatments were significantly different from one another.

Table 19. Multiple range test for effect of competition on total number of pods per plant for three spacings of guar.

Spacing Between Rows (in inches)	20	30	40
Mean Number of Pods*	91.53	125.84	157.51

The three-seed-per-foot population treatment was significantly higher than either the six- or nine-seed-per-foot treatments (Table 20).

Table 20. Multiple range test for effect of competition on total number of pods per plant for three populations of guar.

Population in Seed per Foot	9	6	3
Mean Number of Pods*	96.72	102.41	175.75

*Any two means underscored by the same line are not significantly different.

Number of Mature Pods: As presented in Tables 21, 22, 23, and 24, the number of mature pods exhibited a response in direction and magnitude similar to the analysis for the total number of pods. The differences between the mean squares and the means of the two characters can be attributed to the small number of immature pods found on the plants.

Table 21. Mean squares for number of mature pods, total weight of mature pods, and total weight of seed in guar competition study, 1960.

Source of Variation	D.F.	Mean Squares: Number of Mature Pods	Weight of Mature Pods	Weight of Seed From Mature Pods
Total	242			
P.W.E.U.†	162	2,355	314	119
Replications	2	44,796**	4,573**	1,876**
Treatments	26	26,828**	3,480**	1,355**
Varieties (V)	2	34,718**	6,516**	2,254**
Spacing (S)	2	75,797**	10,608**	4,384**
Linear (L)	1	151,492**	21,209**	8,768**
Quadratic (Q)	1	99	6	1
Population (P)	2	133,680**	16,639**	6,196**
Linear	1	213,407**	26,999**	10,188**
Quadratic	1	53,950**	6,278**	2,204**
V. × S.	4	11,042*	1,689*	664*
V. × S.L.	2	8,462	1,378	575
V. × S.Q.	2	13,619*	2,001*	752*
V. × P.	4	5,466	464	183
S. × P.	4	13,328*	1,489*	566*
S.L. × P.L.	1	18,541*	2,363*	828*
S.L. × P.Q.	1	1,338	214	67
S.Q. × P.L.	1	33,429**	3,378*	1,368*
S.Q. × P.Q.	1	3	1	<1
V. × S. × P.	8	11,226**	1,372*	488*
Error	52	3,905	550	203
Standard Deviation		62.49	23.45	4.78
C.V.%		53.21	56.62	7.30

†P.W.E.U. = Plants within experimental units.
*Indicates significance at the five percent level.
**Indicates significance at the one percent level.

Table 22. Multiple range test for effect of competition on number of mature pods per plant for three varieties of guar.

Variety	Texsel	P.I. 164801	Groehler
Mean Number of Mature Pods*	<u>94.73</u>	<u>122.78</u>	<u>135.27</u>

*Any two means underscored by the same line are not significantly different.

Table 23. Multiple range test for effect of plant competition on number of mature pods per plant for three spacings of guar.

Spacing Between Rows (in inches)	20	30	40
Mean Number of Mature Pods*	86.40	118.33	147.56

Table 24. Multiple range test for effect of competition on number of mature pods per plant for three populations of guar.

Population in Seed per Foot	9	6	3
Mean Number of Mature Pods*	91.67	96.36	164.26

*Any two means underscored by the same line are not significantly different.

When a mature pod is placed under a fluorescent light, the plump seed are clearly visible. However, an immature pod will exhibit small, aborted or underdeveloped seed.

Weight of Mature Pods: Variety, spacing, and population were found to affect the weight of mature pods (Table 21). The spacing treatments gave a linear response; the population rate treatments indicated both linear and quadratic responses. The variety $\times$ spacing interaction was significant at the five percent confidence level and this significance can be attributed to a variety $\times$ spacing quadratic response. At the five percent confidence level, the variety $\times$ spacing interaction was significant. This was due to a spacing linear $\times$ population linear and spacing quadratic $\times$ population linear response. The standard deviation and coefficient of variation were 23.45 grams and 56.62 percent, respectively.

The mean weight of mature pods of plants of Texsel was significantly lower than plants of P.I. 164801 or Groehler (Table 25).

As noted in Table 26, the mean number of pods from plants grown at 20-, 30-, and 40-inch row spacings were 29.84, 41.64, and 52.73 grams, respectively. The three treatments were significantly different from one another.

The three-seed-per-foot population treatment was significantly higher than either the six- or nine-seed-per-foot treatments (Table 27).

Weight of Seed From Mature Pods: As noted in Tables 21, 28, 29, and 30, the weight of seed from the mature pods was affected by all main treatments. Moreover, the mean squares for a given treatment were approximately one-third of the corresponding mean square of the weight of mature pods. This correlation is discussed under threshing percentage.

Table 25. Multiple range test for effect of plant competition on weight of mature pods per plant for three varieties of guar.

Variety	Texsel	P.I. 164801	Groehler
Mean Weight of Mature Pods (in grams)*	31.15	45.30	47.77

Table 26. Multiple range test for effect of plant competition on weight of mature pods per plant for three populations of guar.

Spacing Between Rows (in inches)	20	30	40
Mean Weight of Mature Pods (in grams)*	29.84	41.64	52.73

Table 27. Multiple range test for effect of plant competition on weight of mature pods per plant for three populations of guar.

Population in Seed per Foot	9	6	3
Mean Weight of Mature Pods (in grams)*	32.09	34.22	57.91

Table 28. Multiple range test for effect of plant competition on weight of seed per plant from three varieties of guar.

Variety	Texsel	P.I. 164801	Groehler
Mean Weight of Seed (in grams)*	20.71	29.26	30.33

Table 29. Multiple range test for effect of competition on weight of seed from mature pods per plant for three spacings of guar.

Spacing Between Rows (in inches)	20	30	40
Mean Weight of Seed (in grams)*	19.36	26.85	34.08

*Any two means underscored by the same line are not significantly different.

Percent Mature Pods: Variety was found to affect the percent of mature pods (Table 31). This was the only character studied that was not influenced by either spacing or population. By size of variance, variety seemed to account for the greatest effect. As indicated in Table 32, the mean percent of mature pods of P.I. 164801, Texsel, and Groehler were 92.73, 94.73, and 95.55 percent, respectively.

Threshing Percent: The threshing percent was affected by variety and population rate (Table 31). Population rates exhibited both linear

Table 30. Multiple range test for effect of plant competition on weight of seed from mature pods per plant for three populations of guar.

Population in Seed per Foot	9	6	3
Mean Weight of Seed (in grams)*	20.96	22.51	36.82

*Any two means underscored by the same line are not significantly different.

Table 31. Mean squares for percent of mature pods and threshing percentage in guar competition study, 1960.

Source of Variation	D.F.	Mean Squares: Percent Mature Pods	Mean Squares: Threshing Percent
Total	242		
P.W.E.U.†	162	15.74	7.13
Replications	2	226.04**	111.35**
Treatments	26	41.40	5.59
Varieties (V)	2	170.90**	195.97**
Spacing (S)	2	14.07	2.83
Linear	(1)		
Quadratic	(1)		
Population (P)	2	23.83	132.21
Linear	(1)		137.12*
Quadratic	(1)		128.07*
V. × S.	4	8.32	54.07
V. × P.	4	21.52	41.40
S. × P.	4	42.43	39.14
V. × S. × P.	8	46.22	31.59
Error	52	33.62	22.77
Standard Deviation		5.79	4.78
C.V. %		6.14	7.30

†P.W E.U. = Plants within experimental units.
*Indicates significance at the five percent level.
**Indicates significance at the one percent level.

and quadratic responses at the five percent confidence level. The standard deviation and coefficient of variation were 4.78 percent and 7.30 percent, respectively.

The mean threshing percentage for pods from plants of Groehler, P.I. 164801, and Texsel were 64.10, 65.25, and 67.18 percent, respectively. There were no differences between plants of Texsel and P.I. 164801 and between Groehler and P.I. 164801. The threshing percentages between plants of Texsel and Groehler were significantly different (Table 33).

As noted in Table 34, plants grown at the three-seed-per-foot population had significantly higher threshing percentages than those grown at the nine-seed-per-foot treatment.

Table 32. Multiple range test for effect of competition on the percent mature pods per plant for three varieties of guar.

Variety	P.I. 164801	Texsel	Groehler
Mean Percent of Mature Pods*	92.73	94.73	95.55

Table 33. Multiple range test for effect of competition on threshing percentages per plant for three varieties of guar.

Variety	Groehler	P.I. 164801	Texsel
Mean Threshing Percentage*	64.10	65.25	67.18

Table 34. Multiple range test for effect of competition on threshing percentage per plant for three populations of guar.

Population in Seed per foot	9	6	3
Mean Threshing Percentage*	64.08	65.92	66.54

*Any two means underscored by the same line are not significantly different.

Correlation Values: The correlations among weight of pod, weight of seed in pod, pod length, and number of seed in pod were positive and highly significant regardless of treatment. The correlation ranges were published to point out that on occasion there were low correlation values for a given set. However, even these values were highly significant (Table 35).

Responses of plants from the three varieties to spacing and population treatments indicated that potential sources of bias may be encountered when selecting individual plants from a population. As indicated by size of variances, population rate had the greatest influence on number of mature pods, weight of mature pods, and weight of seed from mature pods. However, population rate had little effect on plant height or number of branches.

In all cases, the mean squares of plants within experimental units were less than the error term. This suggests that the plant values within each experimental unit were fairly consistent with one another.

In order to reduce sampling variation, the ten sampled pods of a selected plant were pooled together with the pods from the other two plants of the same treatment and one correlation value was computed for all thirty pods.

Table 35. Range of correlation values among four characters.

Character	Weight of Pod	Weight of Seed	Pod Length	Number of Seed in Pod
Weight of Pod	1.00	0.99-0.87**	0.96-0.62**	0.96-0.52**
Weight of Seed		1.00	0.95-0.45**	0.96-0.46**
Pod Length			1.00	0.98-0.74**
Number of Seed in Pod				1.00

**Indicates significance at the one percent level.

Summary And Conclusions

Since 1946, viable seed of 81 percent of all the plant introductions of the genus *Cyamopsis* in this country have been maintained at the Oklahoma Agricultural Experiment Station, the Texas Agricultural Experiment Station and/or the Southern Regional Plant Introduction Station. The introductions are principally from India and Pakistan, the present-day center of genetic diversity.

The introductions were classified according to three morphological characters: absence or presence of biramose hairs on pods and leaves, pod length, and branching habit. Of the introductions evaluated, biramose hairs, medium-length pods, and branching plants appeared in 96.1, 94.5, and 82.8 percent, respectively.

The variation in seedcoat color of Groehler guar appears to be environmentally controlled. The specific environmental factor or factors causing the seedcoats to darken was not determined. However, circumstantial evidence points to excess rainfall during the seed maturation period as a possible factor.

Laboratory data indicate that either light or dark-colored seed should be acceptable when planted at 70 degrees F. or higher. Since gum processing companies prefer seed with a light-colored, unwrinkled seedcoat, it might be profitable to separate the harvested seed into light and dark seedcoat categories, with the light seed marketed to industry and the dark seed returned to the farm for planting and feed use.

There was no correlation between the laboratory investigations and the field plot experiments on the effect of light reflectance of the seedcoat on the germination of Groehler guar. While laboratory investigations indicated that dark-colored seed were quite favorable for "planting seed," opposite results were obtained in the field. However, once a seedling started to develop, its seedcoat color was no longer a significant factor. The plants grown from dark- to light-colored seedcoats all grew to about the same height and matured at about the same time.

Three varieties of guar were grown in three spacings with 20-, 30-, and 40-inches between rows and in three population rates of three, six and nine-seed-per-foot in order to study the effects of competition on plant height, number of branches, total number of pods, number of mature pods, weight of mature pods, weight of seed from mature pods, percent of mature pods, and threshing percent.

Under all the types of competition, Texsel had the tallest plants and except for percent of mature pods and threshing percentage had significantly lower values than Groehler and P.I. 164801 in each of the other characters studied. Values for Groehler and P.I. 164801 were similar except that Groehler, as was expected, had fewer branches.

On an equal area basis, and assuming adequate moisture is available for plant growth, the best spacing for guar was at the 20-inch level, and the best population rate was between six and nine-seed-per-foot of row.

In general, as competition increased, the values for each character studied decreased.

The correlation values among the individual plant characters—weight of pod, weight of seed in pod, pod length, and number of seed in pod—were positive and highly significant.

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Oklahoma's Wealth in Agriculture

Agriculture is Oklahoma's number one industry. It has more capital invested and employs more people than any other industry in the state. Farms and ranches alone represent a capital investment of four billion dollars—three billion in land and buildings, one-half billion in machinery and one-half billion in livestock.

Farm income currently amounts to more than $700,000,000 annually. The value added by manufacture of farm products adds another $130,000,000 annually.

Some 175,000 Oklahomans manage and operate its nearly 100,000 farms and ranches. Another 14,000 workers are required to keep farmers supplied with production items. Approximately 300,000 full-time employees are engaged by the firms that market and process Oklahoma farm products.

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