# AN AGRONOMIC STUDY OF GUAR (CYAMOPSIS TETRAGONOLOBA (L) TAUB.) GROWN UNDER SOUTHERN ARIZONA CONDITIONS

by

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# CHAPTER I

## INTRODUCTION

Guar, an annual leguminous plant, has been grown for centuries in parts of India, and has been found in this country at some agricultural experiment stations and a very few farms in the Southwest for about forty years.

Recently it has received some attention as a crop that may occupy a permanent place in Southwestern agriculture. It appears that if guar does become established it will do so because it fulfills, in varying degrees, the following requirements: it is considered an outstanding, summer growing, leguminous, soil building crop; the crop can be grown with a minimum of irrigation water and labor; it can be used as a forage crop; it has possibilities as a cash crop because of the industrial uses that can be made of its seed; the crop fits well into rotations with other crops either as a cash crop, forage crop, or summer growing green manure crop; and finally, guar is well adapted to Southwestern conditions, and is not seriously affected thus far by any insect and disease pests prevalent here.

The need for organic matter in the semi-arid soils of the Southwest is well known, but as long as farm lands continue to produce as they are now doing, the practice of

using green manure crops, and especially a summer growing crop that competes for the land and water with cotton, alfalfa, or sorghums, may gain little if any favor except perhaps with growers of winter vegetables.

Guar can be grown cheaply. It requires a minimum of irrigation water, and its labor requirement compares with that of our crops produced most cheaply. The forage value of the plant is high, it being relatively high in protein and low in crude fiber. While it is somewhat unpalatable to animals not familiar with it, they soon learn to eat it either as pasture or hay.

Although its potential value as a soil building and forage crop was recognized, an additional stimulus was necessary before any extensive experimentation was carried out with this plant. The endosperm of the seed was found to consist of a mucilage, a mannogalactan gum, with extensive possibilities for industrial use, especially in the paper industry. That potential industrial value stimulated renewed interest in guar which has become, as one writer stated, "An old crop with a new future." (2)*

In 1938 experimentation with this crop began at the Arizona Station. The program emphasized the value of the plant for a green manure crop. A two-part program was

*Figures in parentheses refer to literature cited in the Bibliography.

started in 1943 under the sponsorship of General Mills, Inc. in cooperation with the Arizona Agricultural Experiment Station. The industrial part of this program was to perfect the milling and refining process of the seed, and to test the refined product in various industrial uses, especially in the paper industry. At the same time, they sponsored experimental work in the field in cooperation with the University of Arizona and various growers.

The purpose of the agronomic portion of that program was to study the plant's growth in relation to experimental conditions, and to observe the effects of disease and insect pests and other conditions more or less beyond the control of the experimenter in the initial stages of the work. The results of experiments thus far have served as a guide in the preparation of the land for planting, how and when to plant, how to care for the growing crop, including irrigation practices, and how to harvest the crop. Work has been done and progress has been made in plant improvement through selection and introduction of new strains and varieties.

The experiments presented here are in continuation of this program. The study was made within a variety and date of planting test on the Campbell Avenue University Farm at Tucson, Arizona. The effects of variety and date of planting were studied in relation to seed yield and seed quality.

The experimental plots were under close observation throughout the growing season, and various botanical studies of the plants were made. An attempt was made to determine how planting date affected growth and some of the morphological characteristics of three different varieties.

Several related experiments also were carried out. One phase was the effect of weathering on mature seeds as influenced by harvest date and measured by the percentage of high quality, bright colored seed. Another phase studied was the use of guar for hay followed by a subsequent seed crop. An inoculation trial and a defoliation trial were attempted without success. Other studies were made on problems connected with harvesting.

As yet the results obtained by commercial growers have not been too encouraging, and the incidence of crop failure and low yields has been great. While some growers have obtained good yields, experimental results indicate that the best commercial yields have been only what the average grower should attain. Although there is a constantly growing industrial interest in the possibilities of the mannogalactan gum, General Mills, Inc. has stopped its extensive research program because of the high cost of the finished industrial product and because of uncertain economic outlook due to competition with locust bean flour, a foreign produced mannogalactan gum.

In the future, agronomic experimentation will emphasize

the use of guar for green manure. At the same time, a continued search will be made to find better methods and varieties. In the future, growers may be able to produce high yields of good quality seed at prices which will encourage the industrial use of guar rather than the imported substitute.

With the solution of certain recognized problems, guar as a field crop should find a permanent place in Southwestern agriculture.

## CHAPTER II

## REVIEW OF LITERATURE

In reviewing the literature about this plant and its culture, it is evident at once that little has been written about it in this country, and that which has been written in its native land is not generally available here.

The Bureau of Plant Industry Inventory Number 65 (6) quotes Watt in telling of the culture and uses of guar in India. It is described as a robust annual pulse (legume) cultivated in many parts of India from the Himalayas to the Western Peninsula, but it is never found truly wild in India. Three forms are common. Pardeshi is sown sparsely among autumn cereals. Soti guvar grows eight to ten feet high and is used as a shade plant for ginger. The leaves of this type are used for green manure. Also included in this class is surat, grown and irrigated with cucumbers until the rainy season. The pods of this variety are used as a vegetable. The third form, deshi, is the common form with violet seeds. It is used as cattle fodder.

When the plant is used as a vegetable it is grown on highly manured soils near the villages, but when raised on light sandy soils it is used for cattle fodder.

Planting may be done in May with irrigation until the

rainy season. Guar also may be planted when the rains begin then harvested in October. According to Stutzman (11) the rainy season in Western India begins in June or July, depending on the exact location of the area.

The United States Department of Agriculture Yearbook for 1908 (14) reports that the first guar seed obtained by the Department of Agriculture was introduced from India in 1903. It was grown first at Chico, California, and in Texas; and from early results it was believed to be a promising legume because of its drouth resistance and prolific seed yield. Forage value, drouth resistance, and use as green manure were tested in early experiments with guar, according to Piper (8). He also states that guar can be grown in any part of the country where cowpeas are grown, but the pods did not ripen in Northern Virginia. Guar can be used for hay, pasturage, or silage. Reports are somewhat conflicting about the palatability of this plant, but it appears that if the crop is harvested before the plants become woody, livestock will eat them as well as they eat cowpeas.

The interest in the growth and use of guar continued to be very limited until the early part of World War II. Rowland (10) gives the reasons for renewed interest in the production of this crop. For many years paper manufacturers had looked for a substance to be used in hydrating and binding cellulose fibers in paper manufacture. Prior to the war

a mannogalactan mucilage from the carob seed (Ceretonia siliqua) was used, but it had to be imported from the Mediterranean region. When this source of mucilage was stopped because of the war, The Institute of Paper Chemistry began a search that led to the discovery of guar seed as an excellent source of the hydrophylic mannogalactan mucilage. By agreement with the Institute, General Mills, Inc. explored the possibilities of milling the seed, and in cooperation with the University of Arizona conducted experimental work in the field. From this experimental work comes most of the present knowledge of the growth and adaptation of the guar plant in Southwestern United States.

Drouth resistance, beneficial effect to the soil by mechanical action of the heavy tap root, and resistance to Texas Root Rot are listed as advantages of guar by Esser (2). He has found the growing season to be 135 to 165 days, depending on the variety and date of planting, and advised planting between June 15 and July 15. Seasonal requirements of irrigation water are 1 1/4 to 1 3/4 acre feet per acre. Late irrigation is detrimental, he states, since it prolongs the growing period. Harvesting may be done with grain combines when the stems are dry and brittle. Since guar pods are subject to shattering, the reel should be set at the proper height and speed, and synchronized so the plants are not hit by the reel before being cut.

Stutzman (11) reports on an Arizona Experiment Station date of planting test at the Mesa farm. With guar planted on May 15, June 13, June 19, and July 6 in 1943 there was no significant difference in yield for any of these plantings. He then concluded that guar could best be planted between June 19 and July 6, because the land could be used to advantage for some other crop until then. In a similar experiment carried out at the Mesa farm in 1947, three varieties were planted on May 12, May 31, June 23, and July 12. The varieties used were Fine Branching, Regular or Mesa, and Texsel. The average seed yields of the three varieties in pounds per acre were 1608, 2197, 1892, and 1674 for the respective planting dates. Fine Branching and Texsel produced outstanding yields from the May 31 plantings, while the Mesa was favored by later plantings.

Little information is available on the production performance of various varieties. The Regular variety, now called Mesa, has been grown in the Imperial Valley since 1921 according to Esser (3). Fine Branching was a selection made in 1944 from the Regular variety. Stutzman (11), reporting on varieties and strains tested at Iowa Park, Texas, gives PI 116034 as one of the most promising varieties for seed production. Its high-yielding ability may have been due in part to its apparent resistance to Southern Blight caused by Sclerotium rolfsii, which killed or seriously reduced yields of other varieties. Esser (3)

tells of the development of seed stocks of the Early variety, PI 116034, for commercial plantings. This variety, now called Texsel, was made available for commercial plantings in 1947. Mr. Elmer Emrick reports that his forty-acre field of Texsel near Yuma, Arizona, produced an average yield of 1,300 pounds per acre, the highest commercial yield to date.

Seed weight and seed color have been used as criteria of seed quality by Stutzman (11) and Esser (3), the dark or black seeds being low in quality. Esser (3) believes the causes of discoloration to be freezing of immature pods and seeds and weathering. He believes that any delay in maturity of the crop is detrimental and states that:

> Delay subjects the stand to frost damage, and to lengthy, unpredictable, delays in harvesting during which time the quality of the seed crop deteriorates rapidly as it becomes exposed to the numerous, seasonal, light rains and heavy dews (3).

# CHAPTER III

## METHODS AND MATERIALS

### Methods

Three varieties of guar--Mesa or Regular, Fine Branching, and Texsel or Early--were planted on three dates, June 17, July 1, and July 17 in the summer of 1947. The field plots used in this experiment were at the University of Arizona Campbell Avenue Farm near Tucson, Arizona. The soil is a Gila Fine Sandy Loam, and is at an elevation of approximately 2400 feet.

The experimental plots, used for a variety test of corn in 1946, were plowed, dragged or floated, and prepared for irrigation by bordering. The land was irrigated in flat beds or borders. Each border was approximately 225 feet long and 20 feet wide, and within each border 4 plots or replicates were planted in 6-row drilled plots, 100 feet long and 6 feet wide. Since 4 replicates were planted for each variety on each planting date, 9 borders were used, 3 for each date of planting. The borders were randomized and the variety plots within the borders were randomized so that each variety appeared once in two borders and twice in the third border of each planting date.

No exact data were obtained on the amounts of irrigation water applied. A heavy pre-irrigation was applied 4 days prior to planting. On the planting date, the seed bed was worked up and weeds were turned under by disking. The seed was planted in the flat borders with an ordinary grain drill with every other spout closed, giving a 12-inch row spacing and 6 rows to the plot width of 6 feet. The planting rates used were 16 to 18 pounds of seed per acre of the Mesa and Fine Branching varieties, and 12 to 15 pounds per acre of the Texsel. Acid scarified seed was used. The seed had been treated with 75 per cent sulfuric acid for 15 minutes, washed in water and dried. This was done to aid in securing fast germination and a uniform stand. The seed was planted at a depth of about 2 inches.

The irrigation schedule after planting is given in Table I. It was originally planned that four light irrigations were to be applied but, because of drouth symptoms exhibited by the first two plantings, an extra application was given them.

The growth and development of the plants were observed throughout the growing season. Stand determinations were made by averaging the number of plants in two areas of 18 square feet in each plot and calculating the plant population per acre. Weekly measurements of plant height were taken in a study of vegetative growth. Five plants were

TABLE I

IRRIGATION SCHEDULE USED ON GUAR PLANTED AT DIFFERENT TIMES AT TUCSON, ARIZONA, 1947

| Plantings | Irrigations | | | | |
|---|---|---|---|---|---|
| | 1st | 2nd | 3rd | 4th | 5th |
| June 17 | July 5 | July 18 | Aug. 2 | Aug. 20 | Sept. 2 |
| July 1 | July 18 | July 26 | Aug. 16 | Sept. 2 | Sept. 16 |
| July 17 | Aug. 2 | Aug. 16 | Sept. 2 | Sept. 16 | --- |

measured weekly, in each plot, until growth leveled off. For each variety on each planting date the time of occurrence and position of the first flowers, first pods, and first ripe pods were noted. The mean number of pods and the number of seeds per pod were determined for each variety on each planting date. For the pod counts, 10 consecutive plants from one of the center rows in each plot were counted, and the mean of the 4 plots for each variety and date of planting was determined. For the number of seeds per pod, 50 pods were picked at random from each variety of each planting and their mean determined. The difference between counts of both pods and seeds was tested for significance by determining the ratios of mean differences to the probable errors of the mean differences.

The seed crop was harvested during the period of December 14 to 19, with a John Deere model 12A combine harvester. Seed yields were computed on an acre basis for each plot, and the yield figures were subjected to statistical treatment with an analysis of variance.

Seed weight and seed color were studied in connection with seed quality. Duplicate 50-gram samples from each plot were separated into light plump, dark plump, and shriveled. The shriveled seeds would have been removed in seed cleaning operations. Seeds from duplicate 10-gram samples were counted as a measure of individual seed size and weight.

The effect of weathering on the seed quality or color was determined by harvesting samples of seed from the Texsel and Mesa varieties on four dates after maturity had been reached. The harvest dates were October 15, October 29, November 11, and November 26. Samples were harvested from the lower one-third, center one-third, and top one-third of the plants. Seed from 500 pod samples was threshed and analyzed for color.

The possibility of using guar for hay and a subsequent seed crop was studied by clipping duplicate yard-long rows, one at 3 inches above the ground and the other at 6 inches above the ground, of Mesa, Fine Branching, and Texsel. Three clippings were made on each variety, one each as Mesa reached 1, 2, and 3 feet in height. Regrowth was observed and the seed from the new growth was harvested, weighed, and analyzed.

In an inoculation test, seven strains of Rhizobium, isolated from guar, were used to inoculate three varieties, Mesa, Texsel, and PI 156988. The inoculum was applied dry to the seed, and the seed was planted in a moist seed bed.

## Materials

The descriptions in this section are for the purpose of giving the principal varietal differences in the three guar varieties studied.

Mesa or Regular guar has a deep tap root with small,

horizontal, branch roots. This variety produces plants of a branched, bushy type. At each node on the main stalk a leaf subtends an axillary bud which produces either a vegetative branch or a raceme of flowers. The first node may produce either a vegetative branch or a flower raceme. Growth is indeterminate. On the central stalk there are slightly more branches than flower racemes. Vegetative branches likewise have branches at about half of the nodes. The lower three or four branches are larger and coarser, and are termed basal branches. The extent of branching and size of branches are somewhat dependent on plant spacing. Very close plant spacing may allow the branches to grow but little, or may cause them to abscise. The cumulative effect of the branching and rebranching is to have much of the seed crop set late in the season and near the top of the plant. Stems are hollow. The foliage is blue-grey-green in color. Leaves, petioles, and stems are covered with a scabrous pubescence, which is more dense at the angles of the stem and along the principal veins of the leaves.

Leaves are pinnately trifoliate, each leaflet being borne on a sub-petiole. The sub-petiole of the terminal leaflet is three to four times as long as those of the lateral leaflets. Individual leaflets are ovate and slightly toothed. Their average size is about 7 by 4.5 centimeters. Pods are straight to slightly curved, and average 6 to 7 centimeters in length with an average of 7 and 8

seeds per pod. The flowers are attached by a short pedicel to a common peduncle, forming a true raceme. Usually some flowers abscise so that pods formed are fewer in number than the flowers. The pods of this variety are borne in a short peduncle, so they appear to be in small clusters, usually of 3 to 10 pods. Normal seeds are greyish-cream colored, but may be discolored to a purplish black. They are somewhat lenticular in shape and 5 millimeters in diameter and 2.5 millimeters thick. About 15,000 seeds are required to weigh a pound.

Fine Branching is very similar to Mesa guar in most respects, but the branching tendency is more pronounced. The branches, particularly the basal ones, are smaller in diameter. This variety is very similar to Mesa in fruiting and growth habits. Its seed, however, has a rather purplish cast as compared with the seed of Mesa guar.

Texsel or Early guar has a shallower root system. Its central stalk is free from branches except for an occasional basal branch, and is very erect. The leaves at each node are similar to those previously described, but are brighter green in color when growth is rapid. Leaflets are larger than those of Mesa or Fine Branching, averaging 9 by 6.5 centimeters. At each node the axillary bud develops into a raceme of flowers which, when fully matured, vary from a few to as much as 25 centimeters or more in length. Pods are shorter and narrower than those of Mesa or Fine Branching

but have a slightly greater number of seeds, usually averaging slightly more than 8. Good quality seeds are lighter in color than those of Mesa or Fine Branching. They are more rounded, 4 millimeters in diameter and 2.5 millimeters thick, and average about 18,000 seeds per pound. Texsel reaches maturity about two weeks earlier than the two previously described varieties.

## CHAPTER IV

## EXPERIMENTAL RESULTS AND DISCUSSIONS

### Initial Stands

Since guar is known to require a warm or hot climate, the June and July days of Southern Arizona should be favorable to the germinating seeds and the growing plants. After being planted in the moist seed bed, the seeds germinated quickly, and seedlings emerged during the period of 4 to 7 days after planting. The stands determined for each variety at each planting date are given in Table II.

TABLE II

INITIAL PLANT POPULATIONS PER ACRE OF THREE VARIETIES OF GUAR PLANTED ON THREE DATES AT TUCSON, ARIZONA, 1947

| Planting date | Varieties | | |
|---|---|---|---|
| | Mesa | Fine Branching | Texsel |
| June 17 | 189,970* | 174,720 | 181,984 |
| July 1 | 154,880 | 128,260 | 139,150 |
| July 17 | 159,720 | 112,530 | 164,560 |

*Each figure represents plant population per acre

Discussion: It is easily seen that the stands obtained with the first plantings were noticeably heavier for all three varieties. Although conditions for germination and emergence should have been similar in all cases, some of the borders dried out in spots and prevented a uniform stand, particularly with the July 1 plantings and with one plot of the Fine Branching in the July 17 planting. The seed used of the Fine Branching variety was quite badly discolored. The fact that the stands of Fine Branching were less dense than those of Mesa with each planting date may have been due to seed quality. The quality of both Mesa and Texsel seed was excellent.

The plots of the first planting date were favored in that they more nearly escaped serious weed competition from late season weeds. It was necessary to hoe the weeds from plots of the last two planting dates in order to secure a stand. This would be very impractical on a drilled stand under ordinary field conditions. If serious weed competition is anticipated, it would be better to plant the guar in rows that could be cultivated conveniently.

## Vegetative Growth

The growth curves are given in Figures 1, 2, and 3. These show only the total plant height as determined each week. The curves for weekly height increase were not plotted, since they were so irregular they appeared to be of

little value.

Discussion: The individual curves give an approximation of the vegetative growth of each variety at a particular planting date. Miller (7) discusses characteristic growth curves as being S-shaped curves, although they were generally determined by an increase in dry weight. Since the guar plant grows quite erect, the increase in plant height should closely parallel the increase in dry weight of the plant.

When the three curves for each variety are plotted together, they show that the greatest plant height and probably the greatest amount of vegetative growth were attained by plants of the first or first and second plantings. Mesa and Fine Branching attained the greatest height in plots of the June 17 planting, while those of Texsel attained approximately the same height in plots of the first two planting dates.

It is interesting to note that the growth of plants from all three plantings of Texsel leveled off at approximately the same time, although there was one month between the first and last planting dates. A similar convergence is shown, but is much less pronounced with curves of the branching varieties. The convergence in time of maximum growth or time of ripening, regardless of planting time, is an effect widely observed with annual plants. It was not possible to explain the factor responsible in this case.

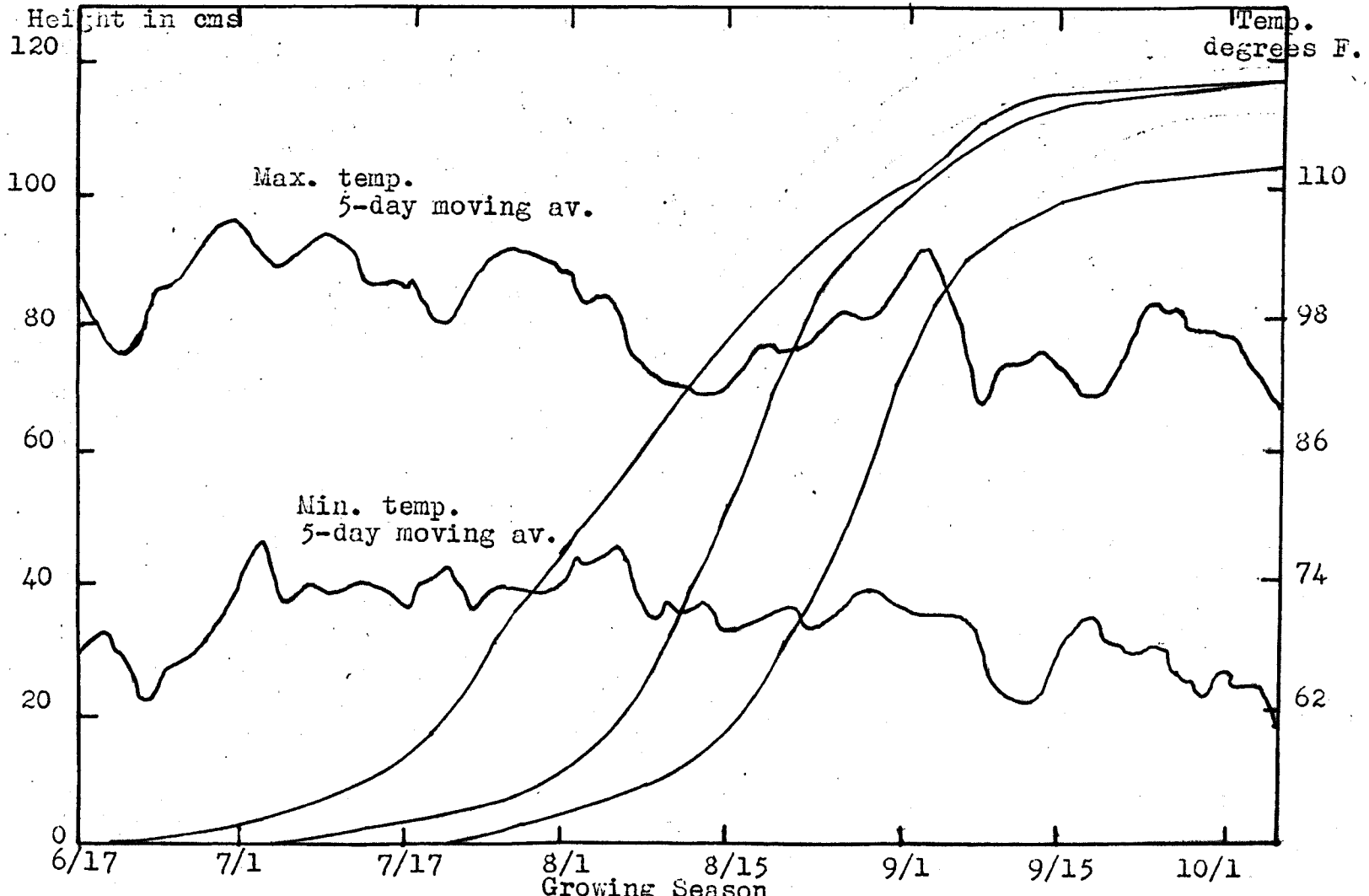


Figure 1. Growth Curves for Texsel Guar

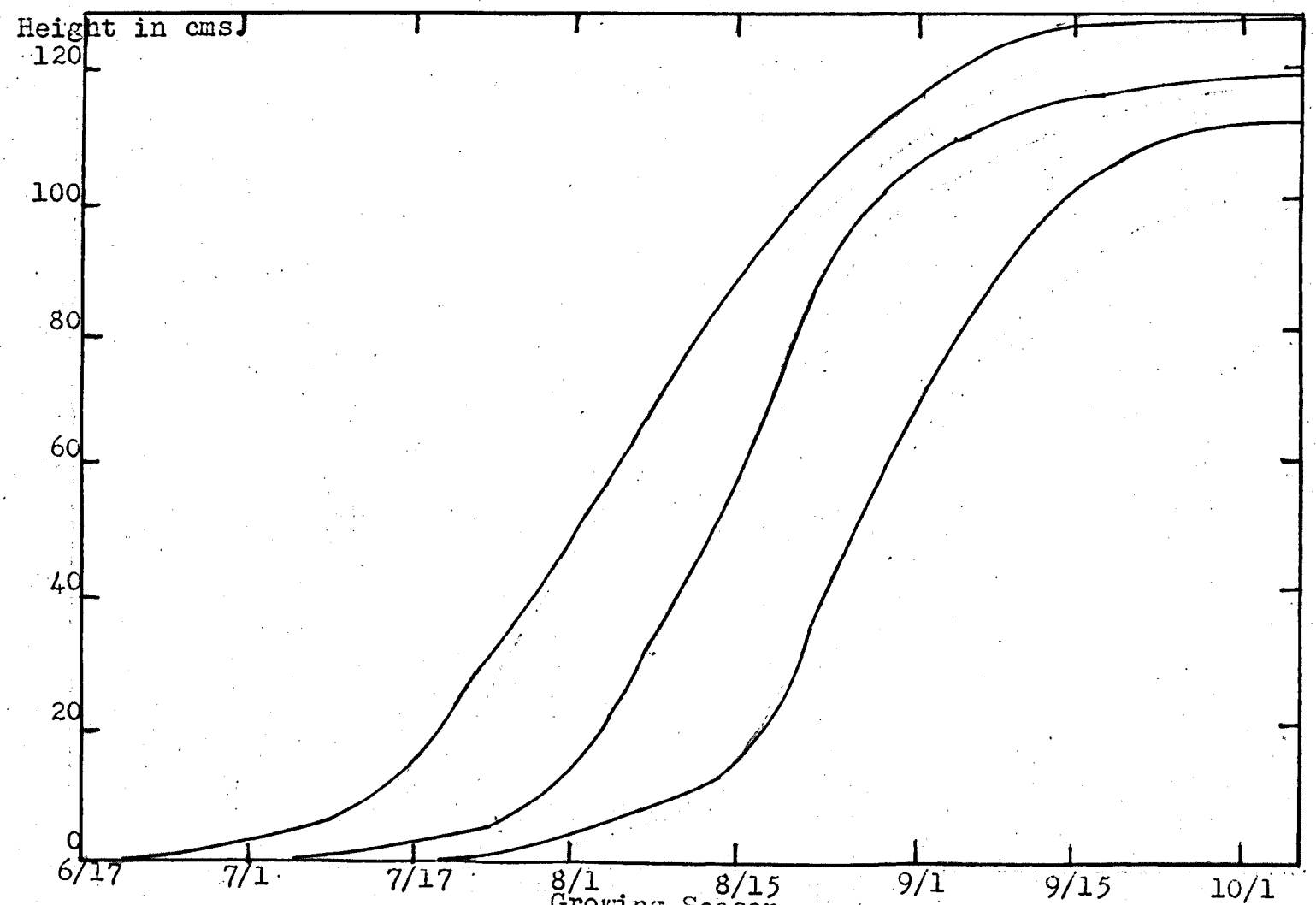


Figure 2. Growth Curves for Mesa Guar

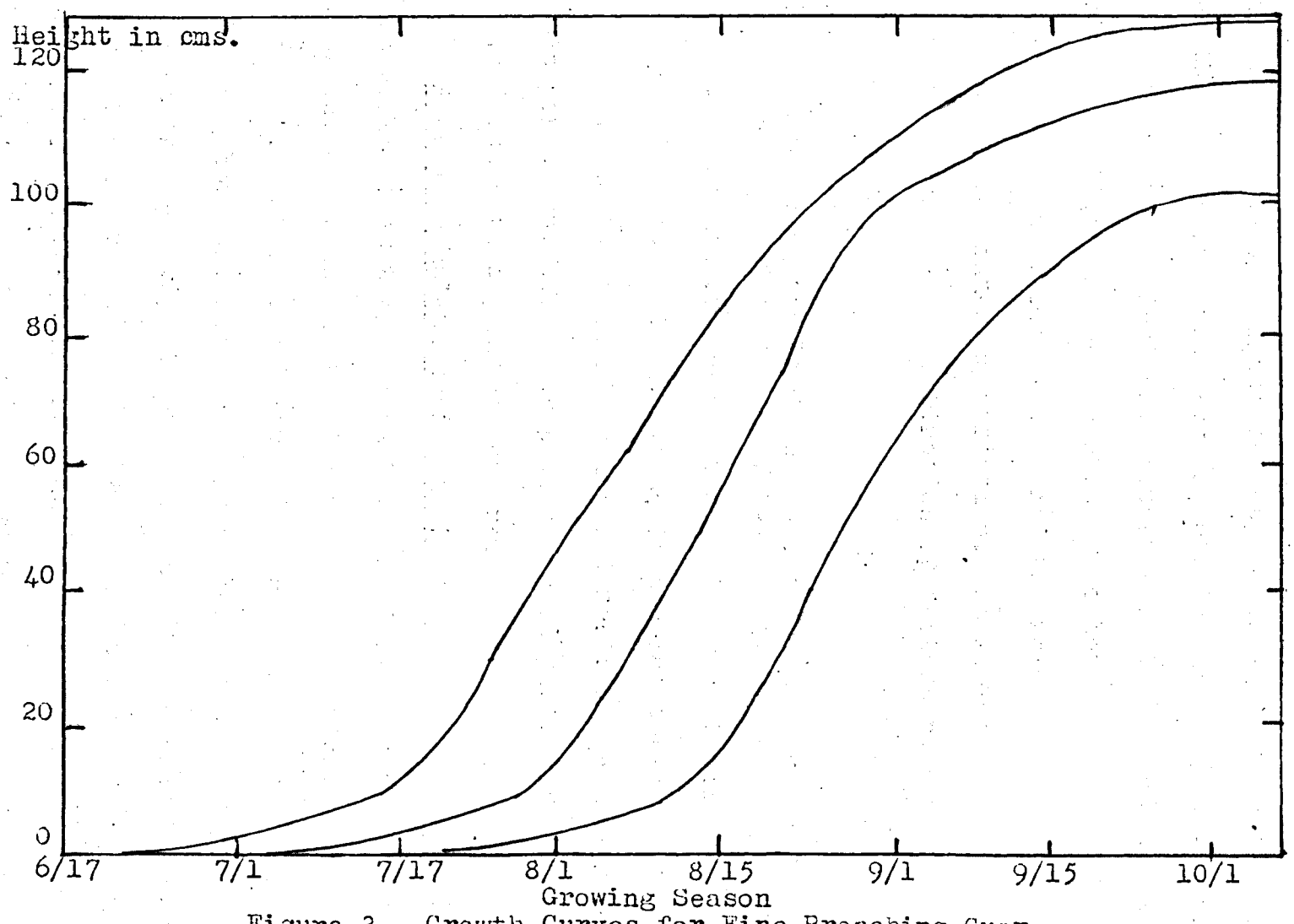


Figure 3. Growth Curves for Fine Branching Guar

The daily maximum and minimum temperatures, plotted with the curves for the Texsel variety, dropped quite noticeably at the time growth was leveling off in this variety. This may have been a coincidence rather than the principal cause, since no effect can be shown on the other varieties. Soil moisture was adequate, and seemed to prolong the vegetative growth of the branching varieties. It is very possible that the cause was a combination of factors rather than any single factor.

## Flowering and Fruiting Habits of the Varieties as Affected by Date of Planting

The results of the study on this subject will be presented, along with discussions, in several topics. Some time relationships in flowering and fruiting, number of pods per plant, seeds per pod, and seed yield will be discussed under this general heading.

Some Time Relationships in Flowering and Fruiting: Table III gives the periods between planting and the first flowers, and between the first flowers and first ripe pods observed. Although all varieties produced their first flowers about the same time, regardless of planting date, the extent of early flowering by the Mesa and Fine Branching varieties was limited. Texsel produced a large raceme of flowers at the first node and at each successive node. The position of the first flowers was at the first node in

TABLE III

NUMBER OF DAYS FROM PLANTING TO FIRST FLOWERS, AND FROM FLOWERS TO MATURE PODS FOR THREE VARIETIES OF GUAR PLANTED AT TUCSON, ARIZONA, 1947

| Variety | Days between planting and first flowers, Date planted: June 17 | July 1 | July 17 | Days between first flowers and mature pods, Date planted: June 17 | July 1 | July 17 |
|---|---|---|---|---|---|---|
| Mesa | 28 | 28 | 28* | 57 | 49 | 42 |
| Fine Branching | 28 | 28 | 28* | 57 | 49 | 42 |
| Texsel | 28 | 28 | 28* | 42 | 42 | 42 |

*The observed figure was 31 days, but many plants had been blooming for several days.

all cases, but since many plants of the Mesa and Fine Branching varieties produce a basal branch at the first node, the first flowers on such plants necessarily would be later.

Discussion: The only seasonal effect noted here is on the time between flowering and the first ripe pods of the Mesa and Fine Branching. The fact that the first ripe pods occurred on these varieties at the same time as they did on Texsel with the July 17 plantings, however, does not mean that the plants of the three varieties will mature at the same time. The Texsel variety is more determinate in its fruiting habits, and after the first pods ripen those at successively higher nodes become ripe in a much shorter period. Texsel was quite well matured at the time of the first frost, November 4, while Mesa and Fine Branching had many immature seeds.

Pods per Plant: Some measure of reproductive growth can be had by studying the fruiting behavior of the plant. With a seed crop, however, the final and important measure of this phase of the activity of the plant is the yield of harvested seed. The data in Table IV were collected in the field by counting the number of pods on mature plants prior to harvest, and were meant to supplement the yield data. Since most of the plots of the Texsel variety were harvested when they were too wet, the yield figures, which will be presented, are not indicative of the ability of this variety

TABLE IV

NUMBER OF PODS PER PLANT ON THREE VARIETIES OF GUAR GROWN AT TUCSON, ARIZONA, 1947

| Planting date | Varieties | | |
|---|---|---|---|
| | Mesa | Fine Branching | Texsel |
| June 17 | 63.1±2.2* | 81.6±2.7 | 76.8±1.7 |
| July 1 | 42.2±2.0 | 60.5±1.5 | 75.6±3.2 |
| July 17 | 46.7±1.6 | 43.5±1.2 | 62.7±1.7 |

*Mean and probable error of the mean

to produce seed. The pod counts are a better indication of the potentialities of this variety.

Table V compares the results of pod numbers on plants from the three planting dates for each variety. The significance of these differences was also tested by determining the ratio of the mean difference to the probable error of the mean difference. This ratio and its significance are indicated for each of the means compared in Table V. The means of different varieties were not compared in this manner because of differences in seed size and number of seeds per pod.

Discussion: According to the observed data in Table IV and the analysis of those data in Table V, the June 17 planting of Mesa and Fine Branching is definitely favored

TABLE V

MEAN DIFFERENCES IN POD NUMBERS ON GUAR PLANTS AND THEIR DIFFERENCE TO PROBABLE ERROR RATIO, GROWN AT TUCSON, ARIZONA, 1947

| Variety | Planting Dates | | |
|---|---|---|---|
| | June 17 and July 1 | July 1 and July 17 | June 17 and July 17 |
| Mesa | +20.88±2.98 | -4.46±2.56 | +16.42±2.73 |
| | 7.01*** | 1.74* | 6.01*** |
| Fine Branching | +21.20±3.07 | +17.00±1.90 | +38.10±2.92 |
| | 6.87*** | 8.95*** | 13.05*** |
| Texsel | +1.15±3.63 | +12.92±3.66 | +13.07±2.27 |
| | 0.32* | 3.53** | 5.71*** |

*ratio indicates no significance
**ratio indicates a significant difference
***indicates a highly significant difference

over either of the later plantings. While no significance is demonstrated in the difference between the first two plantings of Texsel, both have a number of pods per plant that is greater than those of the last planting by a difference significant or highly significant, as indicated in Table V.

Although no statistical comparison was made between the varieties, the Fine Branching seemed superior to the Mesa in the first two plantings; and with the third, the difference could not have been proved statistically significant. On the basis of these figures, the Fine Branching would appear superior to Texsel in the first plantings; but because the seed of the Texsel is about 25 per cent smaller, the seed on the plants of these varieties for the last two plantings should have been about equal in amount by weight.

The Number of Seeds per Pod: The number of seeds per pod, together with a statistical analysis of the varietal difference in this respect, is given in Table VI. No difference could be shown between the numbers from different planting dates of the same variety.

Discussion: Since the number of seeds per pod of the Texsel variety is greater than that of Mesa or Fine Branching by a highly significant difference, this could be considered a varietal difference. The fact that no difference could be demonstrated between Mesa and Fine Branching is

TABLE VI

NUMBER OF SEEDS PER POD OF THREE VARIETIES OF GUAR PLANTED ON THREE DATES AT TUCSON, ARIZONA, 1947

| Planting date | Varieties | | |
|---|---|---|---|
| | Mesa | Fine Branching | Texsel |
| June 17 | 7.68±.145* | 7.50±.138 | 8.06±.144 |
| July 1 | 7.72±.133 | 7.62±.140 | 8.16±.140 |
| July 17 | 7.38±.149 | 7.32±.177 | 8.08±.131 |
| Var. mean | 7.59±.078 | 7.48±.100 | 8.09±.089 |

| Varieties compared | Mean Diff. | P.E. of Diff. | Ratio |
|---|---|---|---|
| Mesa & Fine Branching | 0.11 | 0.13 | 0.85** |
| Mesa and Texsel | 0.50 | 0.12 | 4.17*** |
| Fine Branching & Texsel | 0.61 | 0.13 | 4.69*** |

*Probable error
**No significance
***Difference is highly significant

not surprising, since the Fine Branching is a selection from the Mesa variety. There is wide variability in pod size. The number of seeds per pod ranges from 4 to 11 with all varieties. The pods formed near the top of the plant and late in the season are smaller and have fewer seeds.

Yield: The most important criterion of any crop is its yield. It would seem that potential yield would be the

first consideration in determining what varieties to plant or when to plant them. Table VII gives the yields of the three varieties from the three planting dates. The statistical analysis gives a basis for comparison.

Discussion: The yield figures presented in Table VII show a definite advantage in planting by June 17. The data do not, however, give a true picture of the varietal differences. The narrow plots, 6 feet wide, gave a definite advantage to the branching varieties. The plants of the border rows of Texsel, while larger than the plants of the center rows, were not increased in size proportionately with those of the Mesa and Fine Branching. The Texsel plants shed more pods before they were harvested than the branching varieties. This could have been due to the fact that the Texsel had been mature at least two to three weeks longer. Many of the Texsel plots were harvested when the plants were wet from rain, and less than half the normal yield was recovered from these plots. As a result, only three plots of the June 17 planting, two of the July 1 planting, and one of the July 17 planting of Texsel were harvested when sufficiently dry to give comparable yield figures. Figures from these plots only were used in the data in Table VII. If these varieties were grown in commercial fields where the border effect would be overcome, it is possible that Texsel would outyield the other varieties. As has been mentioned, the highest commercial yield

TABLE VII

GUAR SEED YIELDS AS INFLUENCED BY VARIETY AND DATE OF PLANTING AT TUCSON, ARIZONA, 1947

| Variety | Planting date | | | Var. mean |
|---|---|---|---|---|
| | June 17 lbs/A | July 1 lbs/A | July 17 lbs/A | |
| Mesa | 2,536 | 1,906 | 2,067 | 2,169 |
| Fine Branching | 2,591 | 2,202 | 2,128 | 2,335 |
| Texsel | 2,060 | 1,844 | 1,796 | 1,945 |
| Means for dates | 2,396 | 1,984 | 1,997 | |

Analysis of Variance

| Source | D.F. | T.S.S. | M.S. |
|---|---|---|---|
| Total | 27 | 3,523,110 | 130,485 |
| Varieties | 22 | 573,042 | 286,521 |
| Dates | 2 | 1,958,248 | 979,122 |
| Error | 23 | 991,824 | 43,123 |

Critical difference required for significance at .01 275
at .05 203

of seed to date was obtained from a forty-acre field of Texsel.

With the same varieties at the University Experimental Farm at Mesa, Arizona, dates of planting were May 12, May 31, June 23, and July 12. The best yields were obtained from the May 31 plantings, and the greatest average yield for any variety was the May 31 planting of Texsel.

The data in Table VII show an increase in yield by Mesa and Fine Branching in the June 17 planting over either of the later plantings by a difference significant at the .01 level. The difference between the later plantings can not be shown to be significant statistically. Although a successively smaller yield of Texsel was obtained with later plantings, the differences obtained are not significant statistically.

In comparing varieties, the yield of Fine Branching exceeded that of Mesa on all planting dates; but the difference is significant only with the July 1 plantings, and is greater by a difference significant at the .01 level for this date.

## General Observations and Considerations

In the early stages of growth, the outside rows of plots in the variety and date of planting test were noticeably smaller and had weaker stands. This no doubt was caused by the packing action of the tractor tires on the

moist seed bed at planting time. The effect was over-shadowed later in the season, however, as the plants on the outside rows became larger due to the benefit they received from being border rows. On heavy soil, the packing caused by a tractor could be serious in reducing stands if the seed bed were quite damp at planting time.

The use of scarified seed was no doubt beneficial in securing fast germination and vigorous young stands. No figures for comparison of stands and yields from plots planted with scarified and unscarified seed were obtained, but a guar nursery planted with unscarified seed was grown next to a border of guar planted in rows from scarified seed. Forty days after planting, the plants from the scarified seed were about twice as large as those of any variety in the nursery which had been planted with unscarified seed. Seed may be scarified with sulfuric acid as described in the methods used in the variety and date of planting test, or it can be scarified mechanically. The mechanically scarified seed proved equal or superior to the acid scarified seed in plots planted at the Mesa Farm to compare both methods.

The Texsel guar showed severe water stress at several times throughout the season. The soil had ample moisture below thirty inches, and the branching varieties growing in the same borders showed no water stress. The Texsel, because of a shallower root system, may require more frequent

but lighter irrigations to produce maximum yields.

There was apparently no insect damage to plantings at Tucson in 1947, but a disease condition was observed. A mosaic type disease was observed in all plots on about 1 to 3 per cent of the plants. The diseased plants were chlorotic, stunted, and produced few or no seeds. Leaves of infected plants were somewhat crinkled and chlorotic, with chlorophyl remaining along the principal veins. Black necrotic spots appeared on the leaves, visible from either side of the leaf. The leaves were thick and leathery, the nodes swollen, the stems dry and brittle. This evidently is not the virus disease described by Chester and Cooper (1) because these symptoms were not masked by hot weather, and affected plants showed no tendency to infect nearby plants.

## Seed Quality

Seed Color: It has been considered generally that discoloration of guar seed is caused by the freezing of immature seeds. Probably this is the principal cause of seed discoloration, but Esser (3) believes quality to be reduced by exposing the crop to rains and heavy dews. Table VIII shows the effect of weathering as measured by harvesting samples of seed at four harvest dates and from three positions on the plants.

Discussion: Texsel and Mesa varieties were used in this study. The plants of both varieties were very erect,

TABLE VIII

EFFECT OF WEATHER CONDITIONS ON QUALITY OF GUAR SEED FROM DIFFERENT LOCATIONS ON THE PLANTS GROWN AT TUCSON, ARIZONA, 1947

| Harvest date | Texsel | | | Mesa | | | Total precip. |
|---|---|---|---|---|---|---|---|
| | Lower 1/3 | Center 1/3 | Top 1/3 | Lower 1/3 | Center 1/3 | Top 1/3 | |
| October 15 | 97.4%* | 98.6% | 98.8% | 96.8% | 98.1% | 98.6% | 0.00** |
| October 29 | 92.6 | 98.0 | 98.2 | 96.0 | 98.0 | 98.9 | 0.46" |
| November 11 | 91.4 | 96.7 | 98.6 | 96.1 | 98.2 | 97.3 | 0.65" |
| November 26 | 68.5 | 89.4 | 96.2 | 93.2 | 95.2 | 96.3 | 1.20" |

*Percentage light plump seeds
**0.23" rainfall on the evening of October 15.

and there was little contact of the above-ground parts with the soil. Pods of Texsel occur very near the surface of the soil, however, and there was much greater chance for contact with the soil by pods of this variety. This is not necessarily the case under ordinary field conditions. The heavily branched plants of a variety like Mesa may lodge to a greater extent than Texsel and thus come in close contact with the soil.

Table VIII shows a successively greater discoloration of seed with later harvest dates. This is most noticeable with the seed from the lower third of the Texsel plants, and to a lesser extent with the center third of the Texsel and the lower third of the Mesa plants.

It is not possible to give the exact cause of the discoloration of the seeds, but when discoloration is due to weathering it very likely is related to the activities of common soil microorganisms. Some of the discolored seeds were covered with fungal mycelia, while others appeared to be free from such growth. The pods of discolored seeds are also discolored, and usually are covered with fungal growth. It is possible that some soluble pigment is produced as a result of microbial growth on the pods or surface of the seeds during damp weather.

With these two causes of discoloration in mind, it is easy to interpret the results of the seed color analysis from the variety and date of planting test given in

Table IX. With the Mesa and Fine Branching seed from the June 17 planting, discoloration was due to weathering for the most part, since the plants were quite well matured at the time of the first frost. The July 1 plantings of these varieties had fewer discolored seeds because of a shorter period of weathering after maturity, but seed from the July 17 plantings had a greater percentage discolored than the two previous plantings because many pods were immature at the time of the first frost. All plantings of the Texsel were quite well matured at the time of the first frost; although the July 17 planting showed slight frost damage. With this variety, the best quality seed was obtained from the July 17 plantings. The seed from plots planted on July 1 had a higher percentage discolored than that of the July 17 plantings, and the seed from the June 17 plantings had an even greater percentage discolored. This shows the effect of successively longer periods of weathering on mature seeds. These results emphasize the necessity for harvesting the crop as soon as possible after the plants become ready for harvest. This is especially advisable if the plants are lodged to any extent.

While no distinction was made between seeds discolored by frost and by weathering, it would seem probable that the latter would be less serious. Seeds discolored by frost may have their growth stopped before a normal size is

TABLE IX

COLOR AND WEIGHT OF SEED OF THREE VARIETIES OF GUAR AS AFFECTED BY DATE OF PLANTING AT TUCSON, ARIZONA, 1947

| Variety | Planting dates: June 17 Color | June 17 Seeds/10 gm. | July 1 Color | July 1 Seeds/10 gm. | July 17 Color | July 17 Seeds/10 gm. |
|---|---|---|---|---|---|---|
| Mesa | 76%* | 284 | 84% | 275 | 70% | 275 |
| Fine Branching | 77 | 289 | 80 | 288 | 70 | 292 |
| Texsel | 68 | 353 | 78 | 349 | 86 | 352 |

*Percentage light plump seeds

reached, and probably they would have a low endosperm content. Such seeds can be distinguished from those discolored by weathering. They have a wrinkled seed coat, which would indicate that the endosperm immediately below the seed coat would be deficient. Seeds discolored by weathering are usually more plump, and would be expected to have a more normal endosperm content regardless of color.

Seed Weight: Seed weight as measured by the number of seeds in a 10-gram sample is given for the variety and date of planting test in Table IX. This particular study was made to determine if the date of planting had any effect on the weight of individual seeds of the three varieties tested.

Discussion: In this experiment the seed weight does not give a reliable indication of seed quality. Seed from two plots of the July 17 plantings were the only samples noticeably lighter than the means given. The seed from these plots was badly discolored by frost. Normally matured seed from each variety appears to be of a characteristic weight, but in this experiment planting date had little or no effect on seed weight.

## Guar for Hay and a Subsequent Seed Crop

It would seem that the value of a guar crop might be increased greatly if the plants could be cut for hay once, or pastured off, then be allowed to regrow and mature seed. Small plots of the three varieties were clipped at 6 and 3

inches above the ground and the regrowth was observed. When the plants matured, the seed was harvested; the figures obtained from the harvest of the seed are presented in Table X.

Discussion: Mesa and Fine Branching made excellent regrowth after the first two cuttings, which were made when the plants were 1 and 2 feet high. Texsel made no regrowth after any of the cuttings. It can be clearly seen that Texsel could not be used in a program of this sort. Because of its non-branching habit, the plants seem unable to initiate new growth.

The Fine Branching appeared to be superior to Mesa. In regrowth it produced more branches and more pods, resulting in a greater amount of seed in all cases. The quality, as measured by seed color, was somewhat lower in the seed from the Fine Branching; but because of its vigorous regrowth, more immature pods were present at the time of the first frost.

The guar with which this phase of the study was made was planted June 17. It would be necessary, no doubt, to have guar planted by May 1 or soon thereafter at Tucson if one expected to produce a crop of hay followed by seed. It also would be necessary to have the hay removed and the field irrigated by the first week in August at that location.

It is not possible to say whether the plots clipped on August 14 were retarded because of the time of season, stage

TABLE X

YIELD AND SEED QUALITY FROM PLANTS OF TWO VARIETIES OF GUAR CLIPPED FOR HAY THEN ALLOWED TO REGROW AND PRODUCE SEED AT TUCSON, ARIZONA, 1947

| Date clipped | Height clipped | Mesa | | | Fine Branching | | |
|---|---|---|---|---|---|---|---|
| | | No. Pods* | Yield/A | Quality** | No. Pods | Yield/A | Quality |
| July 24 | 6" | 1,180 | 3,369# | 98.8 | 1,718 | 4,499# | 91.0 |
| | 3" | 1,034 | 3,017 | 88.4 | 1,715 | 4,328 | 83.6 |
| Aug. 7 | 6" | 1,080 | 2,878 | 80.4 | 1,105 | 2,580 | 71.2 |
| | 3" | 412 | 821 | 41.3 | 1,033 | 2,217 | 54.4 |
| Aug. 14 | 6" | 916 | 2,026 | 37.8 | 1,636 | 3,518 | 51.1 |
| | 3" | 0 | 0 | - | 328 | 597 | 15.8 |

*The number of pods on plants occupying one square yard
**The percentage of light plump seeds

of plant maturity, or other factors. The regrowth of the Fine Branching clipped at this date appeared satisfactory, but the seed did not mature.

## Guar Inoculation

An attempt to determine the extent and type of nodulation by the guar plant was made. Although seven cultures of Rhizobium were used to inoculate three varieties, no nodulation took place at any time. The guar plant is placed in the cowpea cross inoculation group by Fred et al. (4), but no information is given in this source as to the relative ability of the plant to nodulate. From available evidence it would seem that guar nodulates very little. Wilson (12) found guar to symbiose with 7 of 32 strains tested; but in an arrangement of the nodulating habits of legumes, he placed guar in a group that had limited nodulating ability. Rogers (8) also noted that guar nodulated sparingly.

The soil on which the inoculation trial was made was at a fairly high level of fertility. It is very possible that guar growing on soil amply supplied with nitrates would produce few or no nodules. It has been reported that guar nodulated very well on the Yuma Mesa with all 7 of the strains of Rhizobium used at Tucson, This could have been due to a lower level of fixed nitrogen in the sandy soil of the mesa.

# CHAPTER V

## SUMMARY AND CONCLUSIONS

Some intensive agronomic experiments have been carried out with the production of guar (Cyamopsis tetragonoloba (L) Taub.) in cooperation with General Mills, Inc. This has been prompted by recent developments in the use of the seed.

The results presented here were derived from experiments and observations at the University of Arizona Experimental Farm at Tucson, Arizona, in 1947.

A variety and date of planting test was carried out with three varieties of guar planted on three dates, June 17, July 1, and July 17. The effect of the three planting dates was studied in relation to the initial stands, vegetative growth, flowering and fruiting habits, seed yield and seed quality. In addition, the time of harvest in relation to seed quality, the plant's ability to produce seed after being cut for hay, and symbiosis with Rhizobium were studied.

The June 17 plantings were superior in that better stands were secured, more vegetative growth was obtained, more pods per plant were formed, and a greater seed yield was produced than with later plantings. There is a possibility that earlier plantings might be equally productive or even

superior. Plantings delayed until July 17 at Tucson are likely to be damaged by frost before they mature.

Of the branching varieties Fine Branching seems superior to Mesa, either for green manure or for seed production. For seed production alone, Texsel is probably the best variety of those tested, although due to certain conditions in these experiments its yield was lower than Mesa and Fine Branching.

Abnormal seed color was used in studying seed quality. Seed color was found to be determined by two factors: the degree of maturity at the time of the first frost, and the length of time mature seed is exposed to unfavorable weather conditions before harvesting. The date of planting had little or no effect on seed weight, unless the seed was very immature.

Should there be an industrial demand for guar seed in the future, the branching varieties might be used for hay then allowed to produce a seed crop from the same plants. Fine Branching would be superior to Mesa in a program of this kind. Texsel could not be used in this manner.

Although guar is known to symbiose with certain strains of Rhizobium, it may do so only under certain conditions. It may nodulate best on light soils with a low level of fixed nitrogen.

Since the demand for guar seed by industry is halted for the present, interest in this crop will be directed

toward its value as a green manure crop. In this less spectacular role, it may yet find a place in Southwestern agriculture.

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# APPENDIX

## GUAR NURSERY OBSERVATIONS

In connection with the guar investigations at Tucson, Arizona, in 1947 a nursery of 27 strains was grown for observation. A brief summary description of each strain is given here, and some data indicating the productive possibilities of each are tabulated.

The strains designated with S-44 are numbered selections from guar grown at the University Experimental Farm at Mesa, Arizona, in 1944. Strains having a PI number are recent plant introductions by the Bureau of Plant Industry. These particular introductions are from India.

Texsel is an erect, non-branching type. Long racemes of flowers are produced at each node. It matures two to three weeks earlier than any other strain observed in the nursery. It produced the heaviest set of pods of any variety or strain observed.

Mesa or Regular has a fairly erect central stem with branches at about half of the nodes.

S-44-1 has coarse bright green stems and large leaves. The central stalk is not erect and is very branched. This selection appeared to be quite uniform. Foliage is nearly glabrous.

S-44-2 is similar to S-44-1, but the S-44-2 plants appear to be in a segregating generation. The nursery rows of this selection contain combinations of erect and bushy types, glabrous and pubescent foliage, and light and dark green foliage.

S-44-3 is very similar to S-44-1, and is quite uniform in growth habit. The first three selections appear very similar in that they lodge quite badly, have many glabrous plants, and have large seeds. They do not appear to have promising qualities, unless they might be desirable as forage. Their character for glabrous foliage, if shown to be an advantage, might be bred into more desirable types.

S-44-4 is very similar to Mesa in appearance, in growth, and branching habits, but it appeared superior in that it set more seed.

S-44-6 is a branched, bushy type very similar to Mesa or Fine Branching. It set seed very well.

S-44-7 is similar to Mesa or Fine Branching, but no special advantage of this selection was noted over Fine Branching.

S-44-8 is very similar to Mesa in all respects.

S-44-9 is finely branched, more so than Fine Branching. It also appeared somewhat resistant to lodging. This selection looked promising early in the season.

S-44-10 is the Fine Branching variety, and was one of the most promising strains in the nursery.

S-44-12 is similar to Mesa, although somewhat taller.

S-44-13 appeared to be in a segregating generation. It is quite similar to Mesa.

S-44-14 is not uniform as to plant type. Some plants were erect, others branched. Some set seed heavily while others were nearly sterile.

S-44-15 is a coarse, erect type. Most plants had one to three coarse branches. It was quite late in maturing seed.

S-44-16 is a coarse, sparsely branched type. Pod formation and seed maturity were late on this selection.

S-44-17 is an erect type with branching high on the plant. Most of the pods were formed near the top of the plant. Stems were coarser than those of Mesa. In the nursery this selection was late in maturing because a stand was not obtained until after the first irrigation after planting. It resisted lodging and appeared to be an excellent type for seed production, although because of its late start it set few pods.

S-44-18 is a tall, erect type with little branching. Stems are very coarse and leaves quite large.

S-44-19 is similar to S-4418. There was considerable variation in the number of pods set by different plants in this selection.

S-44-20 is a coarse, erect type with little branching.

PI 144324 is a branched type similar to Fine Branching. Pods set quite heavily on this introduction.

PI 144325 is similar to PI 144324, but had fewer pods.

PI 144326 is similar to PI 144324.

PI 144327 is similar to PI 144324. Throughout the growing season it appeared to be the most promising of the introduced strains with respect to flowering and fruiting.

PI 144328 is similar to PI 144324, but set fewer pods.

The above recently-introduced plant introductions are very similar in plant morphology, all being branched similarly to Fine Branching. PI 144324 and PI 144327 looked most promising in seed production.

PI 156988 made the most vigorous growth early in the season of any strain in the nursery. It is similar to Mesa in branching habit, but branches are somewhat coarser. It may be a desirable green manure type because of its vigorous growth early in the season.

From each of three replicates in the nursery, 10 plants were harvested. The number of pods and the amount of seed produced by these plants were determined. The area occupied by the 10 plants was used in computing acre yield. The nursery was harvested October 27.

TABLE XI

A SUMMARY OF GROWTH AND FRUITING CHARACTERISTICS OF 27 STRAINS OF GUAR GROWN AT TUCSON, ARIZONA, 1947

| Selection or intro. | Plant height cms. | No. pods per plant | Seeds per pod | Yield per acre | Seed quality |
|---|---|---|---|---|---|
| Texsel (PI 116034) | 123.7 | 137 | 8.1 | 3,057# | 84.8* |
| Mesa | 124.8 | 131 | 7.9 | 1,633 | 96.4 |
| S-44-1 | 127.3 | 103 | 8.4 | 1,585 | 97.4 |
| S-44-2 | 131.7 | 105 | 7.8 | 1,179 | 96.0 |
| S-44-3 | 125.9 | 85 | 8.3 | 1,365 | 96.7 |
| S-44-4 | 117.4 | 163 | 7.7 | 2,227 | 97.3 |
| S-44-6 | 124.6 | 154 | 7.2 | 2,267 | 96.8 |
| S-44-7 | 120.5 | 178 | 7.7 | 2,025 | 95.2 |
| S-44-8 | 116.1 | 139 | 7.8 | 1,780 | 94.6 |
| S-44-9 | 111.5 | 101 | 7.7 | 1,659 | 97.1 |
| S-44-10 (Fine Br.) | 124.2 | 155 | 7.7 | 2,457 | 94.4 |
| S-44-12 | 134.7 | 173 | 7.4 | 1,910 | 94.4 |
| S-44-13 | 126.5 | 125 | 7.5 | 1,418 | 95.1 |
| S-44-14 | 138.3 | 130 | 8.4 | 2,259 | 91.2 |
| S-44-15 | 153.0 | 142 | 8.1 | 2,091 | 94.0 |
| S-44-16 | 130.7 | 147 | 8.1 | 1,853 | 92.7 |
| S-44-17 | --- | 100 | 8.2 | 1,565 | 97.6 |
| S-44-18 | 150.2 | 87 | 7.6 | 1,193 | 96.9 |
| S-44-19 | 150.0 | 122 | 7.8 | 1,502 | 97.3 |
| S-44-20 | 136.3 | 119 | 8.8 | 2,054 | 98.1 |
| PI 144324 | 116.8 | 188 | 7.8 | 2,428 | 96.8 |
| PI 144325 | 116.7 | 123 | 7.6 | 1,707 | 98.0 |
| PI 144326 | 127.9 | 175 | 7.7 | 2,251 | 96.0 |
| PI 144327 | 129.3 | 164 | 7.5 | 2,268 | 96.2 |
| PI 144328 | 119.4 | 135 | 7.9 | 1,671 | 98.7 |
| PI 156988 | 123.6 | 146 | 7.6 | 2,132 | 96.5 |

*Percentage of light plump seeds.