STUDIES ON GUAR - *CYAMOPSIS TETRAGONOLOBA* (L.) TAUB.

By

THEODORE HYMOWITZ

Bachelor of Science
Cornell University
Ithaca, New York
1955

Master of Science
University of Arizona
Tucson, Arizona
1957

Submitted to the Faculty of the Graduate School of
the Oklahoma State University
in partial fulfillment of the requirements
for the degree of
DOCTOR OF PHILOSOPHY
August, 1963

STUDIES ON GUAR - CYAMOPSIS TETRAGONOLOBA (L.) TAUB.

Thesis Approved:

Ralph S. Matlock
Thesis Adviser

L. Herbert Bruneau

Lester W Reed

Jack R. Harlan

U. T. Waterfall

Robert MacVicar
Dean of the Graduate School

ACKNOWLEDGEMENTS

Grateful acknowledgement is made to the faculty and staff of the Agronomy Department, Oklahoma State University, for their encouragement and assistance during the course of these investigations. The author is especially indebted to:

Dr. R. S. Matlock, his major advisor, for the aid and consideration so generously extended;

Dr. L. H. Bruneau, Dr. J. R. Harlan, Dr. H. F. Murphy, and Dr. U. T. Waterfall, the members of his committee;

Dr. R. D. Morrison, Mr. W. Gurley, and Mrs. J. Bedingfield for their aid in the statistical analysis of the data;

Dr. H. L. Hyland and Dr. W. R. Langford, U.S.D.A., for their assistance in obtaining the plant introductions of Cyamopsis;

Mrs. M. E. Howland of the library staff for her aid in acquiring pertinent documents;

Dr. C. L. Leinweber, former Agronomy Department staff member, for the use of his seed germinators;

Mr. J. A. Ameen, undergraduate student, for his aid in collecting data on experiments conducted on guar seedcoat color;

Mr. D. F. Owen and Mr. E. F. Young, Jr., fellow students, for their suggestions and assistance in the preparation of the manuscript;

The Oklahoma State Experiment Station for a research assistantship, the United States Department of Agriculture for financial assistance, the Loeb Foundation for a fellowship, and the United States Department of State for a Fulbright fellowship to India;

Ann E. Hymowitz, the author's wife, for her extreme patience and encouragement; and

Mrs. D. Owen, for typing the manuscript.

TABLE OF CONTENTS

LIST OF TABLES

Table		Page

Table Page

LIST OF FIGURES

Figure | Page

CHAPTER II

CHAPTER V

INTRODUCTION

One means of preventing the production of surplus crops is to grow something else on the surplus producing acres. If a new crop can be grown profitably by American farmers in place of the surplus commodities, it will have a direct preventative effect on the market surplus. Moreover, if the new crop can be utilized by industry, the advantage will be further enhanced. A new or special crop is defined in this country as one not permanently established in the United States.

Of some 250,000 species of angiosperms (89)[1/] which have been identified, about 150 species account for the major proportion of the world's cultivated crops.

> Primitive farmers who found uses for them chose only the species which yielded components, such as fruits, roots, grains, juices or fibers.... Having no laboratories or scientific instruments, they necessarily must have passed over species in which modern techniques may well find valuable industrial or medicinal constituents (183).

Except for Jerusalem artichoke, pumpkin, squash, and sunflower, the agriculture of the United States is based upon introduced plants that came from the wild or were cultivated in other countries. The procurement

---

1/ Figures in parenthesis refer to Literature Cited.

of this raw material for potential new crops has been the official policy of the United States government since the administration of President John Quincy Adams (79).

A new crop, guar - *Cyamopsis tetragonoloba* (L.) Taub. - is an annual drought tolerant legume introduced to the United States from India. The beans of the crop can be processed to make guar flour, which is a source of galactomannan. This gum is valuable to the paper, mining, textile, food, cosmetic, and pharmaceutical industries. The crop can be grown in warm areas from Southwestern Oklahoma through Texas and Arizona. Guar has been cited by the Commission on Increased Industrial Use of Agricultural Products as an alternative or supplementary crop to those now produced in surplus of market requirements.

The potential acreage for guar is yet unknown, mainly because of a lack of adequate research on genetic and cultural improvement.

Investigations on various phases of genetic composition, plant breeding and cultural practices of guar were conducted from 1959 to 1961. They are reported in the following chapters as a series of manuscripts to be presented for publication to various biological journals.

CHAPTER I

THE HISTORY OF GUAR IN THE UNITED STATES

A. THE HISTORY OF GUAR IN THE UNITED STATES PRIOR TO WORLD WAR II.

Guar -- Cyamopsis tetragonoloba (L.) Taub. -- is a drought tolerant, summer annual legume that is grown primarily in India and Pakistan. In these countries it is used principally as forage for cattle, as a green manure, and as a vegetable for human consumption. Chopra et al. (30) reported that the fruit of guar is used as a laxative in biliousness and for night blindness. Watt (181) noted that guar was used as a shade plant for young shoots of ginger.

The first published paper on guar in the United States was written by C. V. Piper (136). Piper stated that guar was first imported into the United States by the Department of Agriculture in 1903. According to the department's records (82) P. I.[1] 9666, the only unnamed seed for that year, was received from the Surat Government Farm, India on May 11, 1903.

---

[1] P. I. stands for Plant Introduction Number.

Hellbusch (77) and Poats (138) ignored this unnamed plant introduction and suggested that 1906 or 1913 was the date of introduction. However, in a letter dated November 13, 1906 (104), McKee stated to Dr. Piper that seed of P. I. 9666 grown at the Chico, California Plant Introduction Garden, was used in 1906 in an irrigation and date of planting study. This statement by McKee eliminates all doubts as to the first introduction of guar.

The first introductions were sent to the federal and state experiment stations located in the Southwest where it was believed to be adapted to the soils, hot climate, and long growing season of the area. Emphasis was placed on its use as a drought tolerant, soil improving legume, and as an emergency forage for cattle. The list of guar introductions prior to 1940, the year introduced, and place of origin are shown in Table 1 (82).

Table 1--Plant introductions of guar prior to 1940.

Introduction Number	Year	Place of Origin
9666	1903	Surat, India
18641	1906	Surat, India
18642	1906	Surat, India
18643	1906	Surat, India
18644	1906	Surat, India
18645	1906	Surat, India

Table 1. (Continued)

18646	1906	Surat, India
18647	1906	Surat, India
18648	1906	Surat, India
18649	1906	Surat, India
18650	1906	Surat, India
18651	1906	Surat, India
21003	1907	Bombay, India
21004	1907	Bombay, India
25708	1909	Poona, India
36549	1913	Nagpur, India
37725	1914	Bombay, India
43503	1916	Mandalay, Burma
49864	1920	Mandalay, Burma
49899	1920	Poona, India
49900	1920	Poona, India
49901	1920	Poona, India
49902	1920	Poona, India
49903	1920	Nagpur, India
49904	1920	Nagpur, India
51371	1920	Poona, India
51372	1920	Poona, India
51373	1920	Poona, India
51598	1920	Surat, India
51599	1920	Surat, India
51600	1920	Surat, India
51601	1920	Surat, India
51696	1920	Madras, India
52785	1921	Nagpur, India
52786	1921	Nagpur, India
57833	1923	Poona, India
66654	1926	Batticotte, Ceylon
67265	1926	Jerusalem, Palestine
114932	1936	Teldeniya, Ceylon
114933	1936	Bangalore, India
115462	1936	Poona, India
115463	1936	Poona, India
115464	1936	Poona, India
116034 2/	1936	Jaipur, India
116105	1936	Bikaner, India
124458	1937	Ujjain, India
124562	1937	Hyderabad, India

2/ The only plant introduction in this list whose germ plasm has been preserved.

In 1906, P. I. 9666 was sown on April 9, May 15, and June 20 at the Chico Plant Introduction Garden.

The first two plantings received irrigation, while that of June 20 was grown without irrigation. McKee (104) reported that the April 9 and May 15 plantings made practically the same growth as that of June 20 and that the seed of the early plantings were as late in ripening as that of the later planting. This was the first indication that guar has an indeterminate type of growth habit. Furthermore, P. I. numbers 18641 to 18651 were grown at Chico in 1906 and evaluated by McKee. He believed P. I. 18645 (Talabda) and 18646 (Sotia) to be the most promising varieties for forage. The locations and dates where guar introductions were grown in the New World are shown in Table 2.

Table 2--Locations and dates where guar introductions were grown in the New World prior to World War II.

Location	Year
Chico, California	1905
San Antonio, Texas	1906
Stillwater, Oklahoma	1908
Tucson, Arizona	1909
Chillicothe, Texas	1911
Honolulu, Hawaii	1911
Lubbock, Texas	1912
Pecos, Texas	1912
St. Croix, Virgin Islands	1912
Beeville, Texas	1913
Denton, Texas	1913

Table 2. (Continued)

Temple, Texas	1913
College Station, Texas	1913
Whittier, California	1913
Angleton, Texas	1914
Nacogdoches, Texas	1914
Spur, Texas	1914
Davis, California	1920
El Centro, California	1921
Iowa Park, Texas	1926
Auburn, Alabama	1929
College Station, Texas	1936
Yuma, Arizona	1939

The following excerpts from correspondence from McKee to Piper (105) in 1908 indicate McKee's findings and opinion of the new crop:

> Eight varieties of guar were sown April 28, 1908, in rows four feet apart. Practically none of the seed germinated....failure in germination was due to the very dry condition of the soil at the time of planting....after three seasons tests with guar we are of the opinion that it is of little or no value....the peculiar taste of the leaves and stems which probably would make them objectionable to stock when fed as fodder.

There is evidence of conflicting opinion, however, as to the palatability of guar to livestock. On page 19 of the 18th Annual Report of the Oklahoma Experiment Station (120) is found the following statement concerning forage grown by the Agronomy Department, "These embrace such well known crops as the cowpea, soybean.... Jerusalem artichoke and guar -- a foreign leguminous plant." Piper (136) maintains that cattle at the Oklahoma Experiment Station readily ate the straw after the seed had been thrashed out. Headley and Hastings (76) planted guar on the San Antonio Experiment Farm in 1906. They reported that guar is very drought tolerant and recommended the plant as a green manure crop or a forage for sheep and goats. The above authors suggested that poor results may be due to a lack of appreciation of the soil fertility and cultural practices necessary to secure the best results.

Thornber (177) commented that during the latter part of May, the Colorado River had an annual flood period of from two to six weeks. An experiment was conducted in 1908 to determine which forage crops could be grown under these conditions. Guar seed with an initial germination of 98 percent dropped to two percent germination when submerged under water for 38 days. However, sesbania, amber cane, and Johnsongrass germinated 75, 45, and 45 percent, respectively, under similar experimental conditions.

In 1911, Bessey (10) noted in a Bureau of Plant Industry Bulletin that guar seemed to be resistant to root knot nematode. However, no further work on guar was reported by this investigator.

Kelly, Wilcox, and McClelland (95) planted a number of crops at the Hawaii Agricultural Experiment Station in 1911 for the purpose of determining their economic feasibility. Guar was planted in rows five feet apart and two to six inches apart in the row. They reported that the guar plots yielded 1,190 to 2,610 pounds of seed per acre and 2,500 to 5,500 pounds of air dry forage per acre.

Further exploratory investigations were conducted at Angleton, Beeville, Chillicothe, College Station, Denton, Lubbock, Nacogdoches, Pecos, Spur, and Temple, Texas (11,16,45,68,85,93,142,202, and 204). Brooks and Harvey (16) reported that guar was intermittently grown at Balmorhea, Beaumont, Iowa Park, Tyler, Weslaco and Winter Haven, Texas. In all of the Texas stations, guar was evaluated for its use as a green manure and for forage. In general, the reports were optimistic for its use as a green manure. Opinion as to its value as a forage for livestock ranges from negative to favorable.

Besides Chico, California, guar was grown at Whittier in the garden of R. S. Woglum who collected the seed while on a trip to Nagpur, India (203). The seeds were presented to the Department of Agriculture and assigned the P. I. number 36549. Hellbusch (77) stated that guar was grown on the University of California Experiment Station in the early 1920's and that a few single plant selections were made. Goar (56) wrote that guar was introduced at the Imperial Valley Field Station near El Centro in 1921 and has been grown there since. The results at Davis and El Centro indicated that guar was an excellent green manure crop (80 and 81). The 1927-1928 report of the California Experiment Station (114) contained the following statement:

> Experiments with summer legumes covering a period of years have shown that guar, mat bean, and Kearny mung are all well-adapted to Imperial Valley conditions. Guar appears to be the best cover crop for the heavy soils of the valley because it grew 3-6 feet tall and produced from 18-25 tons of green matter per acre. Because of its coarse stemmy character and sparseness of leaves, it is of little value for forage.

Thomas (174) reported that an alkali soil reclamation project was carried out near El Centro, California where alkali had accumulated in consequence of poor drainage. Sesbania and guar were used as sources of green manure. The author stated that guar grew well on areas that supported a good growth of sesbania. Moreover, on areas where sesbania had failed to grow, guar likewise failed.

Smith (156) reported that A. B. Connor of the Texas Agricultural Station sent seed of guar to its St. Croix, Virgin Island Experiment Station and the crop was grown there in 1912. Since very poor results were obtained, it was omitted from subsequent plantings.

Taubenhaus and Ezekiel (171) reported that guar was resistant to, or a rather passive carrier of <u>Phymatotrichum</u> root rot. The fungus infected the roots of the plants, but the host developed new roots and produced a seed crop despite the disease. Additional studies with <u>Phymatotrichum</u> in Texas were reported by Brooks and Harvey (16).

Piper (137) reported that guar did not "ripen its seed in northern Virginia." Sturkie (164) found that guar could not withstand the climatic conditions and/or did not appear to be a valuable forage or soil improving crop for the state of Alabama.

A summer legume study to evaluate possible sources for green manure was conducted at the Arizona Agricultural Station in 1933 (18). The report stated that "Guar showed more promise that any of the other kinds of plants and produced a good seed yield. Some difficulty may be experienced in the harvesting of guar seed by machinery but should not be serious."

Guar was grown for green manure at the Yuma station for the first time in 1939 (74). The crop produced a higher average yield than cowpeas and soybeans in the test. Further experiments after 1940 at the Yuma station will be discussed in the second section.

It appears there was little or no attempt to preserve the seed of the early plant introductions. The crop was evaluated for its use as green manure and as forage for cattle and then it remained in virtual oblivion until rather recent introductions were brought into the country. Today, P. I. 116034 is the only germ plasm available from pre-World War II introductions. The introductions from the high rainfall area of Burma and the one obtained by David Fairchild and P. H. Dorsett from Ceylon are lost. With the current unstable political situation and the encroachment of urbanization on agricultural lands in Asia and Africa, it is imperative that all possible genetic variants be collected and maintained. Discussing the problem of plant introductions, Harlan (67) noted, "The fact that many introductions look worthless has led many people to believe that they are worthless."

B. THE HISTORY OF GUAR IN THE UNITED STATES DURING WORLD WAR II AND THE IMMEDIATE POST-WAR ERA

Investigations on guar in the early 1940's were mainly concerned with its use as a green manure or cover crop in Arizona and Texas. These experiments were generally similar in kind to those conducted since the crop's initial introduction in the United States in 1903.

A five-year study at the Mesa Farm in Arizona (20,21,23, and 75) found guar to be the outstanding green manure crop when compared to sesbania, tepary beans, *Crotalaria juncea*, cowpeas or fallow cropping. The green manures were evaluated by yields of the succeeding barley crop. Moreover, additional studies indicated that guar, when compared to other green manure legumes, will produce the highest yields of air dry material regardless of time of planting or date of harvest (19). Furthermore, seed yields of guar showed little variation as affected by the date of planting or the condition of the plants at the time of irrigation (22).

Spacing studies conducted with Mesa variety of guar in 1943 and 1944 (111) indicated that 7-inch and 12-inch row spacings had better yields than those ranging from 24 to 36 inches. Additional studies on fertilization of soil, planting procedures, harvesting practices and equipment were reported by the investigators in the same bulletin. Briggs (14) reported that guar had been used as a green manure by a few vegetable growers in the Yuma Valley in Arizona.

Studies conducted on guar plots at Mesa, Sacaton, and Tucson, Arizona (23) validated the investigations in Texas by Taubenhaus and Ezekiel (171) on Phymatotrichum root rot. The strains of guar in Arizona appeared to be resistant or at least passive carriers of the root-rot fungus. Rogers (146) also confirmed the investigations of the earlier Texas researchers. Matlock, Aepli, and Streets (111) reported additional studies with diseases of guar.

Brooks and Harvey (16) reported that a study was made at Iowa Park, Texas from 1943 through 1947 to determine the adaptation of guar to standard farm machinery. They concluded that a standard grain combine should be able to satisfactorily harvest the seed.

In 1947, the Arizona Experiment Station staff conducted tests with guar at Mesa, Safford, Tucson, and Yuma (24). These tests were part of a continuing series of investigations (25). Earlier results had already been reported elsewhere.

Matlock (112) pointed out that in Oklahoma, one preliminary trial of guar was conducted in 1941, but no data were collected. Concerning new crops in Oklahoma, the 1942-1944 Biennial Report of the Oklahoma Agricultural Experiment Station stated, "Work on minor crops is centered on a search for those having value in Oklahoma as cash crops providing oils and other industrial new materials as sources of home grown feed or as green manure." Among the crops under investigation were safflower, sesbania, sunflower, crotalaria, castor beans, and guar (12). However, Ligon (101) reported that the guar tests conducted in 1944 failed. A virus destroyed the crop and the fear of spreading the disease to other legumes caused it to be eliminated from further tests.

Considering the above investigations, the acreage planted to guar logically should have been limited to the barley and flax fields of Arizona and Texas (63) where the crop served as an excellent green manure. However, other factors appeared which transformed guar from its use as a green manure or cover crop to a cash crop, modified its area of adaptation and altered the type and kind of investigations conducted with the species.

During World War II, the imported stock of carob seed (Ceratonia siliqua L.) from the Mediterranean area was depleted. The endosperm of the seed from this perrenial legume was the source of carob gum, a galactomannan mucilage which was used mainly as a sizing agent for paper and textiles (147, 185, and 186). Carob gum is also known as gum gatto, gum hevo, jandegum, lakoe gum, locust bean gum, lupogum, luposol, rubigum, tragon, and tragosol. As a food for human consumption it is historically known as St. John's bread or swine's bread (150).

The search for domestic sources of galactomannan gums was initiated by the Institute of Paper Chemistry, Appleton, Wisconsin (106). Analyses of seed from trees and shrubs revealed that potential sources of galactomannan gum were the legumes adapted to the semidesert environment of the Southwest United States (147). Further inquiries by the Institute found the University of Arizona and the Soil Conservation Service of the United States Department of Agriculture experimenting with various legumes as potential sources of green manures and cover crops.

Upon the recommendation of S.B. Detwiler of the Soil Conservation Service (13), guar seed were analyzed by the Paper Institute for gum content. The future of guar was indicated when the Paper Institute and Anderson (3) reported that the endosperm of guar contained a usable form of galactomannan gum. The three organizations then combined their resources to develop and promote the use of guar seed as a domestic source of this vegetable gum. Further investigations in Arizona found guar an excellent green manure. It was also highly adapted to mechanical planting, harvesting, and it produced, under irrigation, 1,000 - 1,500 pounds of seed per acre (186).

Briggs (13) reported that the experimental results with guar at the Paper Institute were so encouraging that, in the summer of 1942, supplies of seed were increased. The green manure experimental plots at Mesa and Tucson were allowed to mature and together with a supply grown by the H. P. Garin Company at Yuma, they furnished enough seed for planting approximately 700 acres of guar in 1943.

Rowland (147) pointed out that, in order to provide financial support for the experimental program, 25 paper companies underwrote the adventure. Moreover, in order to induce farmers to grow the experimental crop, they were guaranteed a generous price of 8 cents a pound for the seed produced. The General Mills Company supervised the entire program, from the planting operation to the milling of the seed for its mucilage (48).

In 1943, approximately 550 acres of guar were planted at Mesa and 50 acres at Yuma, Arizona. About 100 acres were planted in the Imperial Valley in California (77). The harvested crop, nearly 100 tons of seed, was shipped to the General Mills plant in Minneapolis for milling. The milled flour was then distributed to various paper organizations for experimental studies on the application of guar mucilage to paper manufacturing. Rowland (147) published an excellent account of the experiments. He summarized the verdict of the paper companies in the following statement, "... The beneficial effects of guar mucilage in the paper processing were sufficient to justify the adoption of the product for regular manufacturing formulas." The program continued from 1944 through 1947 when, according to Matlock, Aepli, and Streets (111), General Mills discontinued its processing program with guar seed. In spite of the fact that there were no industrial outlets for the seed crop, the Arizona and Texas experiment stations exhibited foresight and continued their research programs with guar.

Three varieties of guar were developed in the 1940's, Mesa, Texsel, and Groehler (159 and 160). Matlock, Aepli, and Streets (111) reported that Mesa variety of guar had been grown on the Mesa Experiment Farm since 1943. The variety came about as a selection from an unknown plant introduction. Brooks and Harvey (16) wrote that Texsel variety of guar was developed by closely roguing Plant Introduction 116034, grown at Iowa Park, Texas. The name "Texsel" was fabricated in 1946 by Mr. John A. Esser of General Mills, Inc. Groehler variety of guar was a single plant selection (S-46-1) made in 1946 from a commercial field of Texsel on the Louis Groehler farm south of Mesa, Arizona.

In 1947, Erdman (47) isolated two strains of Rhizobium from Crotalaria sagittalis and from Erythrina indica which were highly effective in promoting nitrogen fixation in guar plants. Musil (121) published a note suggesting that a practical means of securing immediate and uniform germination with guar was to scarify the seed with dilute sulfuric acid and to delay planting until the soil was fairly warm.

In 1947, Purdue investigators (185) initiated experiments with guar in hopes of establishing the crop in the corn belt. C. P. Key (91) attempted to establish guar in South Carolina and Claasen and Staker (32) reported observational plantings in Lincoln, Nebraska. Other investigations on guar may have been published, but the reports were not seen by the writer.

Whistler (186) analyzed dried seed of guar. He found they contain about 7.4 per cent moisture, 26.0 per cent protein, 1.6 per cent fat, 9.9 per cent crude fiber, 3.7 per cent ash, and 51.4 per cent nitrogen free extract. He believed guar could be safely stored at moisture contents of 14 per cent or lower. Upon analysis of the milled guar flour, he learned that it consisted mainly of a carbohydrate polysaccharide. Upon hydrolysis, the polysaccharide produced only mannose and galactose in a ratio of 2:1, hence the name galactomannan.

In 1948, the General Mills Company shifted the emphasis of guar production from the irrigated lands of Arizona and California to North Central Texas and Southwestern Oklahoma. The main reason for this shift was the potential use of guar as a rotation crop with flax and cotton and the lack of response of the crop to irrigation. The company also felt that the support price of guar grown in Arizona and California was inflated and unrealistic in terms of the crop's future growth in the United States. If guar was to succeed as a permanent crop in American agriculture, it was to do so on its own merits (49).

McKelvey (106) predicted the uses of guar by American industry on the basis of technology available in 1947:

> Aside from the paper industry guar mucilage finds potential use in textile sizing, in the production of cheese, processing of leather,

> manufacture of permanent wave sets, and in preparing foods. It may become an ingredient of spaghetti and other pastes, as well as of cereal products. It can be used as a base powder in ice cream and puddings. Pie fillings, jams and marmalades will benefit by the thickening properties of guar mucilage.

C. RECENT ADVANCES IN CHEMISTRY, PLANT BREEDING, GENETICS, AND CULTURAL PRACTICES

From 1948 to 1952 there were no industrial outlets in the United States for guar seed. Except for the agronomic studies conducted by the Arizona and Texas Experiment Stations and by a few farmers in southern Texas who grew it as a green manure crop, the future of guar in the United States looked bleak. As the supply of imported locust beans from the Mediterranean area increased, the need for a domestic supply of galactomannan gum decreased. Nevertheless, it was during this period that a great number of investigations were conducted on the molecular structure (1, 70, 78, 119, 130, 139, 155, 166, 190, 192, and 193), physio-chemical properties (34, 43, 118, 129, 189, 191, 195, and 196), and potential industrial uses of guar gum (17, 27, 69, 86, 115, 116, 128, 140, 143, 162, 167, 168, 169, 170, 184, and 187). Whistler (188), Whistler and Smart (194), and Goldstein and Alter (61) have presented excellent detailed manuscripts on the chemistry and potential uses of guar.

These investigations showed that the guar gum molecule is a polysaccharide consisting of straight chain pyranose units of D-mannose joined by 1-4 beta glycosidic linkages. On the average, a single D-galactose unit joins every other mannose unit by a 1-6 alpha linkage. The molecular weight of the gum has been estimated at 220,000.

Guar gum exhibits the following properties: 1.stable over a wide pH range; 2.forms acid reversible gels with borate ions; 3.forms fiscous colloidal dispersions in hot or cold water; and 4.as a non-ionic polysaccharide, it is not inclined to salt out.

From 1948 to 1952, several patents were issued and papers published on the uses of guar. The various uses were:

1. prevents caving and heaving of formations when used as an additive to water-base drilling mud;
2. increases bursting strength and folding endurance of paper sheets;
3. speeds up production of paper manufacturing;
4. stabilizes ice cream mixes;
5. assists in the rapid disintegration of pills;
6. jells lotions, salves and creams; and
7. maintains turbidity of natural citrus juice in citrus juice concentrates when they are rehydrated.

During the Korean conflict, the supply of locust beans could not keep up with the demand. The price of locust beans increased to the point where guar beans became more competitive. Since locust beans come from a perennial leguminous tree (*Ceratonia siliqua* L.), the supply cannot be increased radically as can be done with guar, an annual plant. When growing conditions damaged the trees during the 1956 season, guar gum had a chance to make inroads into markets dominated by locust bean gum. General Mills, Inc. once again decided to market domestically grown guar gum seed and a plant was built at Kenedy, Texas. The plant has been in operation since 1953. Stein Hall and Co. Inc. has plants in Long Island City, New York and Charleston, South Carolina. Other known importers or manufacturers of guar gum are the Burtonite Co., Colony Import and Export Corp., T. M. Duche and Sons, Inc. Unigum division, Paul A. Dunkel and Co., Hathaway Allied Products, Meer Corp., Morningstar-Paisley, and Tragacanth Importing Corp. Anderson (2), with tongue-in-cheek, wrote a short note concerning the trade name by which one commercial company sells its guar gum - "Jaguar".

In spite of competition from other vegetable and synthetic polysaccharides, guar gum usage has increased tremendously in the United States since 1954.

According to Goldfrank (58), consumption of guar gum has increased from 2.5 million pounds in 1954 to around 22 million pounds in 1960. This increase is mainly due to industry which has sought to find new commercial uses for the gum.

Atwood and Bourne (6 and 7) reported a use for guar gum in the purification of potash by the flotation process. Christianson and Ramstad (31) developed a method whereby guar gum can be readily dispersed in water without clumping. A patent was issued to Taylor (173) for use of the gum as a water resisting agent jacket around explosives. Moe (117) perfected a technique whereby galactomannans and glucomannans are processed to produce products having unusually high viscosity in aqueous solutions at low temperatures. The addition of guar gum with melamine-HCHO resin to photographic paper to increase the wet strength, folding endurance, dry burst strength, and resistance to liquid penetration was elaborated by Spear (158) in 1954. McCarron (102) reaffirmed previous investigations by reporting that addition of galactomannan gums to paper increases the strength of the paper and speeds up the manufacturing process.

In 1953, Haug (70, 71, 72, and 73) published a series of four papers reporting his investigations with guar gum. He found that purified guar gum contained 60.9 per cent mannose and 37.1 per cent galactose. He also revealed that when purified guar gum is added to a borax solution, an insoluble complex is formed, making it possible to disperse guar gum in water at a concentration of seven to eight per cent.

Johnson (87), Jones and Pridham (90), Keen and Opie (94), McNulty (108), Newburger et al. (123), and Strange (163), using infrared absorption spectra, colorimetric and/or water extraction techniques, developed procedures for qualitatively and quantitatively measuring guar gum in foods, drugs, paper products, and cosmetics.

From 1955 to 1960, 25 patents which directly or indirectly involved guar gum were issued to individuals or their companies. The patent numbers, authors, and titles of patents are presented in Table 3. In general, the gum found use mainly in increasing the viscosity and stability, and modifying other properties of liquids or solids. For example, Eatherton, Platz, and Cosgrove (44) tested guar gum as a binding and disintegrating agent for tablets of digitalis, lactose, sulfathiozole, and thyroid. Goldstein (59) revealed the amounts of guar used, methods of preparation, and points of addition when the gum is used as a wet-end additive in paper manufacturing.

Table 3--Patent number, author, reference cited, and title of patents issued from 1955 to 1960 concerning guar gum.

Patent Number	Author	Reference Cited	Title of Patent
U.S. 2,708,175	Samfield *et al.*	149	Tobacco product.
U.S. 2,730,505	Jordan	92	Increasing the viscosity of guar sols by reaction with formaldehyde.
U.S. 2,767,167	Opie and Hamilton	127	Decreasing the viscosity of mannan type gums.
U.S. 2,769,734	Bandel	9	Water-resistant tobacco sheet material.
U.S. 2,774,710	Thompson and Corrente	175	Pharmaceutical preparations for gastic hyperacidity.
U.S. 2,803,558	Fronmuller	54	Treatment of adhesive gums.
U.S. 2,834,774	Anker	4	Improving mannan type gums.
U.S. 2,844,547	Sheldon	154	Textile printing-paste extenders.
U.S. 2,854,407	Mallory	109	Drilling fluid additive.
U.S. 2,856,289	Weinstein	182	Stabilizers for ice cream-type desserts.
U.S. 2,860,448	Carrasso	26	Reclaiming and improving saline and alkaline soils.
U.S. 2,868,664	Goldstein	60	Dry mannogalactan compositions.
U.S. 2,870,059	Williams and Kirchner	201	Stabilization of dithiocarbamate slurries.
U.S. 2,875,185	Wiley	197	Aqueous suspension polymerization of vinylidene compounds.
U.S. 2,891,050	Elverum and Ramstad	46	Treating seeds containing galactomannan polysaccharide.

Table 3. (Continued)

Patent Number	Author	Reference Cited	Title of Patent
U.S. 2,899,261	Voorhees and Scott	180	Oxidation-ingrain color emulsions for textile printing.
U.S. 2,919,802	Drake	41	Concentrating ores.
U.S. 2,937,143	Goren	62	Flocculating and settling of slimes in water.
U.S. 2,941,942	Dahlstrom and Emmett	37	Dewatering foundry sand slimes.
Brit. 834,375	Stein Hall and Co., Inc.	161	Stabilizers for galactomannan gum solutions.
Ger. 954,233	Diamalt Akt.-Ges.	40	Thickeners for dyes.
Ger. 1,005,272	Wiley	198	Suspension polymerization of vinylidene chloride.
Ind. 61,005	Patel	132	Gum.
Ind. 61,044	Patel	133	Process for obtaining gum.
Span. 234,853	Industries Cemar SA	84	Shelling of guar seeds.

Gruenhut (65) discussed, from a theoretical standpoint, fiber attraction, and polysaccharide additives such as guar gum. The writer believed that due to hydrogen bonding, a linear gum aligns itself to the cellulose molecule and is absorbed on the surface, whereas a branched gum, because of cross linking properties, is moored within the cellulose molecule as well as absorbed on the surface.

In 1959, Cushing (35) and Cushing and Schuman (36) reported investigations involving combinations of starches and natural gums as interfiber bonders. They found that when cooked starch and guar gum were used in combination, a paper of higher bursting strength was produced than when either ingredient was used alone.

Lewis and Smith (100) found by use of an electrophoretic technique that gums from guar, Kentucky coffee bean, tara, and flax were all heterogeneous. Peterson and Opie (135) obtained interesting data on the variables affecting the flocculation of silicon dioxide, ferric oxide, and bentonite slimes by nonionic hydrocolloids.

Today, there are numerous commercial guar gums on the market (151). Each is compounded for a specific use and the potential uses are expanding rapidly.

Agronomic technology concerning guar has not kept pace with its chemical counterpart. Coordinated research and the profit motive have aided the investigations on the physio-chemical properties and uses of guar gum. Agronomic technology, that is, plant breeding, genetics, and cultural practices, is largely confined to academic interests. Lack of money, uncoordinated research, and lack of well-organized interest groups have hindered its development. Furthermore, many university investigations which have been conducted have not been published. The data are hidden in unpublished theses on library shelves.

In 1933, Ayyangar and Krishnaswamy (8) published a short note which stated that the haploid chromosome number of guar was 7. Senn (153), studying chromosome relationships in the Leguminosae, hypothesized that in the tribe Galegeae, the genus Cyamopsis was derived by means of aneuploidy with subsequent sexual isolation from the genus Indigofera whose haploid chromosome number is 8. Hymowitz (unpublished data) has found that the haploid chromosome number of C. senegalensis is 7.

A monograph on the genus Cyamopsis was published in 1939 by Chevalier (29). The complete taxonomic histories and descriptions were given for the three species of the genus; C. tetragonoloba (L.) Taub., C. senegalensis Guill. and Perr., and C. stenophylla (Bonnett) Chev. In 1958, Gillett (55) concluded that Chevalier's C. stenophylla was an intermediate form of C. senegalensis and C. serrata Schinz. He preferred to maintain C. serrata as the third species and to leave unsettled the status of the intermediate forms.

Except for Sen and Vidyabhushan (152), who used colchicine to obtain tetraploid plants and their triploid and aneuploid progenies, not a single cyto-morphological investigation involving inter- or intra-specific crosses is cited in the literature. All varieties that are grown in India, Pakistan, and the United States have been developed by introduction or selection.

The lack of full time personnel concentrating solely on guar has hindered varietal development. Since 1947, 156 plant introductions have been brought into the country. Observation nurseries have been set up at Stillwater, Oklahoma and Iowa Park, Texas. The establishment of observation nurseries in Indiana, North Carolina, and South Carolina have failed because of disease organisms or other reasons.

The agronomic history of guar in the United States up to the post World War II period has been presented elsewhere. When General Mills, Inc. built their guar processing plant at Kenedy, Texas, the center of guar production was southeastern Texas. There the crop was planted following the flax harvest. Unfortunately, the rainfall pattern was not conducive to high yields. The rain frequently came before the beans could be combined, and the resulting blackened seed could not be used for manufacturing a usable gum.

The center of guar production then moved to North Central Texas and Southwestern Oklahoma where it is presently located. Here the crop is largely grown as a cash legume crop in rotation with cotton.

Numerous semi-popular articles have been published by commercial people, Soil Conservation Service personnel, and other interested individuals (50, 51, 52, 57, 58, 124, 125, 126, and 144). All extolled one or more of the following virtues of guar:

1. the crop controls wind and water erosion;
2. plants of guar are resistant to drouth;
3. the crop raises the fertility level of the soil;
4. guar plants increase the water intake and water holding capacity of the soil;
5. the crop increases yields of the following crop;
6. the protein in the beans can be used as a feed supplement for cattle; and
7. the beans can be sold as a cash crop.

However, virtues one to five have never been scientifically proven or disproven.

A number of studies have been conducted with the use of guar for feed purposes. Krantz *et al*. (98), using rats as the experimental animal, found that the nutritional efficiency of guar flour was much less than that of wheat flour but comparable to that of locust bean gum. Brochers and Ackerson (15) reported that jack bean, lentil, velvet bean, horse bean, and blackeye cowpeas were improved as sources of protein by autoclaving, while peanut, partridge pea, guar, lespedeza, mung bean, and common vetch were not improved. McIlvain (103) found rolled guar beans to be an acceptable protein supplement for wintering steer calves on grass. Arrington et al. (5) found evidence of poor growth for weanling rats when fed 40 per cent guar meal. They further commented that additional research should be undertaken to obtain more information on guar's value for various animal species.

A committee of staff members of Oklahoma State University (33) evaluated selected potential oilseed and industrial crops in Oklahoma. They estimated that under dryland conditions for Southwest Oklahoma, on a per acre basis, the return to land, labor, risk, and management for grain sorghum, sesame, and guar was 8.20, 12.88, and 8.13 dollars respectively. This report suggests that even virtue number seven may be in jeopardy.

A review of the variety and cultural studies conducted in Oklahoma from 1950 to 1959 was published by Matlock (112) in 1960. Previously, Brooks and Harvey (16) and Matlock, Aepli, and Streets (111) had published reviews of investigations conducted in Texas and Arizona, respectively. Thompson (176) studied sorghum versus sorghum - guar mixture. He found that the legume did not contribute sufficient additional protein to compensate for the reduction in forage yield which occurred in the mixed stand. Taylor and Gardner (172) surprisingly revealed that root penetration abilities of legumes (guar, hairy vetch, cowpeas, sesbania, and mungbeans) were not significantly greater than of non-legumes (cotton and sesame).

The following data are from unpublished theses deposited at the Oklahoma State University library: Williams' (199) investigation of the cultural practices in guar indicated that the mean yields of seed, forage, and protein were highest at the 20-inch row spacing and lowest at the 40-inch row spacing; Jones' (88) data showed that at a rate of four viable seed per foot, a 42-inch row produced more protein per acre and the protein content of the forage was 2.09 per cent higher than the 21-inch rows; and McMurphy (107) concluded that two pounds of 4-(2, 4-dichlorophenoxy) butyric acid per acre could be used satisfactorily as a post-emergence herbicide on fields of guar.

CHAPTER II

A STUDY OF GENETIC DIVERSITY IN THE PLANT INTRODUCTIONS OF THE GENUS *CYAMOPSIS*

The present guar production in Southwest Oklahoma and North Central Texas is only about 10 per cent of industry's needs. The rest is imported from India and Pakistan. Before acreage in this country can be greatly increased beyond the 35 inch rainfall line, the diversity in the genus must be evaluated for potentially adapted biotypes.

The object of this study was to investigate the genetic diversity of certain plant characters in the plant introductions of the genus *Cyamopsis*.

METHODS AND MATERIALS

From 1959 to 1961, all of the available plant introductions of the genus *Cyamopsis* were planted in dryland observation plots on the Agronomy Farm near Stillwater, Oklahoma (96, 110, and 113). In 1960, a duplicate nursery was grown on the Sandy Land Agronomy Research Station near Mangum, Oklahoma. Each row was 16 feet long with a 3-foot alley between rows. The rows were 40 inches apart. Approximately

100 scarified seed pre-treated with Arasan were planted in each row.

As the introductions were received, Oklahoma G Numbers[1/] were assigned to them and were recorded in the experiment station accession book. The plant introductions were numerically coded as shown in Table 1. The coding system used in this study was adapted from the investigations of Patel *et al*. (131). The introductions were coded on the following three independently inherited 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; and

1/ Oklahoma G Number is a coding system used to identify all selections and accessions of guar tested in Oklahoma.

7. Small, medium and large pods.

C. Branching habit. Introduction produced:

1. Erect (plant produces a single primary axis);
2. Erect branching (plant produces one or more branches);
3. Branching (plant produces branches throughout the primary axis;
4. Basal branching (plant produces branches at the base of the primary axis);
5. Erect and erect branching plants;
6. Erect and branching plants;
7. Erect and basal branching plants;
8. Erect branching and branching plants;
9. Erect branching and basal branching plants;
10. Branching and basal branching plants;
11. Erect, erect branching, and branching plants;
12. Erect, erect branching, and basal branching plants;
13. Erect, branching, and basal branching plants;
14. Erect branching, branching, and basal branching plants; and
15. Erect, erect branching, branching, and basal branching plants.

Other characters studied include number of leaflets per leaf, seeds per pod, seed color, leaflet surface, shape of seed, and weight of seed.

Table 1--Plant introductions of the genus <u>Cyamopsis</u>, Oklahoma G number, place of origin, year introduced, and genetic code for each introduction.

Plant Introduction	Okla. G. No.	Origin	Year Introduced	Biramose Hairs	Pod Length	Branching Habit
C. tetragonoloba						
9666		Surat, India	1903			
18641		Surat, India	1906			
18642		Surat, India	1906			
18643		Surat, India	1906			
18644		Surat, India	1906			
18645		Surat, India	1906			
18646		Surat, India	1906			
18647		Surat, India	1906			
18648		Surat, India	1906			
18649		Surat, India	1906			
18650		Surat, India	1906			
18651		Surat, India	1906			
21003		Bombay, India	1907			
21004		Bombay, India	1907			
25708		Poona, India	1909			
36549		Nagpur, India	1913			
37725		Bombay, India	1914			
43503		Mandalay, Burma	1916			
49864		Mandalay, Burma	1920			

Table 1. (Continued)

Plant Introduction	Okla. G. No.	Origin	Year Introduced	Biramose Hairs	Pod Length	Branching Habit
49899		Poona, India	1920			
49900		Poona, India	1920			
49901		Poona, India	1920			
49902		Poona, India	1920			
49903		Nagpur, India	1920			
49904		Nagpur, India	1920			
51371		Poona, India	1920			
51372		Poona, India	1920			
51373		Poona, India	1920			
51598		Surat, India	1920			
51599		Surat, India	1920			
51600		Surat, India	1920			
51601		Surat, India	1920			
51696		St. Thomas Mt., India	1920			
52785		Nagpur, India	1921			
52786		Nagpur, India	1921			
57833		Poona, India	1923			
66654		Batticotte, Ceylon	1926			
67265		Jerusalem, Palestine	1926			
114932		Teldeniya, Ceylon	1936			
114933		Bangalore, India	1936			
115462		Poona, India	1936			
115463		Poona, India	1936			
115464		Poona, India	1936			
116034	122	Jaipur, India	1936	2	2	7
116105		Bikaner, India	1936			

Table 1. (Continued)

Plant Introduction	Okla. G. No.	Origin	Year Introduced	Biramose Hairs	Pod Length	Branching Habit
124458		Ujjain, India	1937			
124562		Hyderabad, India	1937			
144324		Pusa, India	1942			
144325		Chota, Nagpur, India	1942			
144326		Sind, Punjaband, India	1942			
144327		Cawnpore, India	1942			
144328		Cawnpore, India	1942			
144989		Orissa, Cuttack, India	1942			
144990		Orissa, Cuttack, India	1942			
145103		Dacca, Pakistan, via Aust.	1932			
149404		Davis, California	1944			
154365		Beltsville, Maryland	1946			
156988		New Delhi, India	1946			
157013		Sirsa, India	1946			
157014		Sirsa, India	1946			
157015		Sirsa, India	1946			
157016		Sirsa, India	1946			
157017		Sirsa, India	1946			
157020		Kavali, India	1946			
157876		Bombay, India	1947			
158116	123	New Delhi, India	1947	2	2	7
158117		Bihar, India	1947			
158118	38	Sirsa, India	1947	2	2	3
158119	5	Sirsa, India	1947	2	2	8
158120	39	Sirsa, India	1947	2	2	3
158121	125	Sirsa, India	1947	3	2	10

Table 1. (Continued)

Plant Introduction	Okla. G. No.	Origin	Year Introduced	Biramose Hairs	Pod Length	Branching Habit
158122		Sirsa, India	1947			
158123	126	Poona, India	1947	2	2	8
158124	127	Poona, India	1947	2	2	8
158125	128	Poona, India	1947	2	2	8
158126	129	Poona, India	1947	3	2	3
158127		Poona, India	1947			
158128		Poona, India	1947			
158129	130	Poona, India	1947	2	2	12
158130		Poona, India	1947			
163103	131	Delhi, India	1947	2	2	13
163104	132	Jubbulpore, India	1947	2	2	6
164170	133	Nagpur, India	1948	2	2	13
164299	40	Coimbatore, India	1948	3	2	3
164353	96	Jubbulpore, India	1947	2	2	13
164386	97	Jakhal, India	1948	2	2	3
164420	14	Loharu, India	1948	2	2	8
164429	134	Jaipur, India	1948	2	2	3
164446	99	Chatsu, India	1948	2	2	8
164476	100	Jaipur, India	1948	2	2	11
164477	135	Jaipur, India	1948	2	2	12
164485	101	Jaipur, India	1948	3	2	3
164486	339	Jaipur, India	1948	2	2	3
164528	136	Khandar, India	1948			
164592	41	Coimbatore, India	1948	3	3	5
164593	237	Coimbatore, India	1948			
164692	291	Hubli, India	1948			
164765	102	Belgaum, India	1948	2	2	3

Table 1. (Continued)

Plant Introduction	Okla. G. No.	Origin	Year Introduced	Biramose Hairs	Pod Length	Branching Habit
164799	137	Poona, India	1948	2	2	14
164801	4	Poona, India	1948	2	2	3
165511	217	Lucknow, India	1948	2	2	6
165527	139	Malasa, India	1949	3	2	13
173897		United Provinces, India	1949			
176373	140	New Delhi, India	1949	2	2	14
176374	105	New Delhi, India	1949	2	2	3
176375	107	New Delhi, India	1949	2	2	3
176376		New Delhi, India	1949			
176377	108	New Delhi, India	1949	2	2	10
176378	109	New Delhi, India	1949	2	2	3
179682	110	Phulera and Jaipur, India	1948	2	2	3
179683	141	Pokaran and Jodpur, India	1948	2	1	3
179684	42	Marwar, India	1948	2	2	3
179685	43	Jodhpur, India	1948	2	2	10
179686	142	Ahmedabad, India	1949	2	2	14
179926	111	Sakaranpur, India	1948	2	2	10
179927		Jodhpur City, India	1949			
179928	143	Barmer, India	1949	2	2	11
179929	112	Sirohi, India	1948	2	2	10
179930	113	Posalia, India	1948	3	2	10
179931	144	Sihor, India	1949	3	2	8
180285	114	Manadir, India	1948	2	2	10
180286	222	Anandra, India	1948			
180287	146	Mount Abu, India	1949	2	2	11
180288	115	Bhavnagar, India	1949	3	2	10
180431		Abu Road, Sirohi, India	1949			

Table 1. (Continued)

Plant Introduction	Okla. G. No.	Origin	Year Introduced	Biramose Hairs	Pod Length	Branching Habit
180432	5A	Sidhpur, India	1949	1	2	3
180433	116	Ahmedabad, India	1949	2	2	10
180434	148	Rajkot, India	1949	2	2	3
182968	45	Veraval, India	1949	1	2	5
182969	117	Bhuj, India	1949	2	2	7
183129		Junagadh, India	1949			
183315	24	Jamnagar, India	1949	3	2	13
183400	6	Surat, India	1949	3	2	3
183449		Broach, India	1949			
186305		Canberra, Australia	1950			
186477	151	Coimbatore, India	1950	3	2	11
190871		Sao Paulo, Brazil	1950			
198296	152	New Delhi, India	1951	2	2	3
198297	238	New Delhi, India	1951	2	2	5
200826		Mandalay, Burma	1952			
212900		Poona, India	1953			
212986		Baroda, India	1953			
212987		Baroda, India	1954			
212988		Baroda, India	1953			
213503		Dharwar, India	1953			
214041	228	Mysore, India	1954	2	2	14
214319	159	Ferozepur, India	1954	2	2	8
214320	160	Sirsa, India	1954	2	2	8
215590	243	Hansi, India	1954	2	2	10
215591	162	Moga, India	1954	2	2	3
217923	229	New Delhi, India	1954	2	2	7
217924	292	New Delhi, India	1954	2	6	14

Table 1. (Continued)

Plant Introduction	Okla. G. No.	Origin	Year Introduced	Biramose Hairs	Pod Length	Branching Habit
217925	119	New Delhi, India	1954	3	2	11
218022		Bombay, India	1954			
223685	120	Anand, India	1955	2	2	6
223686	121	Anand, India	1955	3	2	6
236478	155	New Delhi, India	1957	3	2	13
236479	156	New Delhi, India	1957	2	2	4
250211	219	Gujrat, Pakistan	1958	2	2	10
250212	223	Gujrat, Pakistan	1958	2	2	3
250213	234	Gujrat, Pakistan	1958	2	2	10
250214	233	Gujrat, Pakistan	1958	2	2	7
250357	218	Lahore, Pakistan	1958	2	2	10
250358	293	Lahore, Pakistan	1958	2	2	3
250359	294	Lahore, Pakistan	1958	2	2	6
250360	220	Lahore, Pakistan	1958	2	2	10
253182	232	Glenn Dale, Maryland	1958	2	2	7
253183	221	Glenn Dale, Maryland	1958	2	2	7
253184	231	Glenn Dale, Maryland	1958	2	2	7
253185	230	Glenn Dale, Maryland	1958	2	2	13
253186	224	Glenn Dale, Maryland	1958	2	2	7
253187	226	Glenn Dale, Maryland	1958	3	2	10
254367	235	New Delhi, India	1958	3	2	3
254368	225	New Delhi, India	1958	2	2	3
255928	237	New Delhi, India	1959			
262149	248	Lyallpur, Pakistan	1960	2	2	4
262150	249	Lyallpur, Pakistan	1960			
262151	250	Lyallpur, Pakistan	1960	2	2	3
262152	251	Lyallpur, Pakistan	1960			

Table 1. (Continued)

Plant Introduction	Okla. G. No.	Origin	Year Introduced	Biramose Hairs	Pod Length	Branching Habit
262153	252	Lyallpur, Pakistan	1960	2	2	3
262154	253	Lyallpur, Pakistan	1960	3	2	6
262155	254	Lyallpur, Pakistan	1960	2	2	3
262156	255	Lyallpur, Pakistan	1960	2	2	13
262157	256	Lyallpur, Pakistan	1960	2	2	3
262158	257	Lyallpur, Pakistan	1960			
263406	295	Yangambi, Congo	1960	1	2	6
263698	262	Khartoum, Sudan	1960	2	2	10
263874	263	New Delhi, India	1960	2	2	3
263875	264	New Delhi, India	1960	2	2	3
263876	265	New Delhi, India	1960	2	2	3
263877	266	New Delhi, India	1960	2	2	3
263878	267	New Delhi, India	1960	2	2	12
263879	268	New Delhi, India	1960	3	2	11
263880	269	New Delhi, India	1960	2	2	14
263881	270	New Delhi, India	1960	2	2	7
263882	271	New Delhi, India	1960	2	2	3
263883	272	New Delhi, India	1960	1	3	5
263884	273	New Delhi, India	1960	3	6	11
263885	274	New Delhi, India	1960	3	2	10
263886	275	New Delhi, India	1960	2	2	11
263887	276	New Delhi, India	1960	2	2	1
263888	277	New Delhi, India	1960	1	3	15
263889	278	New Delhi, India	1960	2	2	7
263890	279	New Delhi, India	1960	3	2	10
263891	280	New Delhi, India	1960	2	2	3
263892	281	New Delhi, India	1960	2	2	3

Table 1. (Continued)

Plant Introduction	Okla. G. No.	Origin	Year Introduced	Biramose Hairs	Pod Length	Branching Habit
263893	282	New Delhi, India	1960	2	2	8
263894	283	New Delhi, India	1960	2	2	8
263895	284	New Delhi, India	1960	2	2	3
263896	285	New Delhi, India	1960	2	2	14
263897	286	New Delhi, India	1960	2	2	3
263898	287	New Delhi, India	1960	2	2	3
263899	288	New Delhi, India	1960	2	2	3
263900	289	New Delhi, India	1960	2	6	13
263901	290	New Delhi, India	1960	3	2	7
268228	337	Bahawalpur, Pakistan	1961	2	2	3
268229	338	Bahawalpur, Pakistan	1961	2	2	3
C. senegalensis						
263525	259	Bambey, Senegal	1960	2	1	3
271025	341	Bambey, Senegal	1961			
C. serrata						
279564	413	Kimberley, South Africa	1962			

RESULTS AND DISCUSSION

Plant introduction 116034 is the only one of 47 accessions available from pre-World War II introductions (Table 1). Prior to 1946, plant introductions were evaluated at a few federal and state experiment stations. Consequently, many guar introductions which were not tested in areas best suited for their growth were discarded and their seed are not available. 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 for industrial uses. Since 1947 viable seed of 77.0 per cent of the introductions of Cyamopsis have been maintained at the Oklahoma Agricultural Experiment Station, 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 (Table 2).

Biramose hairs on pods and leaves appeared in 96.0 per cent of all the introductions, while 22.2 per cent of the introductions produced glabrous plants (Table 3). Roesler (145) evaluated certain plant introductions for edibility of the green pods. She found that the glabrous pods of G-101 as judged by a taste panel were the most acceptable for human consumption. The hairs on the pods of G-40, G-135 and G-137 seemed to mask the taste of the green beans.

Table 2--Source and availability of the plant introductions of the genus *Cyamopsis*

Country	Plant Introduction Numbers		
	Available	Unavailable[a]	Total
India	100	78	178
Pakistan	17	4	21
Burma	0	3	3
Ceylon	0	2	2
Palestine	0	1	1[b]
Senegal	2	0	2
Congo	1	0	1
Sudan	1	0	1
South Africa	1	0	1
Australia	0	1	1[b]
Brazil	0	1	1[b]
United States	6	2	8[b]
Total	128	92	220

a/ The seed of the introductions were lost; when planted, they did not germinate or they arrived in Stillwater too late for the 1961 planting.

b/ These secondary introductions were apparently introduced from an unknown source.

Table 3--Summary of data on the absence or presence of Biramose hairs in the plant introductions of the genus Cyamopsis.

Biramose Hairs	Number of Introductions Containing Character(s)
Absent	5
Present	98
Mixed	23
Total	126

The frequency of medium, large, and small size pods present in the introductions was 96.0, 4.8, and 1.6 per cent, respectively (Table 4). *C. senegalensis* (G-259) and G-141 produced small pods. Based on comparative morphology, G-141 suggests an intermediate form between *C. tetragonoloba* and *C. senegalensis.*

Branching plants appeared in 82.5 per cent of all the introductions, while the frequency of basal branching, erect, and erect-branching plants present in the introductions was 41.3, 35.7, and 27.0 per cent, respectively (Table 5).

Table 4--Summary of data on pod size in the plant introductions of the genus Cyamopsis.

Pod Size	Number of Introductions Containing Character(s)
Small	2
Medium	118
Large	3
Small and medium	0
Small and large	0
Medium and large	3
Small, medium, and large	0
Total	126

Table 5--Summary on branching habit in the plant introductions of the genus Cyamopsis.

Branching Habit	Number of Introductions Containing Character(s)
E[a]	1
Eb[b]	0
B[c]	43
Bb[d]	2
E and Eb	4
E and B	7
E and Bb	12
Eb and B	11
Eb and Bb	0
B and Bb	18
E, Eb, and B	8
E, Eb, and Bb	3
E, B, and Bb	9
Eb, B, and Bb	7
E, Eb, B, and Bb	1
Total	126

a/ E = erect

b/ Eb = erect branching

c/ B = branching

d/ Bb = basal branching

Other characters studied were:

1. Leaflets per leaf. The usual number of leaflets per leaf is three. However, in 1959, a vegetative branch of G-132 produced four leaflets per leaf and a vegetative branch of G-156 produced five leaflets per leaf.

2. Seed per pod. The number of mature seed per pod ranges from five to eleven. In the summer of 1961, a pod of G-272 was found to contain 12 fully grown mature seed (Figure 1). This pod was the first of its kind to appear in an examination of approximately 35,000 pods.

3. Seed color. Depending on environmental conditions, seed of guar are usually colored from dull white to dark grey. In 1960, on the Sandy Land Research Station, plants from G-117, G-118, and G-128 were found to contain yellow colored seed. In 1961, a plant of G-117 was found to contain pink colored seed.

4. Rough leaflet surface. Occasionally a rough leaflet will appear in a normal smooth-leaved plant. Perhaps, these plants are carriers of a virus as described by Chester (28).

5. Shape of seed. According to Saber *et al*. (148) seed of *C. tetragonoloba* are "rhomboidal and flattened in shape varying from 4 to 6 mm. in length, 3 to 5 mm. in breadth, and 1 to 2 mm. in thickness." Seed of *C. senegalensis* are ridged and barrel-shaped.

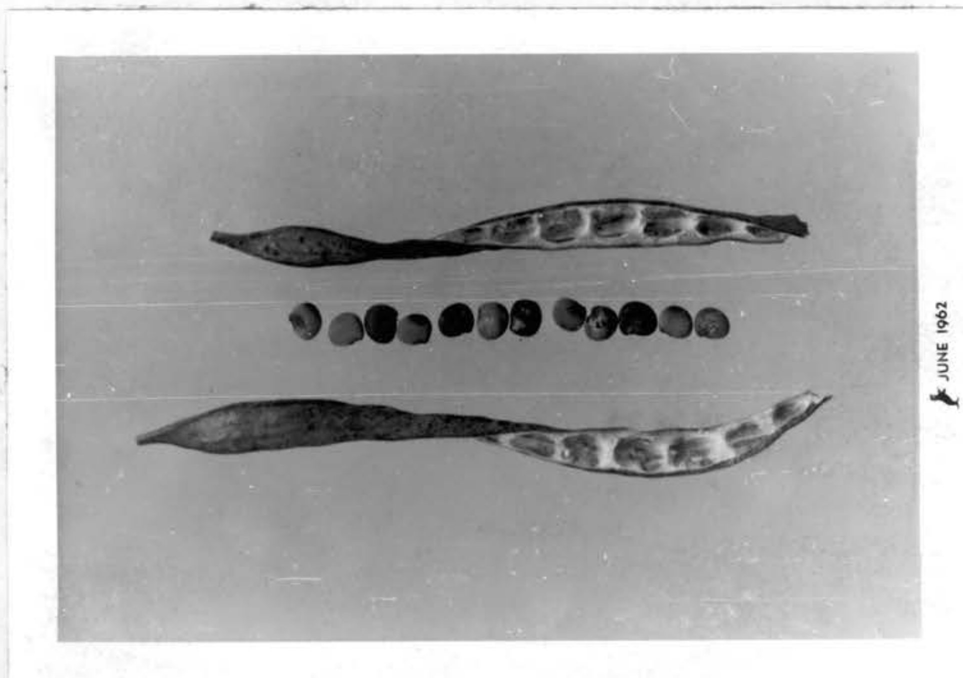

Figure 1. Pod and 12 Seed of G-272.

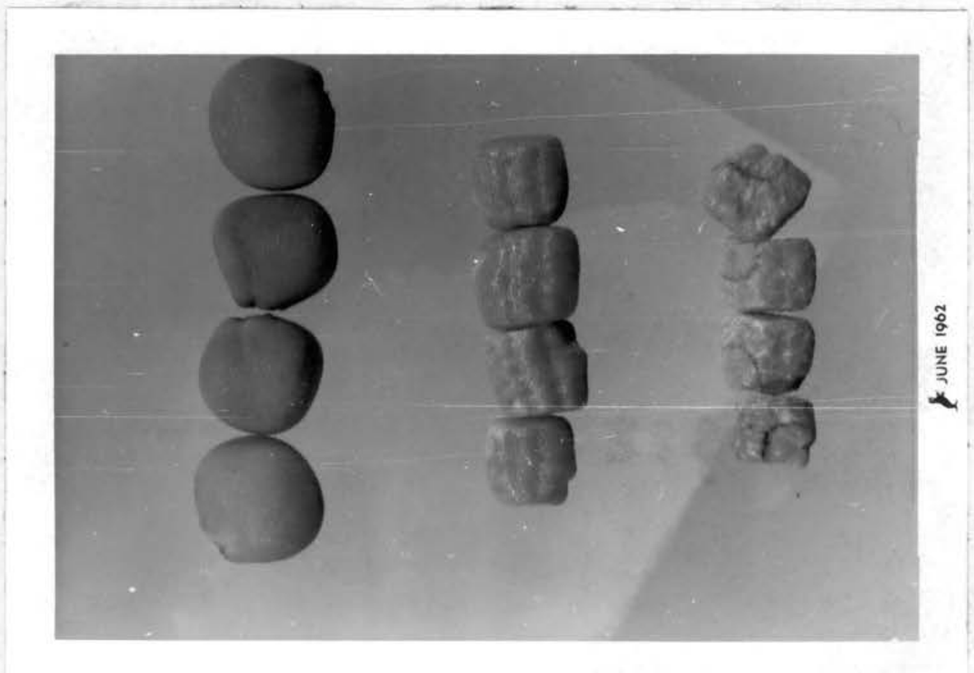

Figure 2. Seed of the Genus Cyamopsis. Left to Right are C. tetragonoloba, C. senegalensis and C. serrata. Approximately 5X.

They are about 3 mm. in length, 3 mm. wide, and 2 mm. thick. Seed of C. serrata are irregularly rhomboidal and contain a red line around the periphery of the hilum. They are about 2 mm. in length, 2 mm. wide, and 1.5 mm. thick. The seed of the species are shown visually in Figure 2.

6. Weight of seed. Matlock (112) reported that the weight of 100 seed of C. tetragonoloba varies from 2.3 to 5.0 grams. Seed of C. senegalensis and C. serrata weigh approximately 1.8 and 0.9 grams per 100 seed, respectively.

As calculated from Table 2, 78.1 per cent of all the available introductions are from India. Furthermore, the greatest proportion of the introductions are from the states of Gujerat, Maharashtra, Punjab, and Rajasthan of western India. In these states, and throughout India and Pakistan, the species has many colloquial names. This can be attributed to the multitudinous dialects and languages of the region.

The colloquial names are listed below in alphabetical order: Bakuchi, bhatmas, buru raher, chari, chivali kaj, cluster beans, dararhi, darari, dararu, darera, dareri, gauri, gawar, gawarfulli bean, gorchikudu, goreekaye, gouare, gowar, gowas, gualin, guar, guara, guar kiphali, guar-phali, gura, guvar, guwar, kachhur, kauri, khulti, khurti, kotaveri, kothaveray, kulti, kuwara mutki, pai-pazoon, phaligwar, ramdana, salna, Siam bean, syansundari, and wawa (38, 39, 83, 122, 131, and 134).

Vavilov (178) believed that the geographic center of variability of guar was India. This concept holds true today. However, several writers (53, 99, 137, 147, 165, and 179) have interpreted this to mean that geographic center of variability is the same as the center of origin or "native to India." Guar is unknown in the wild state, but the two related species, C. senegalensis and C. serrata are found in the wild state in Tropical Africa (29 and 55).

Chevalier (29) postulated that C. senegalensis is the ancestral form of guar. "Formerly the area for C. senegalensis extended to Sind, and it is there that it had been domesticated and given the cultigen forms which entered the Indian agriculture and are scattered today over a large part of Tropical Asia", he noted. Gillette (55) postulated that South Tropical Africa was the center of origin. His views are based on the geographical distribution of the wild species. The confusion as to the center of origin is due to the lack of experimental evidence and accurate historical documentation of the colonization and trading routes of man between Africa and Asia.

CONCLUSION

Since 1946, viable seed of 77.0 per cent of all the plant introductions of the genus *Cyamopsis* 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 center of genetic diversity.

The introductions were classified according to three independently inherited characters; absence or presence of biramose hairs, pod length, and branching habit. Biramose hairs, medium length pods, and branching plants appeared in 96.0, 96.0, and 82.5 per cent, respectively, of the introductions evaluated.

C. tetragonoloba has approximately 44 colloquial names in the Indo-Pakistan region. Guar, a Sanskritean word, is the most widely used colloquial name.

CHAPTER III

COMPETITION STUDIES IN 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 (16) found that guar plants have the ability to adapt themselves to a wide range of spacings. Matlock, Aepli, and Streets (111) reported that higher mean yields for Mesa variety of guar were obtained from 7-inch and 12-inch spacings than from 24- or 36-inch spacings. Investigations by Williams (199) suggested that the mean seed yield of Groehler and Plant Introduction[1/] 164801

1/ Plant Introduction Number is abbreviated P.I.

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 relationship between weight of pod, weight of seed in pod, pod length, and number of seed in 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 Dougherty fine sandy loam, located on the Paradise Agronomy Research Station, five and one-half miles northeast of Coyle, Oklahoma. 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 three 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 base 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 20, 30, and 40 inches between rows. The population rates were three, six, and nine viable seed per foot of row (Table 1).

Table 1--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
		9
	40	3
		6
		9

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 pod, pod length, and number of seed in the pod. The rest of the pods in the bags were threshed and weighed.

Mr. William Gurley, a graduate student in the Statistics Department of Oklahoma State University, designed a program 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 per cent, 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 response for the significant treatment main effects were evaluated as presented by Snedecor's (157) orthogonal comparisons. The means of each significant treatment main effect were analyzed according to Duncan's new multiple range test (42).

RESULTS AND DISCUSSION

Mean squares of the eight characters measured are presented in Tables 2, 11, and 21. 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 2). The spacing treatment exhibited a linear response and was significant at the one per cent confidence level.[2/] On the average, plant height decreased as the distance between rows decreased. The standard deviation and the coefficient of variation were 11.75 cm. and 11.79 per cent, respectively.

2/ Probability levels will be expressed at the one per cent confidence level unless otherwise stated.

Table 2--Mean Squares for plant height, number of branches, and total number of pods for the guar competition study, 1960.

Source of Variation	DF	Mean Squares: Plant Height (cm)	Mean Squares: Number of Branches	Mean Squares: Total Number of Pods
Total	242			
P.W.E.U.[a]	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**	252,955**
Quadratic	1		9.98*	61,750**
V. x S.	4	36	6.00*	11,892*
V. x S.L.	2		10.64**	9,313
V. x S.Q.	2		1.94	14,536*
V. x P.	4	183	3.00	6,087
S. x P.	4	174	1.50	15,104*
S.L. x P.L.	1			23,856*
S.L. x P.Q.	1			691
S.Q. x P.L.	1			35,783**
S.Q. x P.Q.	1			92
V. x S. x 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

a/ P.W.E.U. = Plants within experimental units.
* Indicates significance at the five per cent level.
** Indicates significance at the one per cent level.

The mean plant height for Texsel was significantly taller than for plants of P. I. 164801 or Groehler. There were no significant differences between P. I. 164801 and Groehler (Table 3).

Table 3--Multiple range test for the effect of competition on the mean plant heights in cm. of three varieties of guar.

Varieties	P.I. 164801	Groehler	Texsel
Means in cm.[a]	90.26	92.64	115.95

a/ Any two means underscored by the same line are not significantly different at the one per cent level.

The mean heights for plants grown at 20-, 30-, and 40-inch row spacings were 94.57, 101.63, and 102.65 cm., 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 4).

Table 4--Multiple range test for the effect of competition on the mean plant height in cm. of three spacings of guar.

Spacing in Inches Between Rows	20	30	40
Means in cm.[a]	94.57	101.63	102.65

a/ Any two means underscored by the same line are not significantly different at the one per cent level.

<u>Number of Branches</u>: As noted in Table 2, varieties, spacings, and population rates 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 per cent, respectively.

The mean number 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 5).

Table 5--Multiple range test for the effect of competition on the number of branches of three varieties of guar.

Varieties	Texsel	Groehler	P.I. 164801
Means[a]	0.28	2.44	10.83

a/ Any two means underscored by the same line are not significantly different at the one per cent level.

The mean number of branches for plants grown at 20-, 30-, and the 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 number of branches for plants grown at the 20- and 40-inch rows were significantly different (Table 6).

Table 6--Multiple range test for the effect of competition on the number of branches of three spacings of guar.

Spacing in Inches Between Rows	20	30	40
Means[a/]	4.11	4.54	4.90

a/ Any two means underscored by the same line are not significantly different at the one per cent level.

As presented in Table 7, 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. Further data on the effect of spacing on the branching of Texsel is presented in Chapter 5.

Table 7--Multiple range test for the effect of competition on the number of branches of three populations of guar.

Population in Seed Per Foot	6	9	3
Means[a/]	4.23	4.30	5.02

a/ Any two means underscored by the same line are not significantly different at the one per cent level.

Total Number of Pods: The total number of pods was affected by varieties, spacings, and population rates. The spacing treatments indicated a linear response while the population rate treatments displayed significant linear and quadratic responses. The variety x spacing interaction was significant at the five per cent level and was due to a quadratic response. The first order interaction of spacing x population was significant at the five per cent confidence level. This was due to a spacing linear x population linear and spacing quadratic x 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 per cent, respectively.

The mean number 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 number of total pods of plants from P. I. 164801 and Groehler (Table 8).

Table 8--Multiple range test for the effect of competition on the total number of pods of three varieties of guar.

Varieties	Texsel	P.I.164801	Groehler
Means[a/]	99.74	132.05	143.09

a/ Any two means underscored by the same line are not significantly different at the one per cent level.

The mean number of total pods from plants grown at 20-, 30-, and 40-inch row spacings were 91.53, 125.83, and 157.51, respectively (Table 9). The three treatments were significantly different from one another.

Table 9--Multiple range test for the effect of competition on the total number of pods per plant for three spacings of guar

Spacing in Inches Between Rows	20	30	40
Means[a]	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 10).

Table 10--Multiple range test for the effect of competition on the total number of pods per plant for three populations of guar.

Population in Seed Per Foot	9	6	3
Means[a]	96.72	102.41	175.75

a/ Any two means underscored by the same line are not significantly different at the one per cent level.

Number of Mature Pods: As presented in Tables 11, 12, 13, and 14, the number of mature pods exhibited a similar response in direction and magnitude as 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.

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

Weight of Mature Pods: Varieties, spacings, and populations affected the weight of mature pods (Table 11). It was found that the spacing treatments gave a linear response. The population rate treatments indicated both linear and quadratic responses. The variety x spacing interaction was significant at the five per cent confidence level and this significance can be attributed to a variety x spacing quadratic response. At the five per cent confidence level, the variety x spacing interaction was significant. This was due to a spacing linear x population linear and spacing quadratic x population linear response. The standard deviation and coefficient of variation were 23.45 grams and 56.62 per cent, respectively.

The mean weight of mature pods of plants of Texsel were significantly lower than plants of P.I. 164801 or Groehler (Table 15).

As noted in Table 16, 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

Table 11--Mean squares for the number of mature pods, total weight of mature pods, and total weight of seed of the guar competition study, 1960.

Source of Variation	DF	Number of Mature Pods	Weight of Mature Pods	Weight of Seed From Mature Pods
Total	242			
P.W.E.U.[a]	162	2,355	314	119
Replications	2	44,796**	4,573**	1,876**
Treatments	26	26,828**	3,580**	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. x S.	4	11,042*	1,689*	664*
V. x S.L.	2	8,462	1,378	575
V. x S.Q.	2	13,619*	2,001*	752*
V. x P.	4	5,466	464	183
S. x P.	4	13,328*	1,489*	566*
S.L. x P.L.	1	18,541*	2,363*	828*
S.L. x P.Q.	1	1,338	214	67
S.Q. x P.L.	1	33,429**	3,378*	1,368*
S.Q. x P.Q.	1	3	1	<1
V. x S. x 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

a/ P.W.E.U. = Plants within experimental units.
* Indicates significance at the five per cent level.
** Indicates significance at the one per cent level.

Table 12--Multiple range test for the effect of competition on the number of mature pods per plant for three varieties of guar.

Varieties	Texsel	P.I. 164801	Groehler
Means[a/] in cm.	94.73	122.78	135.27

Table 13--Multiple range test for the effect of plant competition on the number of mature pods per plant for three spacings of guar.

Spacing in Inches Between Rows	20	30	40
Means[a/]	86.40	118.33	147.56

Table 14--Multiple range test for the effect of competition on the number of mature pods per plant for three populations of guar.

Population in Seed Per Foot	9	6	3
Means[a/]	91.67	96.36	164.26

Table 15--Multiple range test for the effect of plant competition on the weight of mature pods per plant for three varieties of guar.

Varieties	Texsel	P.I. 164801	Groehler
Means[a/] in grams	31.15	45.30	47.77

a/ Any two means underscored by the same line are not significantly different at the one per cent level.

Table 16--Multiple range test for the effect of plant competition on the weight of mature pods per plant for three spacings of guar.

Spacing in Inches Between Rows	20	30	40
Means[a/] in Grams	29.84	41.64	52.73

Table 17--Multiple range test for the effect of plant competition on the weight of mature pods per plant for three populations of guar.

Population in Seed Per Foot	9	6	3
Means[a/] in Grams	32.09	34.22	57.91

Table 18--Multiple range test for the effect of plant competition on the weight of seed per plant from three varieties of guar.

Varieties	Texsel	P.I. 164801	Groehler
Means[a/] in Grams	20.71	29.26	30.33

Table 19--Multiple range test for the effect of competition on the weight of seed from mature pods per plant for three spacings of guar.

Spacing in Inches Between Rows	20	30	40
Means[a/] in Grams	19.36	26.85	34.08

a/ Any two means underscored by the same line are not significantly different at the one per cent level.

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 17).

Weight of Seed From Mature Pods: As noted in Tables 11, 18, 19, and 20, 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 20--Multiple range test for the effect of plant competition on the weight of seed from mature pods per plant for three populations of guar.

Population in Seed Per Foot	9	6	3
Means[a/] in Grams	20.96	22.51	36.82

(In the original, a single line underscores 20.96 and 22.51, and 36.82 is underscored separately.)

a/ Any two means underscored by the same line are not significantly different at the one per cent level.

Per Cent Mature Pods: Varieties affected per cent mature pods (Table 21). This was the only character studied that was not influenced by either spacing or population. By size of variance, varieties seemed to account for the greatest effect. As indicated in

Table 21--Mean squares for the per cent mature pods and threshing percentage of guar competition study, 1960.

Source of Variation	DF	Mean Squares: Per cent Mature Pods	Mean Squares: Threshing Per cent
Total	242		
P.W.E.U.[a]	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. x S.	4	8.32	54.07
V. x P.	4	21.52	41.40
S. x P.	4	42.43	39.14
V. x S. x P.	8	46.22	31.59
Error	52	33.62	22.77
Standard Deviation		5.79	4.78
C. V. %		6.14	7.30

a/ P.W.E.U. = Plants within experimental units.
* Indicates significance at the five per cent level.
** Indicates significance at the one per cent level.

Table 22, the mean per cent mature pods of P.I. 164801, Texsel, and Groehler were 92.73, 94.73, and 95.55 per cent, respectively.

Threshing Per Cent: The threshing per cent was affected by varieties and population rates (Table 21). The population rates exhibited both linear and quadratic responses at the five per cent confidence level. The standard deviation and coefficient of variation were 4.78 per cent and 7.30 per cent, respectively.

The mean threshing percentage for pods from plants of Groehler, P.I. 164801, and Texsel were 64.10, 65.25, and 67.18 per cent, respectively. There were no differences between plants of Texsel and P.I. 164801 and between Groehler and P.I. 164801. The threshing percentage between plants of Texsel and Groehler were significantly different (Table 23).

As noted in Table 24, plants grown at the three seed per foot population had significantly higher threshing percentages than those grown at the nine seed per foot treatment.

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 25).

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

Varieties	P.I. 164801	Texsel	Groehler
Means[a/] in Per cent	92.73	94.73	95.55

Table 23--Multiple range test for the effect of competition on the threshing percentage per plant for three varieties of guar.

Varieties	Groehler	P.I. 164801	Texsel
Means[a/] in Per cent	64.10	65.25	67.18

Table 24--Multiple range test for the effect of competition on the threshing percentage per plant for three populations of guar.

Populations in Seed Per Foot	9	6	3
Means[a/] in Per cent	64.08	65.92	66.54

a/ Any two means underscored by the same line are not significantly different at the one per cent level.

The response of the plants from 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 25--Range of correlation values among weight of pod, weight of seed in pod, pod length, and number of seed in pod.

Character	Weight of Pod	Weight of Seed	Pod Length	Number of Seed
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				1.00

** Indicates significance at the one per cent level.

CONCLUSION

Three varieties of guar were grown in three spacings of 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, per cent mature pods, and threshing per cent.

Regardless of competition, Texsel had the tallest plants, and except for per cent mature pods and threshing percentage, had significantly lower values when compared to 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 than P.I. 164801.

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

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

CHAPTER IV

STUDIES ON SEEDCOAT COLOR

A. VARIATIONS IN SEEDCOAT COLOR OF GROEHLER GUAR--GENETIC OR ENVIRONMENTAL?

In establishing guar as a cash crop, several important agronomic problems arise. One problem concerns gradations in seedcoat color, ranging from black to dull white. Guar gum processing companies prefer seed with a light-colored unwrinkled seedcoat. Musil (121) noted that the proportion of black seed varies from year to year and was believed to be due to frost.

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

METHODS AND MATERIALS

In the fall of 1959, a portion of a border row of Groehler variety surrounding the guar variety test on the Sandy Land Agronomy Research Station near Mangum, Oklahoma, 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 1000 grams was separated into four groups based on the light reflectance of the seedcoat[1/] (Table 1).

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

The plants were harvested in November, 1960. Approximately 750 grams of seed from each row were individually separated into the 4 original seedcoat reflectant categories.

RESULTS AND DISCUSSION

The data reported in Table 1 indicate that it is futile to select plants on the basis of seedcoat colors that vary from black to dull white. Similar percentages of seedcoat reflectance categories were obtained from each parental category. However, the proportion of seed in each light reflectance category varied between 1959 and 1960. These results agree with the observations of Musil (121).

CONCLUSION

The variation in seedcoat color for Groehler guar appears to be environmentally controlled. The specific

---

1/ The seed were separated by the Electric Sorting Machine Company, Houston, Texas.

Table 1--Percentage and color of guar seed separated by light reflectance of the seedcoat in 1959 and percentage of each group in progeny grown in 1960 from original seed separates.

Components By % Light Reflectance	Original Seed		Mixed Seed	Reflectance of 2nd Generation Progeny Seedcoats		
	Per Cent	Color	%	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
Total	100.00		99.9	100.00	100.00	99.9

environmental factor or factors causing the seed to darken was not determined in this experiment.

B. THE EFFECT OF TEMPERATURE, THE LIGHT REFLECTANCE OF THE SEEDCOAT, AND SCARIFICATION OF THE SEED ON THE GERMINATION OF GROEHLER GUAR.

Musil (121) reported that 86° F. constant was the most satisfactory temperature to germinate guar. However, she did not separate the dark seedcoats from the light-colored ones.

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 Section A of this chapter. A General Electric refrigerator 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°F., 70°F., 80°F., and 90°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 and multiple range tests are presented in Tables 2, 3, and 4.

Table 2--Analysis of variance of the effect of temperature and the light reflectance of the seedcoat on the 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 per cent level.

Table 3--Multiple range test of the effect of temperature on the per cent germination of Groehler guar.

Temperature in F.°	60	70	80	90
Means[a/] in per cent	23.4	80.8	89.3	97.3

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

Table 4--Multiple range test of the effect of light reflectance of the seedcoat on the per cent germination of Groehler guar.

		Light Reflectance Categories			
Seedcoat Categories		55-75%	Mixed Seed	35-55%	Below 35%
Means a/ in per cent	1%	62.9	73.9	74.9	78.9
	5%				

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

RESULTS AND DISCUSSION

At the one per cent 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. Moreover, as measured by Duncan's multiple range test (42), there was a significant difference in germination at the one per cent level of significance among per cent germination at the various levels. At the same confidence level, the 55-75 per cent light reflectant seedcoats were significantly inferior in germination than the other seedcoat categories. The germination means at the various temperatures fit a quadratic curve.

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°F. or above.

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 laboratory germinations, the dark-colored seed germinate equally as well as light-colored seed.

Dark-colored seed appear to be scarified by nature while light-colored seed retain the hard seedcoat. To determine the effect of scarification on light grey seed (55-75% light reflectance) when germinated at 70°F, seed were scarified for five minutes using a modified Hamilton Beach mixer with a rheostat setting on 40. Results were as follows:

	Germinated Seed per cent	Hard Seed per cent
Unscarified Seed	75.5	24.5
Scarified Seed	92.8	7.2

Scarifying the seedcoat increased the mean germination percentage 17.3 per cent and reduced hard seed to 7.2 per cent. Musil (121), using dilute sulfuric acid as the scarifying agent, obtained similar results. In the event of a cool season, scarification may insure the farmer against poor stands.

CONCLUSION

The data indicate that light or dark-colored seed should be acceptable for planting when planted at 70°F. or higher. Since the guar gum processing companies require 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.

C. THE INFLUENCE OF THE LIGHT REFLECTANCE OF THE SEEDCOAT ON SEEDLING EMERGENCE AND ON THE RATE OF GROWTH OF GROEHLER GUAR DURING THE GROWING SEASON.

The previous two sections dealt with 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 per cent reflectant group used in section B.

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. Each day from June 13 to June 26 and once again on July 10, emergence counts were taken.

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 to September 11.

RESULTS AND DISCUSSION

As shown in Table 5, the 55 to 75 per cent 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 per cent 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 per cent) was on June 16 in the scarified seed treatment. The below 35 per cent 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.

Table 5--Influence of the light reflectance of the seedcoat on per cent germination.

Date	Mixed Seed	Categories of Light Reflectant Seedcoats: Below 35%	35-55 %	55-75 %	Scarified 55-75%
		Per cent 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	45.6	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

As presented in Table 6, 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 6--Mean plant height in centimeters of each category of light reflectant seedcoats during the growing season.

Date		Mixed Seed	Categories 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

CONCLUSION

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", the opposite results were obtained in the field. However, once a seedling has started to develop, its seedcoat color is 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.

CHAPTER V

AN INVESTIGATION ON THE BRANCHING HABIT OF TEXSEL VARIETY OF GUAR

Texsel variety of guar was developed by closely roguing plant introduction 116034 for an erect primary axis type that matures in 125 - 135 days and for prolific seed yield (16). Since 1946, when the variety was released, there has been much controversy over the single basal branch that occurs in 15 to 20 per cent of the plants. The certification of the variety was delayed for a few years in Texas because of the apparent "off type" plants in certification fields.

The object of this investigation was to determine whether the single basal branch in Texsel was a genetic or environmental phenomenon.

METHODS AND MATERIALS

In the summer of 1960, an investigation concerning the branching habit of guar was conducted on the Agronomy Farm near Stillwater. Among the types of guar planted was a single row consisting of nine seed from a single pod of Texsel. The plants were spaced 18 inches by 40 inches. In September, six plants of the original nine seed planted matured. Four plants were of the erect primary axis type, while two plants had an erect primary axis with a single basal branch. These types are shown visually in Figure 1. The pods of each plant were harvested, threshed and maintained separately for planting in 1961.

In 1961, the seed from the branched and non-branched parents were planted on the Agronomy Farm at the normal seeding rate of 2.5 inches between seed in the row and 40 inches between rows, and at a wide spacing rate of 42 inches between seed in the row and 40 inches between rows.

RESULTS AND DISCUSSION

As presented in Table 1, the percentage of branching at the wide spacing rate of non-branching parents was 17.6 compared to 16.3 of the branching parents. Therefore, the data indicate that branching and non-branching plants of Texsel are genetically alike insofar as this morphological character is concerned. Furthermore, as evidenced by the reduced percentage of branching at the normal spacing rate, branching is a physiological expression which is directly related to plant competition. Unpublished data by Mr. L. E. Brooks of Substation 16, Iowa Park, Texas, verify these findings.

The nine branching progeny of N. B. Parent 2 grown

Figure 1. Two types of growth habit of Texsel variety of guar. (A) An erect primary axis with a single basal branch; (B) An erect non-branched primary axis.

Table 1--The effect of spacing rate on the percentage of branching and non-branching parents of Texsel variety of guar.

	Wide Spacing			Normal Spacing		
Parents	N. B.[a/] Progeny	B.[b/] Progeny	% B.	N. B. Progeny	B. Progeny	% B.
N. B. Parent 1	38	7		45	2	
N. B. Parent 2	32	12		37	9	
N. B. Parent 3	45	8		35	2	
N. B. Parent 4	25	3		42	3	
Mean No. of Plants	35.0	7.5	17.6	39.5	4.0	9.1
B. Parent 1	44	4		40	1	
B. Parent 2	28	10		50	2	
Mean No. of Plants	36.0	7.0	16.3	45.0	1.5	3.2

a/ N. B. = Non-Branching

b/ B. = Branching

at the normal spacing rate can be explained by a lack of even stand in the planted row. This resulted in reduced competition among the plants.

CONCLUSION

Evidence is presented to support the thesis that it is futile to rogue basal branched plants in fields of Texsel. This morphological character is directly related to plant competition rather than to allelic heterozygosity.

CHAPTER VI

DETERMINATION OF THE CRITICAL POINT FOR X-RAY DOSAGE OF DORMANT SEED OF GUAR

Irradiation of plant material for increasing genetic variability may be desirable where the conventional techniques of introduction, selection, and hybridization are difficult to use (97). Rawlings, Hanway, and Gardner (141) reported that irradiation of Adams and Hawkeye soybeans with X-rays and thermal neutrons substantially increased the genetic variability for yield, plant height, maturity, and seed size. Williams and Hanway (200) found significant differences in oil and protein content of R_2 progenies of irradiated Adams and Hawkeye soybeans. Gregory (64) observed that irradiated Virginia Bunch peanuts had approximately four times the genetic variance of the control group.

At present, the only available means for developing new varieties of guar are by introduction and selection. Guar plants have very small purplish flowers produced in axillary racemes which are difficult to manipulate for hybridization experiments. Until hybridization techniques are known, irradiation of seed may serve as an excellent tool for increasing genetic variance in a given guar line. Before studies with guar can be conducted, the optimum irradiation dosage levels must be determined.

The object of this investigation was to find the critical point or the LD_{50} of guar, the dosage where approximately 50 per cent of the seed germinate and survive four weeks of growth.

METHODS AND MATERIALS

Groehler variety of guar was used as the experimental material. The variety resulted from a single plant selection in a field of Texsel guar grown near Mesa, Arizona (16). Texsel was developed by roguing plant introduction 116034. United States Department of Agriculture plant explorer Walter N. Koelz collected the seed of accession 116034 from Jaipur, India in 1936.

During the winter of 1959, air-dry seed of Groehler guar were X-ray irradiated at the 5,000, 10,000, 20,000, and 40,000r levels at the rate of 7,500r per hour. On March 7, 1960, 50 seed of each treatment plus an unirradiated control were planted singularly in 200 ml. paper Dixie cups that were filled with a soil - peat moss mixture. A small hole was punched through the bottom of the cups to permit aeration and drainage. The cups were placed in the greenhouse and arranged in a complete randomized design. Emergence counts were made once a week starting March 14 and continued for four consecutive weeks (Table 1).

Table 1--Comparison of the mean number of plants of Groehler guar that emerged and survived, for a control and four X-ray radiation treatments.

Treatment	Number of Plants Surviving at Various Dates			
	March 14	March 21	March 28	April 4
Control	31	40	37	38
5,000r	30	37	30	31
10,000r	26	34	31	31
20,000r	33	37	32	31
40,000r	33	30	24	22

RESULTS AND DISCUSSION

If the mutation frequency increases up to the LD_{50}, then the optimum number of mutations should be obtained with a dosage at approximately 40,000r. At this level a LD_{42} was obtained (Table 2).

Table 2--The lethal dosage of radiation received by guar seed at the end of the fourth week.

Treatment	Lethal Dosage[a/] per cent
Control	
5,000r	18
10,000r	18
20,000r	18
40,000r	42

a/ Lethal Dosage = $\left(1 - \frac{\text{Treatment Plant Survival}}{\text{Control Plant Survival}}\right)(100)$

Gregory (64) reported that the optimum dosage level for peanuts was between 10,000 to 20,000r. Gustaffson (66) found the critical point was 5,000 to 10,000r for common peas, 10,000r for field beans, and 5,000 to 7,500r for soybeans. Apparently the common cultivated legumes have different critical points.

In the summer of 1961, on the Agronomy Research Station near Perkins, a branch of an R_2 plant of the 40,000r dosage level was found to have developed "dubbed pods". These pods had wrinkled surfaces and contained only two to three seed. The normal Groehler pod has a smooth surface and the pod contains eight to nine seed.

Chevalier (29) suggested that *C. senegalensis* might be the ancestral form of guar, *C. tetragonoloba.* Furthermore, he believed that selection and domestication by man of *C. senegalensis* had given rise to the cultigen forms which are now grown throughout the Indo-Pakistan region. To test this hypothesis, seed of *C. senegalensis* should be irradiated and the subsequent mature plants analyzed for increased genetic variance and for gross morphological mutations which suggest directional changes to *C. tetragonoloba.*

CONCLUSION

Irradiating seed of outstanding varieties of guar and selecting the most favorable lines is offered as an alternative until the time that hybridization techniques become available for varietal improvement. Air-dry seed of guar should be irradiated at approximately 40,000r to obtain the optimum number of mutations per radiation dosage.

LITERATURE CITED

1. Ahmed, Z. F. and Whistler, R. L. The structure of guaran. J. Am. Chem. Soc. 72:2524-2525. 1950.

2. Anderson, Edgar. Guar and jaguar. Herbarist 20:9-10. 1954.

3. Anderson, Ernest. Endosperm mucilages of legumes: occurance and composition. Ind. Eng. Chem. 41:2887-2890. 1949.

4. Anker, C. A. (to General Mills, Inc.). Improving mannan-type gums. U.S. 2,834,774. 1958.

5. Arrington, L. R., Jeffords, T. H., and Wagner, S. Preliminary observations on guar seed meal - a potential protein supplement. Florida Ag. Exp. Sta. Animal Husbandry Mim. Ser. 55:1-4. 1955.

6. Atwood, G. E. and Bourne, D. J. Process development and practice of the potash division of the Duval Sulfur and Potash Co. Mining Eng. 5:1099-1103. 1953.

7. ________________. (to Duval Sulphur and Potash Co.). Flotation of sylvite ore. U.S. 2,696,912. 1953.

8. Ayyangar, G. N. and Krishnaswamy, N. A note on the chromosome numbers in cluster beans, Cyamopsis psoraloides DC. Indian J. of Agr. Sci. 3:934-935. 1933.

9. Bandel, D. (to International Cigar Machine Co.) Water-resistant tobacco sheet material. U.S. 2,769,734. 1956.

10. Bessey, E. A. Root knot and its control. USDA Bur. Pl. Ind. Bull. 217:14. 1911.

11. Binford, E. E. Progress report, substation number 1. Beeville, Texas 1910-1914. Texas Agr. Exp. Sta. Bull. 214:14. 1917.

12. Blizzard, W. L. Oklahoma Agricultural Experiment Station Biennial Report, July 1, 1942 to June 30, 1944. p. 25. 1944.

13. Briggs, I. A. Guar - a new crop in Arizona. Agr. Leaders Dig. 25:12-14. 1944.

14. ______________ Guar - a summer growing legume in Arizona. Seed World. 55:9. 1944.

15. Brochers, R. and Ackerson, C. W. The nutritive value of legume seeds. X. Effect of autoclaving and the trypsin inhibitor test for 17 species. J. Nutrition 41:339-345. 1950.

16. Brooks, L. E. and Harvey, C. Experiments with guar in Texas. Texas Agr. Exp. Sta. Circ. 126:1-10. 1950.

17. Brown, A. D. High polymeric addition agents; their relation to the physical properties of pulp and paper. Proc. Australian Pulp Paper Ind. Tech. Assoc. 3:121-140. 1949.

18. Burgess, P. S. Forth-fifth annual report for the year ending June 30, 1934. Univ. Ariz. Agr. Exp. Sta. p. 39. 1934.

19. ______________ Fifty-second annual report for the year ending June 30, 1941. Univ. Ariz. Agr. Exp. Sta. pp. 35-36. 1942.

20. ______________ Fifty-third annual report for the year ending June 30, 1942. Univ. Ariz. Agr. Exp. Sta. p. 32. 1943.

21. ______________ Fifty-fourth annual report for the year ending June 30, 1943. Univ. Ariz. Agr. Exp. Sta. pp. 38-39. 1944.

22. ______________ Fifty-fifth annual report for the year ending June 30, 1944. Univ. Ariz. Agr. Exp. Sta. p. 31. 1945.

23. ______________ Fifty-sixth annual report for the year ending June 30, 1945. Univ. Ariz. Agr. Exp. Sta. p. 26. 1946.

24. Burgess, P. S. Fifty-ninth annual report for the year ending June 30, 1948. Univ. Ariz. Agr. Exp. Sta. p. 17. 1949.

25. ______________ Sixtieth annual report for the year ending June 30, 1949. Univ. Ariz. Agr. Exp. Sta. pp. 17-18. 1950.

26. Carrasso, F. M. Reclaiming and improving saline and alkaline soils. U.S. 2,860,448. 1958.

27. Cassel, N. S. and Clifford, A. T. (to Interchemical Co.). The pad dyeing of fabrics using pigments. U.S. 2,515,170. 1950.

28. Chester, K. S. A lethal virus of guar (Cyamopsis psoraloides DC). Phytopath. 34:998. 1944.

29. Chevalier, A. Research on the species of the genus Cyamopsis, forage plants for tropical and semi-arid countries. (Trans. by Laurel J. Burley. Edited by Theodore Hymowitz.) Rev. Bot. appl. 19:242-249. 1939.

30. Chopra, R. N. Nayar, S. L., and Chopra, I. C. Glossary of Indian medicinal plants. Council of Scientific and Industrial Research. New Delhi. p. 85. 1956.

31. Christianson, G. and Ramstad, P. E. (to General Mills, Inc.). Readily dispersible hydrophylic gum. U.S. 2,662,882. 1953.

32. Claasen, C. E. and Staker, E. V. Sixty-first annual report of the agricultural experiment station. Univ. of Nebr. Coll. of Agr. p. 23. 1948.

33. Committee of Staff Members; Division of Agriculture, Oklahoma State University. The potential in Oklahoma for selected oilseed and industrial crops -- a chemical, agronomic, and economic appraisal. December, 1960.

34. Conrad, H. E., Whistler, R. L., and Zimmerman, J. L. Sixty-third annual report of the director. Purdue Univ. Agr. Exp. Sta. Lafayette, Indiana. p. 106. 1950.

35. Cushing, M. L. An evaluation of combinations of starches and natural gums as papermaking aids. Tappi 41:155A-158A. 1958.

36. Cushing, M. L. and Schuman, K. R. Fiber attraction and interfiber bonding - the role of polysaccharide additives. Tappi 42:1006-1016. 1959.

37. Dahlstrom, D. A. and Emmett, R. C. (to Eimco Corp.). Dewatering foundry sand slimes. U.S. 2,941,942. 1960.

38. Department of Land Records and Agriculture. North Western Provinces and Oudh Agr. Ser. Bull. 4:1-89. 1896.

39. Department of Land Records and Agriculture. United Provinces of Agra and Oudh Agr. Ser. Bull. 30:1-95. 1930.

40. Diamalt Akt-Ges. Thickeners for dyes. Ger. 954,233. 1956.

41. Drake, R. T. N. (to Sherritt Gordon Mines Ltd.). Concentrating ores. U.S. 2,919,802. 1960.

42. Duncan, D. B. Multiple range and multiple F tests. Biometrics 11:1-42. 1955.

43. Durso, D. F., Schall, E. D., and Whistler, R. L. Automatic fraction collector for chromatographic separations. Anal. Chem. 23:425-427. 1951.

44. Eatherton, L. E., Platz, P. E., and Cosgrove, F. G. Guar gum as a binder and disintegrator for certain compressed tablets. Drug Standards 23:42-47. 1955.

45. Edwards, R. W. Report of experiments at substation number 12. Chillicothe, Texas. Texas Agr. Exp. Sta. Bull. 253:27. 1919.

46. Elverum, G. W. and Ramstad, P. E. (to General Mills, Inc.). Treating seeds containing galactomannan polysaccharides. U.S. 2,891,050. 1959.

47. Erdman, L. W. Strains of _Rhizobium_ effective of guar, _Cyamopsis tetragonoloba_. Amer. Soc. Agron. J. 40:364-369. 1948.

48. Esser, J. A. Guar - an old crop with a new future. Prog. Thru Res. 1:7-9. 1947.

49. Esser, J. A. Guar, an old crop with a new future. Good Earth Mag. 2:6-8. 1948.

50. ___________. Guar gains after long efforts for farm and market progress. Chem. Dig. 15:4-7. 1956.

51. ___________. Guar - a versatile crop. Seed World 80:12. 1957.

52. ___________. Guar: its development and uses. Chem. Dig. 17:9-12. 1958.

53. Fernandez, A. S. The use of guar (Cyamopsis psoraloides) in the feeding of laying hens and its influence on egg laying. (Trans. by Theodore Hymowitz and Juan Cardenas.) Biologia Animal. 4:197-228. 1958.

54. Fronmuller, G. D. (to Commonwealth Color and Chemical Co.). Treatment of adhesive gums. U.S. 2,803,558. 1957.

55. Gillett, J. B. Indigofera (Microcharis) in Tropical Africa with the related genera Cyamopsis and Rhynchotropsis. Kew Bull. Add. Ser. 1:1-166. 1958.

56. Goar, L. G. Guar is a good crop. California Cult. 93:317. 1946.

57. Goldfrank, H. Guar: its commercial uses and agricultural characteristics. Chem. Dig. 16:10-11. 1957.

58. ___________. A plant gum with many uses. Chem. Dig. 19:10-11. 1960.

59. Goldstein, A. M. Gums as wet-end additives in paper. Tappi 40:180A-182A. 1957.

60. _____________. (to Stein Hall and Co., Inc.). Dry mannogalactan compositions. U.S. 2,868,664. 1959.

61. _____________ and Alter, E. N. Guar gum. Industrial gums, polysaccharides and their derivatives. Academic Press, Inc. New York. pp. 321-341. 1959.

62. Goren, M. B. (to Kerr-McGee Oil Industries Inc.). Flocculating and settling of slimes in water. U.S. 2,937,143. 1960.

63. Gregory, L. K. Guar - new legume for flax lands. Prog. Farmer, Texas edition. 64:15. 1949.

64. Gregory W. C. X-ray breeding of peanuts (*Arachis hypogaea* L.) Agron. J. 47:396-399. 1955.

65. Gruenhut, N. S. Mannogalactan gums - the mechanism of retention of paper fibers. Tappi 36:297-301. 1953.

66. Gustafsson, A. The X-ray resistance of dormant seeds in some agricultural plants. Hereditas. 30:165-178. 1944.

67. Harlan, J. R. Distribution and utilization of natural variability in cultivated plants. Genetics in Plant Breeding. Brookhaven Symposia in Biology 9:191-206. 1956.

68. Hastings, S. H. Forage crop experiments at the San Antonio field station. USDA Bur. Pl. Ind. Circ. 106:26. 1913.

69. Haug, A. J. Conversion of purified guar mannogalactan for tub-sized adhesive. Tappi 32:410-413. 1949.

70. __________. Guar mannogalactan studies. I. Purification and characterization of purified fractions. Tappi 36:47-53. 1953.

71. __________. Guar mannogalactan studies. II. Effect of certain variables, including borax, on the rate of oxidation of the purified mucilage. Tappi 36:53-58. 1953.

72. __________. Guar mannogalactan studies III. Characterization of the oxidized and hydrolyzed mucilage. Tappi 36:59-62. 1953.

73. __________. Guar mannogalactan studies IV. Conversion of purified mucilage for the tub-size adhesive. Tappi 36:62-64. 1953.

74. Hawkins, R. S. Fiftieth annual report for the year ending June 30, 1939. Univ. Ariz. Agr. Exp. Sta. p. 51. 1939.

75. _____________ and Aepli, D. C. The Mesa experiment farm helps farmers help themselves. Univ. Ariz. Exp. Sta. Bull. 171:159-186. 1941.

76. Headley, F. B. and Hastings, S. H. The work of the San Antonio experiment farm in 1907. USDA Bur. Pl. Ind. Circ. 13:12. 1908.

77. Hellbusch, C. E. Guar grows in popularity. California Cult. 91:58. 1944.

78. Heyne, E. and Whistler, R. L. Chemical composition and properties of guar polysaccharides. J. Am. Chem. Soc. 70:2249-2252. 1948.

79. Hodge, W. H. and Erlanson, C. O. Federal plant introduction - a review. Econ. Bot. 10: 299-334. 1956.

80. Hutchinson, C. B. Agronomic research in California. Report of the Agricultural Experiment Station of the University of California (Bien.). p. 50. 1929-1930.

81. ________________. Agronomic research in California. Report of the Agricultural Experiment Station of the University of California. (Bien.) p. 19. 1935-1936.

82. Hyland, H. L. Personal correspondence, March 20, 1961 and April 11, 1962. New Crops Research Branch, USDA, and from USDA Inventory of Seeds and Plants.

83. Hymowitz, T. Colloquial names of guar - Cyamopsis tetragonoloba (L.) Taub. Chem. Dig. 20:11. 1961.

84. Industries Cemar, SA. Shelling of guar seeds. Span. 234,853. Chem. Abs. 53:618a. 1958.

85. Jackson, J. W. Progress report, substation number 9. Pecos, Texas. Texas Agr. Exp. Sta. Bull. 221:18. 1917.

86. Jayne, J. E., Tongren, J. C., and Jackson, D. T. Use of beater and headbox additives for the improvement of sheet characteristics. Tappi. 33:32-35. 1950.

87. Johnson, R. H. Determination of gums in process cheese spreads. J. Assoc. Offic. Agr. Chemists 39:286-290. 1956.

88. Jones, B. C. A forage and protein yield study of sorghum grown alone and in combination with four summer legumes, guar, cowpeas, mungbeans, and soybeans (Unpubl. M.S. Thesis, Oklahoma State University, 1959).

89. Jones, G. N. On the number of species of plants. Scientific Monthly. 72:289-294. 1951.

90. Jones, J. K. N. and Pridham, J. B. Colorimetric estimation of sugars with benzedrine. Biochem. J. 58:288-290. 1954.

91. Jones, R. J. Yearbook of the Department of Agriculture of the State of South Carolina, 1946-1947. p. 91. 1947.

92. Jordan, W. A. (to General Mills, Inc.). Increasing the viscosity of guar sols by reaction with formaldehyde. U.S. 2,730,505. 1956.

93. Karper, R. E. Progress report, substation number 8. Lubbock, Texas. 1909-1914. Texas Agr. Exp. Sta. Bull. 219-32. 1917.

94. Keen, J. L. and Opie, J. W. Colorimetric method as a means of studying carbohydrate sorption on pulps. Tappi 40:100-104. 1957.

95. Kelly, W. P., Wilcox, E. V., and McClelland, C. K. Field crops at the Hawaii Station. Hawaii Agr. Exp. Station Rpt. p. 63. 1911.

96. Killinger, G. B. (chairman). Minutes of the meeting of the technical committee, southern regional cooperative project S-9, new plants. pp. 20-22. 1960.

97. Konzak, C. F. Genetic effects of radiation on higher plants. Quar. Rev. Biol. 32:27-45. 1957.

98. Krantz, Jr., J. C., Carr, C. J., and Farson, deC. B. Guar polysaccharide as a precursor of glycogen. J. Am. Dietet. Assoc. 24:212. 1948.

99. Lachover, D. and Plaut, M. Guar as a valuable industrial plant. (Trans. by Isaiah Fidler and Theodore Hymowitz.) Hassadeh. 35:329-333. 1955.

100. Lewis, B. A. and Smith, F. Heterogeneity of polysaccharides as revealed by electrophoresis on glass-fiber paper. J. Am. Chem. Soc. 79:3929-3931. 1957.

101. Ligon, L. L. Will it grow in Oklahoma? Okla. Agr. Exp. Sta. Bull. B-307:1-12. 1947.

102. McCarron, R. D. Mannogalactan additives in paper. Pulp Paper Mag. Can. 55:190, 200. 1954.

103. McIlvain, E. H. Feeding guar beans to steer calves on grass. Cattleman 41:148-149. 1954.

104. McKee, R. Letter to C. V. Piper concerning guar grown at Chico, California. USDA. 1906.

105. ________ Letter to C. V. Piper concerning guar grown at Chico, California. USDA. 1908.

106. McKelvey, N. W. Guar seed for a chemical age. Farm and Ranch. 66:32-33. 1947.

107. McMurphy, W. E. The effect of 4-(2,4-dichlorophenoxy) butric acid on alfalfa, cowpeas, guar, mungbeans, peanuts, safflower, and sesame. (Unpubl. M. S. Thesis. Oklahoma State University, 1961).

108. McNulty, J. A. Isolation and detection of gums in frozen desserts. J. Assoc. Offic. Agr. Chemists 43:624-632. 1960.

109. Mallory, H. E. (to Great Western Drilling Co.). Drilling fluid additive. U.S. 2,854,407. 1958.

110. Martin, J. A. (chairman). Minutes of the meeting of the technical committee, southern regional cooperative project S-9, new plants. p. 26. 1959.

111. Matlock, R. L., Aepli, D. C., and Streets, R. B. Growth and diseases of guar. Univ. Ariz. Exp. Sta. Bull. 216:1-42. 1948.

112. Matlock, R. S. Guar variety and cultural studies in Oklahoma, 1950-1959. Okla. Agr. Exp. Sta. Proc. Ser. P-366:1-37. 1960.

113. Matlock, R. S. (chairman). Minutes of the meeting of the technical committee, southern regional cooperative project S-9, new plants. p. 20. 1961.

114. Merrill, E. D. Agronomic research in California. Report of the Agricultural Experiment Station of the University of California (Bien.). pp. 55-56. 1927-1928.

115. Moe, O. A. (to General Mills, Inc.). Carboxyalkyl ethers of carbohydrate gums. U.S. 2,520,161. 1950.

116. ________________________________. Gels of carboxyalkyl ethers of carbohydrate gums. U. S. 2,599,771. 1952.

117. ________________________________. Galactomannans and glucomannans. U.S. 2,650,917. 1953.

118. Moe, O., Miller, S. E., and Buckley, M. Investigations of the reserve carbohydrates of leguminous seeds. II. Derivatives. J. Am. Chem. Soc. 74:1325-1327. 1952.

119. Moe, O. A., Miller, S. E., and Iwen, M. H. Reserve carbohydrates of leguminous seeds. I. Periodate oxidation. J. Am. Chem. Soc. 69:2621-2625. 1947.

120. Moorhouse, L. A. Eighteenth annual report. Okla. Agr. Exp. Sta. p. 19. 1908-1909.

121. Musil, A. F. The germination of guar, _Cyamopsis tetragonoloba_ (L.) Taub. Amer. Soc. of Agron. J. _38_:661-62. 1946.

122. Narasimhachar, S. G. Latin and Kannada names of indigenous and medicinal plants of Mysore. Mysore State Dept. of Agr. Bot. Ser. Bull. 1:1-40. 1952.

123. Newburger, S. H., Jones, J. H., and Clark, G. R. A technique for obtaining infrared spectra of water-soluble gums. II. Identification of gums. Proc. Sci. Sect. Toilet Good Assoc. 19:25-29. 1953.

124. Nixon, W. M. Income rises as the farm mends. Soil Conservation 15:251-254. 1950.

125. Nixon, W. M. New summer legume (guar) increases cotton yields. What's New In Crops and Soils 6:14-15. 1953.

126. Olds, J. Guar ends a voyage. Org. Gard. and Farming 1:56-59. 1954.

127. Opie, J. W. and Hamilton, R. M. (to General Mills, Inc.). Decreasing the viscosity of mannan type gums. U.S. 2,767,167. 1956.

128. Osborne, G. E. and Lee, C. O. A study of guar and its mucilages. I. Pharmaceutical preparation. Bull. Natl. Formulary Comm. 19:4-12. 1951.

129. ______________________________. A study of guar and its mucilages. II. The effect of certain factors on the viscosity of guar and other certain factors. Bull. Natl. Formulary Comm. 19:12-19. 1951.

130. Palmer, K. J. and Ballantyne, M. The structure of (I) some pectin esters and (II) guar galactomannan. J. Am. Chem. Soc. 72:736-741. 1950.

131. Patel, P. L., Patel, G. C., and Patel, R. M. Guwars (cluster beans) of Gujerat. B. A. Agr. Col. Mag. 4:3-7. 1951.

132. Patel, R. R. Gum. Indian 61,005. Chem. Abs. 52:21190c. 1958.

133. ____________. Procedure for obtaining gum. Indian 61,044. Chem. Abs. 52:21190c. 1958.

134. Patil, P. C. The crops of the Bombay Presidency. Bombay Dept. of Agr. Bull. 109:1-132. 1921.

135. Peterson, L. E. and Opie, J. W. Flocculation of slimes by guar. Ind. Eng. Chem. 50: 1013-1016. 1958.

136. Piper, C. V. The search for new leguminous forage crops. USDA Yearbook. pp. 245-260. 1908.

137. ____________. Forage plants and their culture. The Macmillan Company. New York. pp. 614-616. 1924.

138. Poats, F. Guar, a summer row crop for the Southwest. Econ. Bot. 14:241-246. 1961.

139. Ralique, C. M. and Smith, F. The constitution of guar gum. J. Am. Chem. Soc. 72:4634-4637. 1950.

140. Ramstad, P. E. and Anker, C. A. (to General Mills, Inc.). Precipitation of mannogalactans and glucomannans from aqueous sols. U. S. 2,508, 726. 1950.

141. Rawlings, J. O., Hanway, D. G., and Gardner, C. O. Variations in quantitative characters of soybeans after seed irradiation. Agron. J. 50:524-528. 1958.

142. Reynolds, E. B. Letter to L. E. Brooks concerning guar grown in Texas. Department of Agronomy. Texas A and M, College Station, Texas. 1949.

143. Roberts, P. L. (to Phillips Petroleum Co.). Drilling fluid. U.S. 2,483,936. 1949.

144. Robey, V. In the Salt Fork S. C. D. guar is big crop news. Soils and Water Mag. 4:20-21. 1955.

145. Roesler, H. N. The acceptability of four edible varieties of guar. - Cyamopsis tetragonoloba (L.) Taub. - by a taste panel in relation to maturity, methods of preparation, and protein content. (Unpubl. M. S. thesis. Oklahoma State University). 1961.

146. Rogers, C. H. Cotton root rot studies with special reference to sclerotia, cover crops, rotations, tillage, seeding rates, soil fungicides and effects on seed quality. Tex. Agr. Exp. Sta. Bull. 614:1-45. 1942.

147. Rowland, B. W. The use of guar in paper manufacture. Chem. Dig. 4:369-375. 1945.

148. Saber, A. H., Ahmed, Z. F., and Darwish, M. A contribution to the study of guar seeds grown in Egypt. Bull. de l'Institute du Desert d'Egypte. 6:67-78. 1956.

149. Samfield, M. M., Brock, B. A., and Locklair, E. E. Tobacco product. U.S. 2,708,175. 1955.

150. Schery, R. W. Plants for man. Prentice-Hall, Inc. New York. p. 212. 1952.

151. Schlakman, I. A. and Bartilucci, A. J. A comparative study of commercially available guar gums. Drug Standards 25:149-154. 1957.

152. Sen, N. K. and Vidyabhushan, R. V. Studies on tetraploid cluster bean varieties and their triploid and aneuploid progenies. Cytologia 25:426-436. 1960.

153. Senn, H. A. Chromosome number relationships in the Leguminosae. Bib. Gen. 12:175-336. 1938.

154. Sheldon, F. A. (to Sherwin Williams Co.). Textile printing-paste extenders. U.S. 2,844,547. 1958.

155. Smart, C. L. and Whistler, R. L. Stress - strain characteristics of guaran triacetate. J. Polymer. Sci. 4:87-90. 1949.

156. Smith, L. Field crop experiments. Report of the Agr. Exp. Sta. St. Croix, Virgin Islands. p. 9. 1912-1913.

157. Snedecor, G. W. Statistical Methods. Fifth ed. Iowa State College Press, Ames. 1956.

158. Spear, D. R. (to Eastman Kodak Co.). Wet-strength photographic paper. U.S. 2,685,508. 1954.

159. Staten, R. D. and Brooks, L. E. Guar, a dual purpose summer legume. Tex. Agr. Prog. 3:6-7. 1957.

160. ______________________________. Guar--a dual purpose summer legume. Texas Agr. Exp. Sta. leaflet 482. 1960.

161. Stein Hall and Co. Inc. Stabilizers for galactomannan gum solutions. Brit. 834,375. 1960.

162. Stevens, J. W. and Pritchett, D. E. (to Sunkist Growers Inc.). Citrus-juice products having stabilized cloud. U.S. 2,599,519. 1952.

163. Strange, T. E. Detection of gums in catsup and related tomato products. J. Assoc. Offic. Agr. Chemists 40:482-486. 1957.

164. Sturkie, D. G. Plant introduction studies. Forth-third Annual Report of the Agr. Exp. Sta. of the Ala. Polytech. Inst., Auburn. p. 14. 1932.

165. Subramanian, A. and Premskhar, S. Seed production in guar (cluster beans) Cyamopsis psoraloides. Madras Agr. Jour. 47:134-135. 1960.

166. Swanson, J. W. Methylation of guar polysaccharide. J. Am. Chem. Soc. 71:1510-1511. 1949.

167. ____________. Conversion of mannogalactan mucilages in aqueous borax solutions for use as tub sizing and coating adhesives. Tappi 33:77-81. 1950.

168. ____________. The effects of natural beater additives on paper making fibers. Tappi 33: 451-462. 1950.

169. ____________. (to Institute of Paper Chemistry). Mannogalactan mucilages and process for producing them. U.S. 2,444,412. 1948.

170. ____________. (to Institute of Paper Chemistry). Dextrinization of manno-galactans. U.S. 2,553,485. 1951.

171. Taubenhaus, J. J. and Ezekiel, W. N. A rating of plants with reference to their relative resistance or susceptibility to Phymatotrichum root rot. Texas Agr. Exp. Sta. Bull. 527:21. 1936.

172. Taylor, H. M. and Gardner, H. R. Relative penetrating ability of different plant roots. Agron. J. 52:579-581. 1960.

173. Taylor, W. J. (to Atlas Powder Co.). Water resistant explosives. U.S. 2,654,666. 1953.

174. Thomas, E. E. Reclamation of white-alkali soils in the Imperial Valley. Univ. of Calif. Agr. Exp. Sta. Bull. 601:8. 1936.

175. Thompson, K. W. and Corrente, A. M. (to Organon, Inc.). Pharmaceutical preparations for gastric hyperacidity. U.S. 2,774,710. 1955.

176. Thompson, L. Sorghum versus sorghum - guar (Cyamopsis tetragonoloba) mixtures for forage and protein production. Okla. Acad. Sci. Proc. 38:31-32. 1958.

177. Thornber, J. J. Univ. Ariz. Agr. Exp. Sta. Bull. 60:438-441. 1908.

178. Vavilov, N. I. The origin, variation, immunity and breeding of cultivated plants. (Trans. by K. Starr Chester.) Chronica Botanica. Vol. 13. Waltham, Mass. 1949-1950.

179. Veeraswamy, R. and Kunjamma, V. K. Guar or cluster-bean (Cyamopsis tetragonoloba) and its scope as a short duration green manure crop. Madras Agr. Jour. 45:7-9. 1958.

180. Voorhees, A. and Scott, E. F. (to American Cyanamid Co.). Oxidation - ingrain color emulsions for textile printing. U.S. 2,899,261. 1959.

181. Watt, G. The commercial products of India. John Murray, London. pp. 449-450. 1908.

182. Weinstein, B. (to Crest Foods Co., Inc.). Stabilizers for ice cream-type desserts. U.S. 2,856,289. 1958.

183. Welsh, J. L. (chairman). Report to the president's appointed bipartisan commission on increased industrial use of agricultural products. January, 1957.

184. Werbin, S. J. (to Stein, Hall and Co. Inc.). Ice cream stabilizer. U.S. 2,502,397. 1950.

185. Whistler, R. L. Guar - a new industrial crop. Chem. Indus. 62:60-61. 1948.

186. ______________. A promising new crop in American agriculture. Impl. and Tractor. 63:44-45. 1948.

187. ______________. Sixty-second annual report of the director. Purdue Univ. Agr. Exp. Sta. Lafayette, Indiana. p. 62. 1949.

188. ______________. Guar gum, locust bean gum, and others. Adv. Chem. Sers. 11:45-50. 1954.

189. ______________ and Durso, D. F. The isolation and characterization of two crystalline disaccharides from partial acid hydrolysis of guaran. J. Am. Chem. Soc. 73:4189-4190. 1951.

190. Whistler, R. L. and Durso, D. F. Crystalline trisaccharide from partial acid hydrolysis of guaran and the structure of guaran. J. Am. Chem. Soc. 74:5140-5141. 1952.

191. ______________., Eoff, W. H., and Doty, D. M. Enzymatic hydrolysis of guaran. J. Am. Chem. Soc. 72:4928-4939. 1950.

192. ______________., Heyne, E., and Bachrach, J. Aldehydo-D-galactose heplaacetate and aldelhydro-D-xylose hexaacestate from acetolysis of guaran and xylan. J. Am. Chem. Soc. 71:1476-1477. 1949.

193. ______________., Li, T. K., and Dvonck, W. Branched structure of guaran. J. Am. Chem. Soc. 70:3144-3145. 1948.

194. ______________. and Smart, C. L. Polysaccharide chemistry. Academic Press, Inc. New York. pp. 296-299. 1953.

195. ______________. and Smith, C. G. A crystalline mannotriose from the enzymic hydrolysis of guaran. J. Am. Chem. Soc. 74:3795-3796. 1952.

196. ______________. and Stein, J. Z. A crystalline mannobiose from the enzymatic hydrolysis of guaran. J. Am. Chem. Soc. 73:4187-4188. 1951.

197. Wiley, R. M. (to Dow Chemical Co.). Aqueous suspension polymerization of vinylidene compounds. U.S. 2,875,185. 1959.

198. ______________________________. Suspension polymerization of vinylidene chloride. West Ger. 1,005,272. 1957. Chem. Abs. 54:4055e. 1960.

199. Williams, C. A cultural study of guar involving three varieties, three-row spacings and three rates of planting. (Unpubl. M. S. thesis. Oklahoma State University. 1960.)

200. Williams, J. H. and Hanway, D. G. Genetic variations in oil and protein content of soybeans induced by seed irradiation. Crop Sci. 1:34-36. 1961.

201. Williams, M. P. and Kirchner, C. T. (to E. I. duPont deNemours and Co.). Stabilization of dithiocarbamate slurries. U. S. 2,870,059. 1959.

202. Winters, N. E. Experiments at substation number 3. Angleton, Texas. 1909-1916. Texas Agr. Exp. Sta. Bull. 229:23-24. 1918.

203. Woglum, R. S. Inventory of seeds and plants. USDA Bur. of Plant Industry. No. 37. p. 30. 1913.

204. Youngblood, B. Fieldcrops work at the Texas Station. Texas Station Rep. 1913. Abstract in Experiment Station Record. 32:226. 1915.

VITA

Theodore Hymowitz

Candidate for the Degree of

Doctor of Philosophy

Thesis: STUDIES ON GUAR - CYAMOPSIS TETRAGONOLOBA (L.) TAUB.

Major Field: Plant Breeding and Genetics

Biographical:

Personal data: Born February 16, 1934 at New York City, the son of Bernard and Ethel Hymowitz.

Education: Attended the Crown Heights Yeshivah in Brooklyn, New York; graduated from Boys High School, Brooklyn, New York in 1951; received the Bachelor of Science degree from Cornell University, with a major in Agronomy in June, 1955; received the Master of Science degree from the University of Arizona, with a major in Agricultural Chemistry and Soils in May, 1957; attended Graduate School at Oklahoma State University 1959 - 1962.

Professional experience: Employed on a Graduate Scholarship on funds supplied by the Atomic Energy Commission at the University of Arizona, 1955 - 1956; entered U.S. Army in January, 1957 and served as a physical scientist at the Quartermaster Research and Engineering Center, Natick, Massachusetts until January, 1959; employed as a Graduate Research Assistant in the Agronomy Department, Oklahoma State University, 1959 - 1962; Fulbright Scholar at the Indian Agricultural Research Institute, New Delhi, India, 1962 - 1963.

Professional organizations: Member of Phi Sigma, Sigma Xi, Oklahoma Academy of Science, American Society of Agronomy, Indian Society of Genetics and Plant Breeding, and the Society for Economic Botany.

Date of final examination: August, 1963.