THE EFFECTS OF PLANT POPULATION AND GEOMETRY ON YIELD AND WATER UTILIZATION BY PEANUTS (*ARACHIS HYPOGAEA* L.)

By

EDWARD W. CHIN CHOY

Bachelor of Science
University of Southwestern Louisiana
Lafayette, Louisiana
1965

Master of Science
Oklahoma State University
Stillwater, Oklahoma
1967

Submitted to the Faculty of the
Graduate College of the
Oklahoma State University
in partial fulfillment of
the requirement for
the Degree of
DOCTOR OF PHILOSOPHY
May, 1972

THE EFFECTS OF PLANT POPULATION AND

GEOMETRY ON YIELD AND WATER

UTILIZATION BY PEANUTS

(ARACHIS HYPOGAEA L.)

Thesis Approved:

John F. Stone
Thesis Adviser

Lavoy I. Croy.

James E. Garton

Ralph S. Matlock

D. Durham
Dean of the Graduate College

ACKNOWLEDGMENTS

It is the author's desire to express sincere appreciation to Dr. J. F. Stone, Professor of Agronomy and the author's major adviser, for the counsel, guidance and his constructive critique received during the period of this study.

To Drs. L. I. Croy, J. E. Garton and R. S. Matlock special thanks are due for serving on the author's advisory committee and for reviewing this manuscript. Gratitude is expressed to Drs. Matlock, Garton and Stone for the use of the yield data of 1960, 1961 and 1964.

At this point, thanks is extended to the Department of Agronomy, Oklahoma State University, for the financial support received throughout the course of this study. Recognition is also due to those who have assisted in the collection of the data presented, specifically the personnel in Soil Physics of the Department of Agronomy and those at the Caddo Peanut Research Station.

Since this is probably the termination of the author's formal education, the author would like to acknowledge all those who have encouraged and assisted him during the long educational process. Persons who have to be mentioned because of their exceptional influence: Edward and Lillian Chin Choy, my parents; C. A. McMullan, S. J., for his faith and confidence in the author's ability; Dr. C. C. Cain, his undergraduate adviser and Dr. J. F. Stone, his graduate adviser.

To my wife, Hwaling, without whom this thesis would not have been written, and to whom the author is indebted, deep gratitude is expressed.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Figure | Page

CHAPTER I

INTRODUCTION

The increase of world population combined with a limited amount of arable land has compelled soil scientists to seek more efficient use of our natural resources. The natural resources of concern to these scientists are land and water, with good quality water the most limiting of these resources.

In the conservation of these resources, a measure of efficiency would be an increase in crop production with a decrease, or at least a static level, in the consumption of these resources. Furthermore, this efficiency needs to be economically feasible and easily adaptable to the prevailing cultural practices.

An increase of production of row crops can be achieved in many cases by increasing the plant population density if the variety being used is well-suited to the specific environmental condition. Plant population density can be increased by: a) reducing the row width, b) increasing the number of plants within the rows or c) by a combination of these. The elected choice and its magnitude would be dependent on economic considerations.

Conservation of irrigation water applied to row crops can be achieved by a) decreasing the total amount of supplemental water applied to the crop during the growing season, b) retarding water losses by the plant and the soil surface in the evapotranspirational processes with the use of physical barriers, c) reducing the energy available for evapotranspiration by utilizing the physical characteristics of the crop and its terrain and d) combination of any or all of the preceding methods. Again, the economic and feasibility factor would temper the elected choice.

The row crop used for this study was the peanut (Arachis hypogaea. L.). This legume is of importance because: a) its high economic value in Oklahoma, and b) the high gross value of this crop enables both irrigated and nonirrigated culture to be economically profitable.

The purpose of this study was to investigate the effects of high plant population density on yield. High plant populations were obtained by varying both row widths and by varying the plant population within rows. The influence of row spacings and direction of rows on water evaporation from the plots was also studied.

CHAPTER II

REVIEW OF LITERATURE

The predominant peanut varieties now being used in commercial production exhibit two contrasting morphological characteristics--an open, low growing type which is commonly referred to as the runner type and an erect, compact plant which is commonly referred to as the bunch type. Since the work which is being reported here deals mainly with the bunch type, the literature reported herein will be mainly this type, but the runner type will be mentioned and noted where there is a deficiency of information about the bunch or spanish type.

Population Studies

The earliest reported work showing the effect of plant population on the yield of peanuts was done by Bennett at Arkansas in 1889 (2). Although he gave no details of the experimental procedure he used, his investigations dealt with yield versus plant spacings and widths of row. The plant spacings of 4, 6, 8, 12 and 18 in. were used on rows 2 and 3 ft. wide. His results showed that the 4-in. plant spacings on the 2-ft. rows had the highest yield of 172 bu. per acre, but another yield peak occurred with the same plant spacings on the 3-ft. rows. For convenience of the cultural practice at the time, he recommended the 8-9 in. plant spacings on 30 in. rows would give the optimum yield.

The next major work on row spacing-plant density effects on yield was done in Alabama in 1924 (8). Yield results were using 4 row spacings (18, 24, 30, and 36 in.) with 3 planting densities (4, 8, and 12 in. between plants). The results concurred with those of Bennett's--the general closer rows and higher populations gave higher yields with plants 4 in. apart, regardless of the row spacing giving the highest yield of the plant spacings and rows 18 in. apart gave the highest yield of the row spacings. The two yield peaks occurred one at the 72 sq. in. per plant and the other at the 216 sq. in. per plant. The 72 sq. in. per plant was about 25 percent higher than the other spacing.

In 1931, McClelland reported further studies in Arkansas (14). In these studies, the yield from the 30-in. rows with plants spaced 6 to 9 in. apart averaged the highest yield over a 10 year period. The yield was about 18 percent higher than that of the 36 in. rows of similar plant spacing. In 1944 he made a report on the continuation of the study (15). For a 9-year average between 1931 and 1941, he found that the 36-in. rows of 8-in. plant spacings averaged about 3 percent more than that of the 30-in. rows. A possible source for this contradiction was the extremely arid years which were encountered during the study. Another possible source was that a change in variety was made in 1937, from Spanish to Improved Spanish.

West (26) in Mississippi surveyed the work done in that state and Texas in a 1942 bulletin. In the Mississippi work, White Spanish peanuts gave the highest average yield in trials conducted in 1940 and 1941. The row spacings of 24, 30 and 36 in. were compared while the plant spacings were 6, 12, and 18 in. within the various rows. As expected, the closest plant density--24-in. rows with plants 6 in.

apart--gave the highest yield. This yield was three times greater than that of the 36-in. rows with plants 18 in. apart. The work which was reported from Texas was carried out at Angleton and Nacagdoches between 1915 and 1922. In the reported work at Angleton, row width was kept constant at 30 in., while plant spacings varied from 3 to 30 in. in multiples of 3 in. This work was rather spotty as there were several treatments missing within years. Nevertheless, there was a general tendency for closer plant spacing to give the highest yield within each year. In the Nacogdoches study, the average yield of the 18-in. rows was higher than that of the 36-in. rows. The plant population within rows was not studied and a 'normal' stand was assumed each year. The row widths which were used were 18 and 36 in.

In studies conducted in the eastern states, closer row spacings with close plant spacings gave higher yields. In Georgia, Parkham (21) recommended that Improved Spanish variety should be planted in 18-in. rows 6 in. apart. This recommendation was a result of an experiment in which row widths varied from 6 to 36 in. with plant spacings of 6 in. On the 36-in. rows, he varied the plant population with plant spacings of 3, 6, 12, and 18 in. He found that the spacings of 6 in. for the 6, 18, and 24 in. rows averaged the same yield, but higher than the other treatments.

Killinger, et al. in 1928 and 1929 concurred with similar findings in Florida (12). Using Spanish peanuts on rows of 30 in. they varied the spacings between plants in increments of 3 in. Their results showed that the mean yield of the 3-in. spacings was higher than that of the 6 and 9 in. by about 22 percent and 36 percent, respectively.

Beattie, et al. in South Carolina using plot size of 1/20 acre compared plant spacings with 30 and 36 in. rows (1). The plant spacings used were: 3, 6, 9, 12, and 15 in. Their 3-year average showed that the 3-in. spacings produced about 20 percent more than the 6-in. spacing on both the 30 and 36 in. rows. The 3-in. spacings on the 30-in. rows had the highest yield, while the 15-in. spacing on the 36-in. rows had the lowest.

In North Carolina, the early recommendation in peanut culture implied that closer row spacing is more important in the increase of yield than closer plant spacings (29). This recommendation was later confirmed by the work of Cox and Reid (4). The latter workers using the Virginia bunch variety, NC2, had plant spacings at 3, 6, 12, and 18 in. on rows of 12, 18, 24, and 36 in. These workers concluded that the prime effect in plant population studies was the reduction of row spacing rather than plant spacing. The basis of this conclusion was that the magnitude of change was higher between row spacings than between plant spacings. In addition to the row spacing effect, these investigators concluded that the effect of spacing of plants in the rows was highly dependent on the environmental conditions of the prevailing year and that for the NC2 variety when the yield approached 3600 pounds per acre the optimum yield was attained.

In Virginia, Duke and Alexander had row spacings of 12, 18, and 36 in. and plant spacings of 6, 9, and 12 in. using Virginia Bunch 46-2 (7). The highest yield was obtained with rows spaced 12 in. apart and plants within rows 6 in. apart. The three-year mean yield was less than one percent greater than the 18 in. between rows and 6 in. between plants. Again the results showed a yearly effect in the analysis of variance. Furthermore, pooling of the 3 years of data showed that the row spacing and plant spacing treatments were not significantly different.

In Oklahoma, row spacing and plant spacing studies were conducted at two locations in 1960 (17). In addition to these variables, two Spanish bunch varieties--Argentine and Spantex--were studied with 4 planting dates. Irrigated and nonirrigated treatments were imposed on these treatments. The locations where the study was undertaken were the Perkins Agronomy Research Station and the Paradise Agronomy Research Station. The row spacings were: 20, 30, and 40 in. while the plant spacings were 2.4, 4.8, and 9.6 plants per foot. The results showed that the earliest planting date had the higher yield; varieties reacted differently to the planting densities, with the Spantex variety being the least sensitive to the change of growing area; the highest yield was obtained from the narrow rows, and irrigated conditions gave the higher yields of better quality than the dryland condition. Over both locations, the Spantex variety had the highest mean yield at the 2.4 plants per foot level over all row spacings, while the Argentine variety had the highest mean yield at the 2.4 and 4.8 plants per foot spacing.

In Samaru, Nigeria, Meredith (19) used two row spacings--30 and 36 in.-- and varied the plant population from 14,520 to 129,392 plants per acre in 1960 and 4,840 to 58,080 plants per acre in 1961. For all three years, a plant population of 29,040 plants per acre gave the optimum yield regardless of the row spacing which was used. He did not mention the variety which he used in this experiment.

Water Requirement

In the studies of water requirement of a peanut crop, as affected by plant population, no prior research was found in the literature. However the effects of irrigation on yield using prevailing row spacings and plant population are reported.

In Oklahoma (18) comparisons were made between 1956 and 1959 on various irrigation frequencies on 36- and 40-in. rows at 2 locations. The criteria for irrigation were: water tensions of a) 6 atmospheres in the top 6 to 12 in. of the soil profile, b) 2 atmospheres in the same zone, and c) 1 atmosphere tension in the same zone. There was also a treatment without supplemental water. The amount of water applied at each irrigation was a little more than 2 in. The water treatment of c gave the highest yield in the three years of study, and if monetary return is taken as the criteria of overall quality and yield, then this would be the ideal treatment. Nevertheless, a combination of either treatment b or c would have given the optimum yield as these values were not statistically different at the 95 percent level of confidence.

In Israel irrigation frequencies were studied and a 14-day frequency gave the highest yield of 6 irrigation frequencies (16). Again statistically, the variance was not significantly different from the yield obtained from the 30-day frequency. Of interest in this study was that less than 20 percent of the water lost by evapotranspiration in frequencies of 21 days and less was extracted from the 4 to 5 ft. depth of the soil profile. These workers also showed that in Israel about 26 in. of water would be needed to produce an optimum yield of peanuts.

CHAPTER III

MATERIALS AND METHODS

Plant Population Studies

The investigations of 1960 and 1961 were undertaken at the Agronomy Research Station at Perkins, Oklahoma, while those of 1964, 1968, 1969, and 1971 were at the Caddo Peanut Research Station, near Ft. Cobb, Oklahoma. In the 1960, 1961 and 1964 studies, the plant population densities were varied by using various row spacings and plant spacings. The 1968, 1969 and 1971 studies had two row spacings and a nominal plant spacing of 2 to 4 plants per foot. Irrigated and nonirrigated treatments were imposed on the 1960, 1961, 1964 and 1968 studies, while those of 1969 and 1971 had only the irrigated treatment.

The soil on which the 1960 and 1961 studies were located was the Teller fine sandy loam. The 1964 study was the Meno fine sandy loam, while the 1968, 1969 and 1971 on the Cobb fine sandy loam and the Meno fine sandy loam. The Cobb fine sandy loam was in 2 phases: 1-3 percent slope and 3-5 percent slope, severely eroded. The replications were oriented such that 2 replications were on the Cobb fine sandy loam, and the other on the Meno fine sandy loam.

Studies of 1960, 1961 and 1964

Since the 1960, 1961 and 1964 experiments contained the same treatments, these years will be treated separately from the other years.

The cultural practices for 1960, 1961 and 1964 experiments were similar. In each year, the peanut crop was preceded by a rye cover crop and the seeds were planted with a Planet Jr. single row planter. Weeds were controlled by hoeing, insects by DDT and leafspot by Dithane.

The row spacings which were used in 1960 were: 40, 30 and 20 in. In the 1961 and 1964 experiments, a 10 in. row spacing was added to the study. The planting densities in 1960 were: 2.4, 4.6 and 9.6 viable seeds per foot. The 1961 and 1964 planting densities were 2.25, 4.50 and 6.75 viable seeds per foot. The viability of the seeds was based on 85 percent germination percentage.

In all three years of the study, there were four replications with the treatments completely randomized. The plot size was 19 feet long and approximately 13.2 ft. wide. The width of a plot was determined by the width of the row spacing. Thus there were four 40 in., six 30 in., eight 20 in. and sixteen 10 in. rows in the plots of those row spacings.

The plots were irrigated when the soil moisture in the top 6 to 12 in. zone was approximately -1 bar soil water pressure. The irrigation was by sprinklers located on 30 ft. centers atop 2 ft. risers. A nominal 1 in. of water was applied at each irrigation.

At the end of the growing season, the center two rows from each plot were hand harvested and the yield of cleaned, air-dried, unshelled pods, along with the final plant population was determined. The

Oklahoma Federal-State Inspection Service at Durant, Oklahoma, graded samples of the unshelled pods from the plots of 2 replications.

The measurements which were derived from the above data were: yield, (pounds of unshelled peanuts per acre); yield, (grams per plant); percentage of sound mature kernels; percentage of other kernels; and the final plant population of the harvested area. These values were then used in the regression model:

$$\hat{Y} = \beta_0 + \beta_1 X_1 + \beta_2 X_1^2 + \beta_3 X_2 + \beta_4 X_2^2 + \beta_5 X_1 X_2$$

with the independent variable: X_1 being row spacings, in inches, and X_2 plant spacings, in plants per foot.

The dependent variables $(\hat{Y})$ were: pounds of unshelled peanuts per acre; grams per plant; percentage of sound mature kernels; percentage of other kernels and the net value of the crop. The net value of the crop was calculated from the schedule published from the Southwestern Peanut Grower's News, representing the then current market value of the crop, minus the seed costs. The value of the seeds was based on the current costs of medium size, certified seeds. The least squares technique was used in the evaluation of the parameters, with all calculations being done on the high speed digital computers located at the Oklahoma State University Computer Center.

<u>Study of 1968</u>

In 1968, a new test plot area was instituted at the Caddo Peanut Research Station. With no prior knowledge of the homogeniety of the soil with respect to plant yield response, a latin square experimental design was instituted. There were 4 replications of 4 treatments in the experiment. The treatments were: irrigated and nonirrigated, and 12 and 36 in. row spacings. A plant density of 2 to 4 plants per foot was planted in all treatments. The size of the plots was 75 by 90 ft.

Seed of the Starr variety of peanut was planted using a Planet Jr. single row planter on June 3. Treflan herbicide was incorporated in the soil before planting for weed control, and 250 pounds of 8-32-16 fertilizer was applied broadcast. Fungicide and insecticide was applied as needed, the fungicide being sulphur and the insecticide methyl-parathion. Both fungicide and insecticide were applied aerially.

On November 19, an area 16 by 6 ft. in the center of each plot was hand harvested. The width of the harvested area was either 6 rows of 12 in. row spacing or 2 rows of 36 in. row spacings. From the harvested area, the final plant population was counted. The harvested peanuts were dried, cleaned and shelled for yield determination.

Studies of 1969 and 1971

In the 1969 and 1971 studies, only irrigated treatments were considered. There were 4 treatments, with 3 replications per treatment in both years. The treatments were 12 and 36 in. row spacings of north-south and east-west orientation. In both years the treatments within replications were randomly assigned, Figure 1 showing the results. The size of the plots were 100 by 100 ft.

In 1969, the herbicide Treflan and 250 pounds of 8-32-16 fertilizer per acre was incorporated into the soil before planting. Starr variety of peanuts was planted with a single row Planet Jr. seed planter on June 5, and was hand harvested on October 30. The harvested

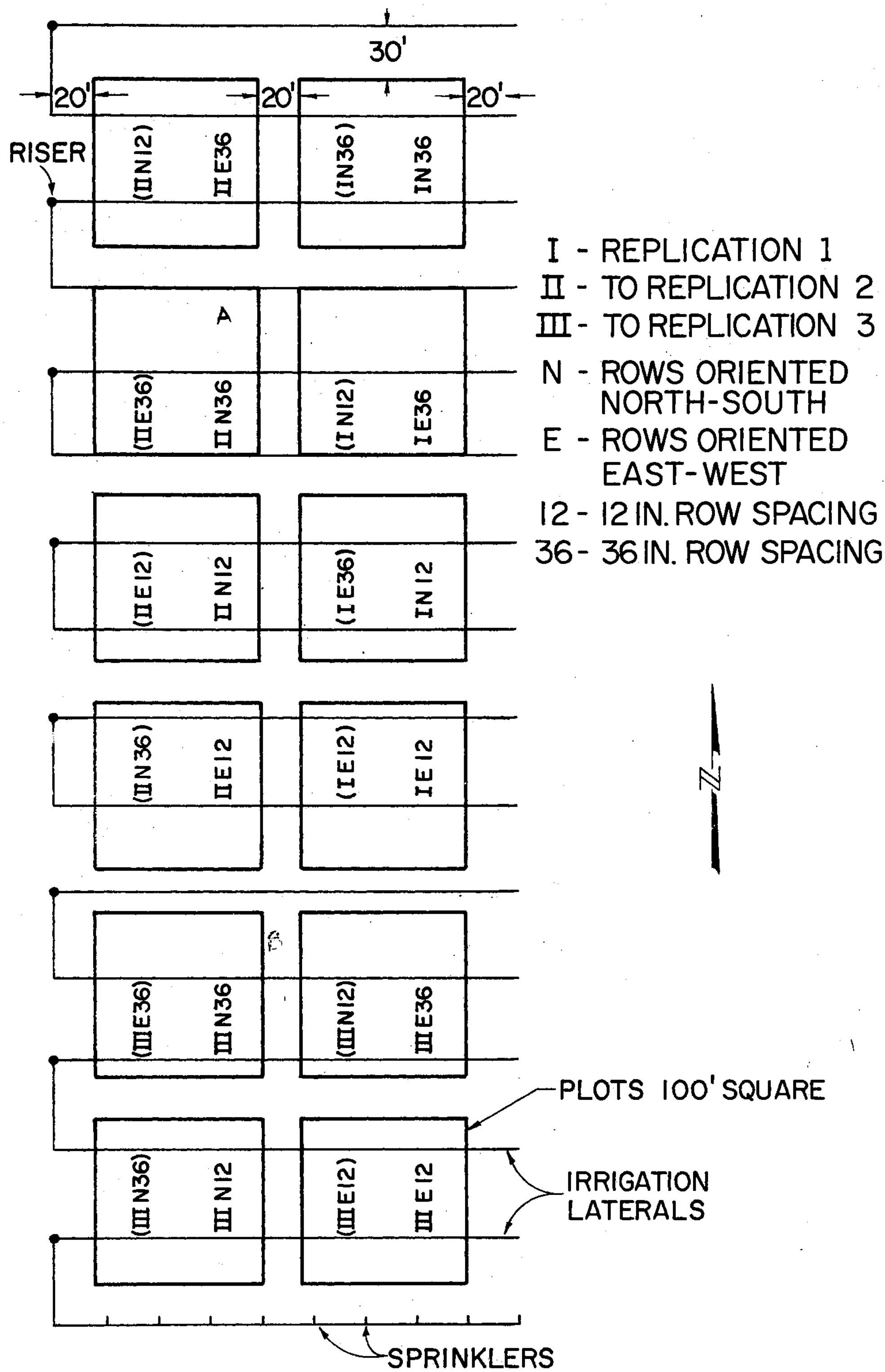

Figure 1. Field Layout of 1969 and 1971 Study. Numbers in Parenthesis Refer to 1969 Study

area was 16 by 6 ft. from the center of each plot and from an area which seemed to be representative of the plant population of that plot. The plant population and the pounds of cleaned, dried and shelled peanuts were determined as before. A sample from each plot was sent to the Oklahoma Federal-State Inspection Service at Durant, Oklahoma, to be graded.

In 1971, no herbicide was deemed necessary. Thus, 250 pounds of 8-32-16 per acre of fertilizer was applied before planting. Comet variety of peanut was planted on June 4 with a six row seed planter, and hand harvested on November 2. As before, the harvested area was a 16 by 6 ft. section in the center of the plots which seemed to be representative of the plot. The harvested plants were counted and the weight of the cleaned, dried and shelled peanuts determined. The samples were then graded.

Water Requirement Study

In the 1961 study, the soil water content of the top 48 in. of the soil profile of specific plots was regularly monitored, using a Nuclear Chicago P-19 probe. The plots which were monitored were the four replications of the 10 and 40 in. row spacings of 4.8 planted seeds per foot, for both the irrigated and the nonirrigated treatments. There was one neutron access tube per plot, this being located near the center of the plot and in an area which seemed to be representative of the plant population. For the irrigation treatment, water was applied on July 31, August 4, 16, and 28.

In the 1968 study, the water content of the top 48 in. of the soil profile for all plots were monitored by the neutron method, using a Nuclear Chicago P-19 probe. The plots which were monitored were the four replications of the 10 and 40 in. row spacings of 4.8 planted seeds per foot, for both the irrigated and the nonirrigated treatments. There was one neutron access tube per plot, this being located near the center of the plot and in an area which seemed to be representative of the plant population. For the irrigation treatment, water was applied on July 31, August 4, 16, and 28.

In the 1968 study, the water content of the top 48 in. of the soil profile for all plots were monitored by the neutron method, using a Nuclear Chicago P-19 probe, immediately before and after each irrigation. Since these plots were larger than the 1961 study, the neutron access tubes were located at about 10 ft. from the north edges of the plots, in areas which seemed to be representative of the plant population. In the selection of the north edge of the plot for the location of the neutron access tube, the maximum distance for the upwind fetch was considered, on the assumption that the predominant winds were from the south. Hence, the north edge of the plot afforded this and also easy access to the tubes.

As can be seen in Figure 21, the averaged water content of the plots in the 1961 season for the treatments at the commencement of the neutron determination, had a maximum spread of about 0.5 in. of water. At the end of the monitoring period the spread of water contents which occurred suggested that the use and accumulation of soil moisture by the various treatments was dependent on row spacing. The 1968 data did not show this wide spread at the end of the growing season (Figure 22).

A difference in this layout of the 1961 and 1968 experiments was the orientation of the row with respect to the direction of the prevailing wind of the growing season. In the 1961 study, the rows were north-south oriented, or parallel to the prevailing wind, while the rows of 1968 were east-west and hence perpendicular to the prevailing wind. Thus in 1969 and 1971, studies were undertaken to investigate whether a difference in evapotranspiration existed between north-south and east-west oriented rows and between wide (36 in.) and narrow (12 in.) rows.

In order to obtain the magnitude of evapotranspiration between these various treatments, a complete water budget was necessary. The values for the water content of the soil obtained by the neutron method gave the change of water content within the measured profile, but did not indicate the direction of flow of water. Some knowledge as to the direction and magnitude of water flux at the 4 ft. depth of the soil profile should be known to separate water lost by evapotranspiration and by drainage from the plots. This could be accomplished by monitoring this depth with a tensiometer and applying water pressure gradient information to those equations.

The tensiometers were constructed in the laboratory and were similar to the plastic type of Perrier and Evans (22). The matric suction was measured with a mercury manometer. The direction of flow below the 4 ft. depth could be determined by locating tensiometers at the 4 and 5 ft. depth of the soil profile to measure the difference of the matric suction. Since the flow of water is in the direction of the higher matric suction, the flow of water in this zone can be ascertained. By using the values for the hydraulic conductivity determined previously by Davidson et al. (5) in the Darcy equation, the flux of water could be calculated. Integrating the flux of water over days would yield the magnitude of water into or out from the root zone, i.e., the top 48 in. of the soil profile.

Since neutron measurements using a Nuclear Chicago P-19 probe were made in the monitored plots immediately after and before each irrigation, the change of soil water content of the plot between this period could be determined. As the direction and magnitude of water flow through the 4 ft. depth of the soil profile was ascertained by the tensiometers, then by selecting periods of time between neutron measurements which were free from heavy rainfall, evapotranspiration calculations could be made.

In both 1969 and 1971, the neutron access tubes and tensiometers were located 10-15 ft. from the north edge of the plots. The tensiometers were located at the 4 and 5 ft. depth and were 5 to 10 ft. from each other. The mercury manometers for the tensiometers were located at the edge of the plot and were connected to the tensiometers by 4 mm O.D. nylon tubing. There was one neutron access tube per plot, with the depth of measurement being to 4 ft. Both neutron access tube and tensiometers were located in areas of the plot which seemed to be representative of the plant population of that plot. In the field, the tensiometers were read regularly, and purged of air when needed.

The cultural practices for 1969 and 1971 have been previously discussed. The capacity of the irrigation system was about 200 gpm and allowed only two laterals to be operative at a time, thus the area was irrigated in 4 sets. Two inches of water was applied per irrigation, this taking 4 hours per set. The distribution of applied water was checked at random points in the plots with a rain guage and this confirmed the amount of water and uniformity of distribution by the system.

In 1969, the dates of irrigation were: July 31, August 10, 21, and September 1. In 1971, the dates of irrigation were: July 16, August 2, 12, 22 and September 1.

CHAPTER IV

RESULTS AND DISCUSSION

Plant Population

Results

Reports on plant population studies are characterized by large differences in yield between irrigated and nonirrigated conditions (17, 18). In this study, large differences also existed between years with respect to yield, both qualitatively and quantitatively. Thus the irrigated and nonirrigated data of this study were analyzed independently. Because of the large year-to-year effect, each year was handled separately.

Table I shows the harvested plants per foot for the study conducted in 1960, 1961 and 1964. The ranges of plant spacings between years and between treatments are clearly evident. Although the same amount of viable seeds were planted in each treatment within a specific year, a different harvested population resulted. This anomaly occurred within each row spacing treatment and under both irrigated and nonirrigated conditions, and was expected because of different environmental conditions which existed, thereby affecting germination. Damage to the seeds which occurred during planting could also account for part of the anomaly.

TABLE I

PLANT SPACINGS FOR 1960, 1961 AND 1964

Row Spacing (in)	1960			1961			1964		
	Planted Viable Seed/Ft	Irrigated Plants/Ft	Non-Irrigated Plants/Ft	Planted Viable Seed/Ft	Irrigated Plants/Ft	Non-Irrigated Plants/Ft	Planted Viable Seed/Ft	Irrigated Plants/Ft	Non-Irrigated Plants/Ft
40.0	2.40	2.07	2.68	2.25	2.60	2.65	2.25	1.82	1.95
40.0	4.60	4.00	4.23	4.50	5.02	5.40	4.50	2.70	3.17
40.0	9.60	8.30	8.27	6.75	5.88	6.65	6.75	4.00	4.45
30.0	2.40	2.07	2.33	2.25	2.68	2.42	2.25	1.78	1.70
30.0	4.60	3.60	4.30	4.50	5.25	5.88	4.50	2.42	3.60
30.0	9.60	7.00	8.33	6.75	6.22	7.10	6.75	3.38	4.62
20.0	2.40	2.37	2.57	2.25	3.08	2.58	2.25	1.45	1.90
20.0	4.60	4.10	4.67	4.50	4.72	5.73	4.50	2.90	3.88
20.0	9.60	7.17	8.57	6.75	7.00	7.10	6.75	2.75	4.22
10.0	-	-	-	2.25	2.95	2.85	2.25	1.58	1.78
10.0	-	-	-	4.50	4.78	6.15	4.50	2.50	3.30
10.0	-	-	-	6.75	6.50	6.98	6.75	2.36	4.60

Table II shows the upper and lower limits which were selected for the observed range of harvested plants per foot for each year. These limits were arbitrarily selected to represent the range in which confidence would be placed on extrapolation of the regression of harvested plants per foot on the row spacing treatments. The upper limit of extrapolation was selected at 8 plants per foot for the 1960 and 1961 study. For the 1964 study, 5 plants represented the upper limit of extrapolation because of the narrow range of plants which was harvested that year, the highest level of plant spacing which was observed in the year was 4 plants per foot, with this occurring on the 40 in. row spacing. Thus it was not odd that the extrapolated value for 6 plants per foot calculated yields in excess of 6,000 pounds of unshelled peanuts per acre for all row spacings.

TABLE II

RANGES OF PLANT SPACINGS USED IN SURFACE RESPONSE GRAPHS (PLANTS PER FT.)

		YEAR 1960		1961		1964	
		Irrigated	Non Irrigated	Irrigated	Non Irrigated	Irrigated	Non Irrigated
Upper	Observed	7.0	8.0	6.5	7.0	3.5	4.5
	Extrapolated	8.0	8.0	8.0	8.0	5.0	5.0
Lower	Observed	2.0	2.5	2.75	2.5	1.5	2.0
	Extrapolated	1.0	1.0	1.0	1.0	1.0	1.0

Table III shows the summary of the least squares fit response surfaces for yield. As can be seen in this table, there was a wide range of values between years and between irrigated and nonirrigated conditions for all the calculated $\hat{Y}$ values. Hence, the $\hat{Y}$ will be discussed independently, except for the irrigated and nonirrigated treatments of the same year, which will be discussed together.

Yield

Figures 2, 3 and 4 show the response surfaces for yield in terms of pounds of unshelled peanuts per acre, for the three years of study. The model which was used in fitting the data was acceptable, as evidenced by the small 2σ values (two standard deviations) which were obtained for the six sets of data. The year effect is shown in the three years of data, evidenced by the magnitude of the various parameters, i.e., values which were obtained.

In comparing the irrigated and the nonirrigated treatments of 1960 (Figure 2) the extrapolated 10-in. row spacing had the highest yield. In both irrigated and nonirrigated treatments, the 3 to 5 plants per foot was the highest yielding plant spacing for the observed data. The highest yields, however, were obtained by the 10 and 20 in. irrigated row spacings of 1 to 3 plants per foot, values which were obtained upon extrapolation of the regression model. The lowest yield of the irrigated treatment exceeded the highest of the nonirrigated treatment by 584 pounds of unshelled peanuts per acre. Also of note in this figure is that under irrigated conditions no interaction between plants under close spacings could be concluded, but the 'saddleback' type of response of the nonirrigated treatment suggested some interaction.

SUMMARY OF SURFACE RESPONSE GRAPHS

Dependent Variable	Treatment	Year	Std. Dev.	Highest Value of Observed - Cal. Value	Lowest Value on Graph	Plant Spacing Plants Per Foot	Row Spacing (in)	Highest Value on Graph	Plant Spacing Plants Per Foot	Row Spacing (in)
Yield (Pounds/ Acre)	Nonirrigated	1960	31.71	27.67	790.95	1	40	1864.92	5	10
		1961	108.02	140.53	1342.45	1	40	2569.50	5	10*
		1964	160.72	-214.46	1508.64	1	40	2806.47	5	10
	Irrigated	1960	99.10	82.56	2450.91	1	40	5086.73	2	10
		1961	122.13	131.39	1847.39	8	40	3198.86	8	10
		1964	185.99	214.70	2067.05	3	40*	6716.33	5	10
Grams Per Plant	Nonirrigated	1960	4.35	-4.25	0.77	7	20*	30.44	1	10
		1961	0.46	0.58	3.24	6	10*	28.95	1	40
		1964	1.96	-2.24	4.86	4	10*	41.20	1	40
	Irrigated	1960	1.72	-1.71	3.32	7	10	61.56	1	40
		1961	0.99	1.20	4.57	8	40	37.85	1	40
		1964	1.55	-2.26	11.56	2	10*	83.75	1	40
Percent Sound Mature Kernels	Nonirrigated	1960	0.41	0.40	69.41	5	20*	71.68	8	40*
		1961	1.55	-2.59	59.94	8	10	68.74	1	10
		1964	1.80	-2.20	57.21	5	10*	69.17	3	40*

	Irrigated	1960	2.15	-1.94	68.67	5	10	73.28	8	30
		1961	1.24	-1.41	60.59	1	40	67.40	5	20
		1964	1.27	1.65	62.11	5	10	70.27	3	40*
Percent Other Kernels	Nonirrigated	1960	0.55	-0.63	2.25	8	40*	5.26	8	10
		1961	0.65	0.86	1.80	1	10	6.24	7	20*
		1964	1.28	1.45	5.32	5	40	11.43	5	10
	Irrigated	1960	1.00	0.99	1.45	1	30	2.54	5-6	10
		1961	0.83	-0.88	3.00	5	40-30*	5.39	8	10
		1964	0.26	0.29	0.05	5	10	4.10	1	10
Net Value of Crop (Dollars/ Acre)	Nonirrigated	1960	15.75	14.83	90.62	1	40	155.10	4	10
		1961	20.59	31.44	149.89	1	40	273.27	1	10
		1964	24.68	32.64	161.18	1	40	253.80	1	10
	Irrigated	1960	27.86	-35.32	209.44	8	20	549.09	7	10
		1961	28.10	35.66	74.22	8	40	330.01	7	10
		1964	37.00	-51.98	221.92	3	40*	446.95	5	20

*Within region of observed value

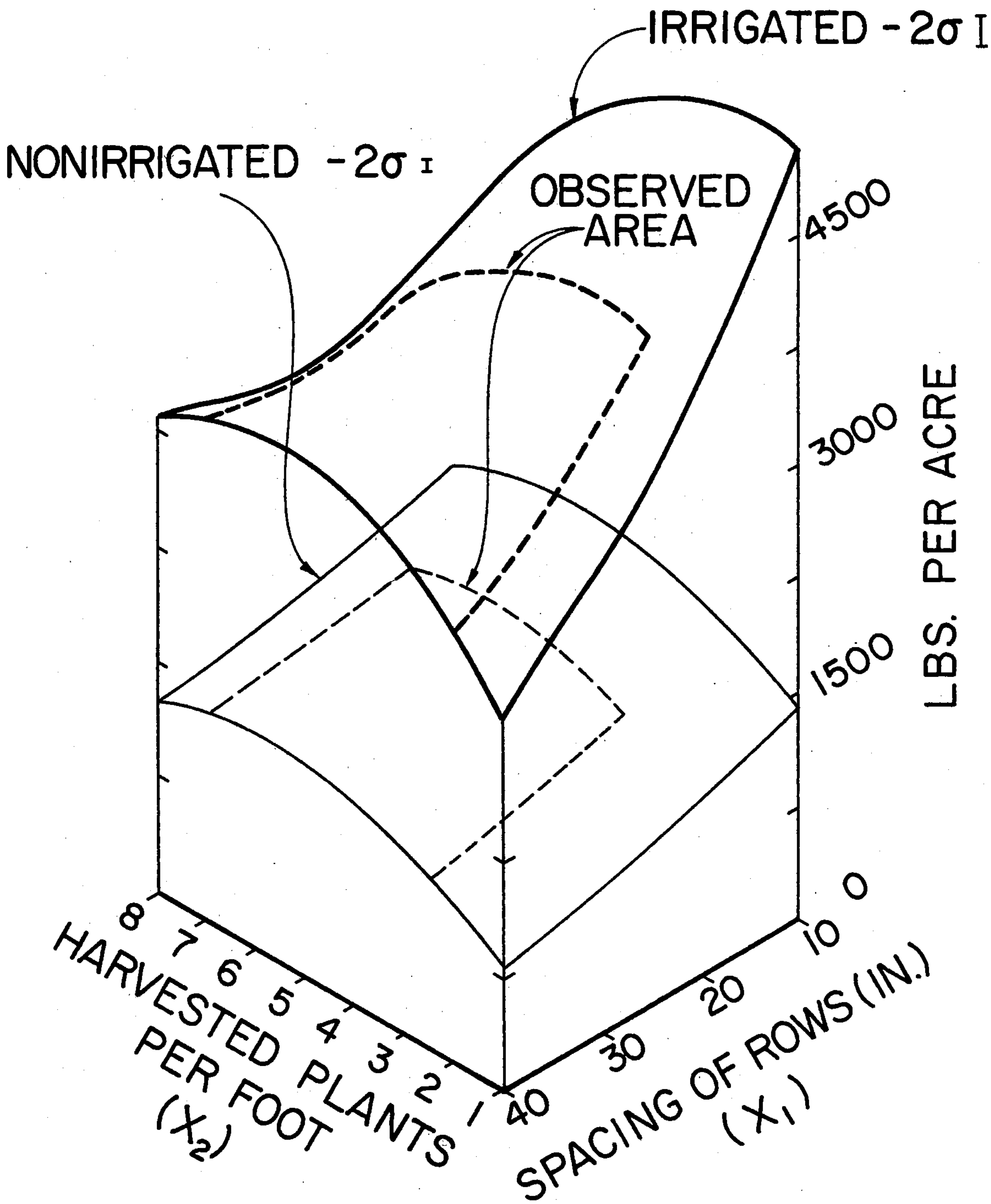

Figure 2. Surface Response for Irrigated and Nonirrigated Treatments for 1960.

Y is pounds of unshelled nuts per acre. The models are:

Irrigated $Y = 6530.33 - 170.25X_1 + 1.42X_1^2 + 30.75X_2 - 45.63X_2^2 + 11.91X_1X_2$

Nonirrigated $Y = 1452.91 - 32.43X_1 + 0.22X_1^2 + 266.42X_2 - 26.53X_2^2 + 0.90X_1X_2$

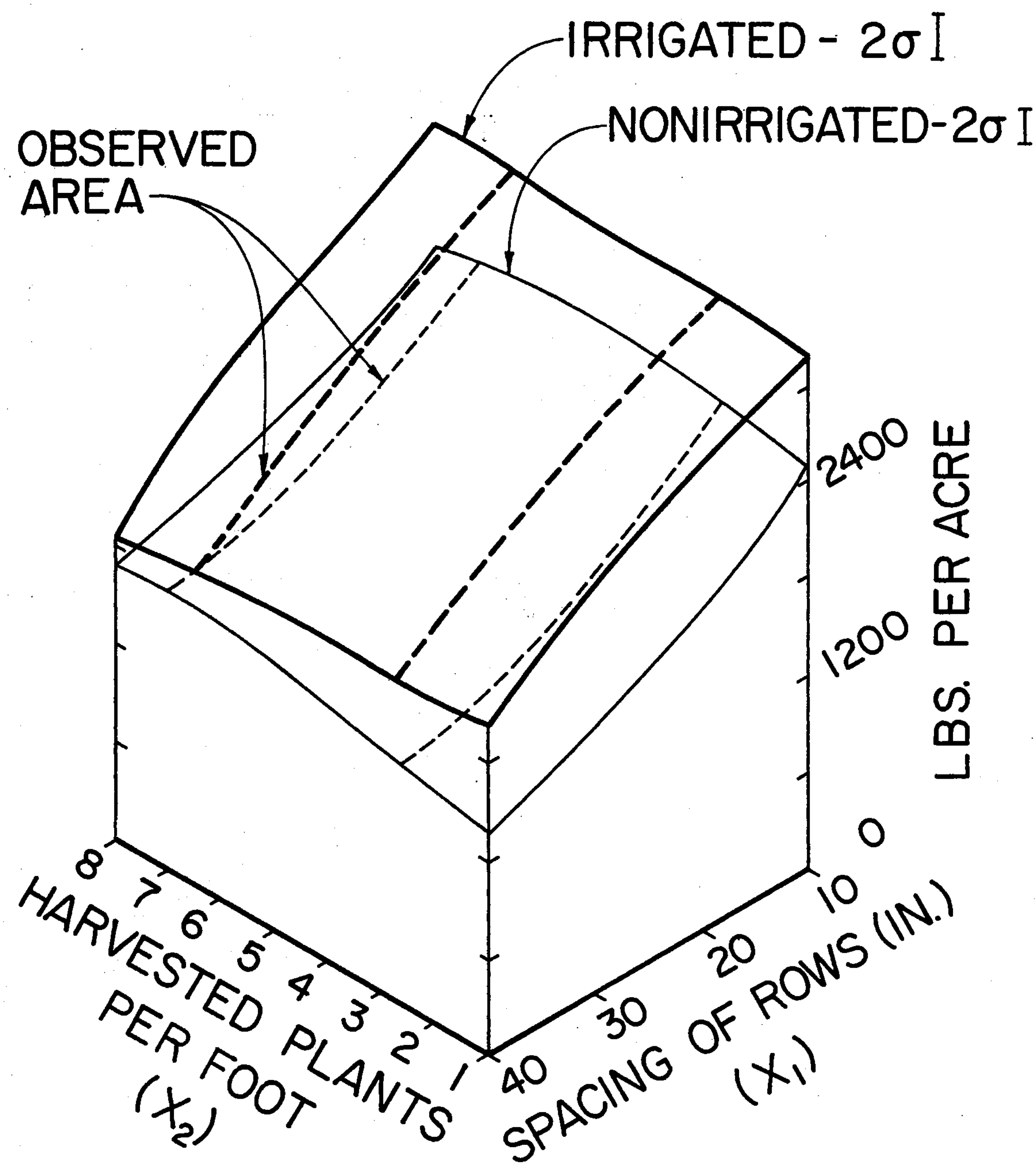

Figure 3. Surface Response for Irrigated and Nonirrigated Treatments for 1960.

Where $\hat{Y}$ is pounds of unshelled peanuts per acre, the models are:

Irrigated $\hat{Y} = 3308.61 - 15.59X_1 - 0.41X_1^2 + 9.69X_2 + 1.57X_2^2 - 1.14X_1X_2$

Nonirrigated $\hat{Y} = 2979.36 - 68.91X_1 + 0.63X_1^2 + 75.47X_2 - 8.84X_2^2 + 1.20\ X_1X_2$

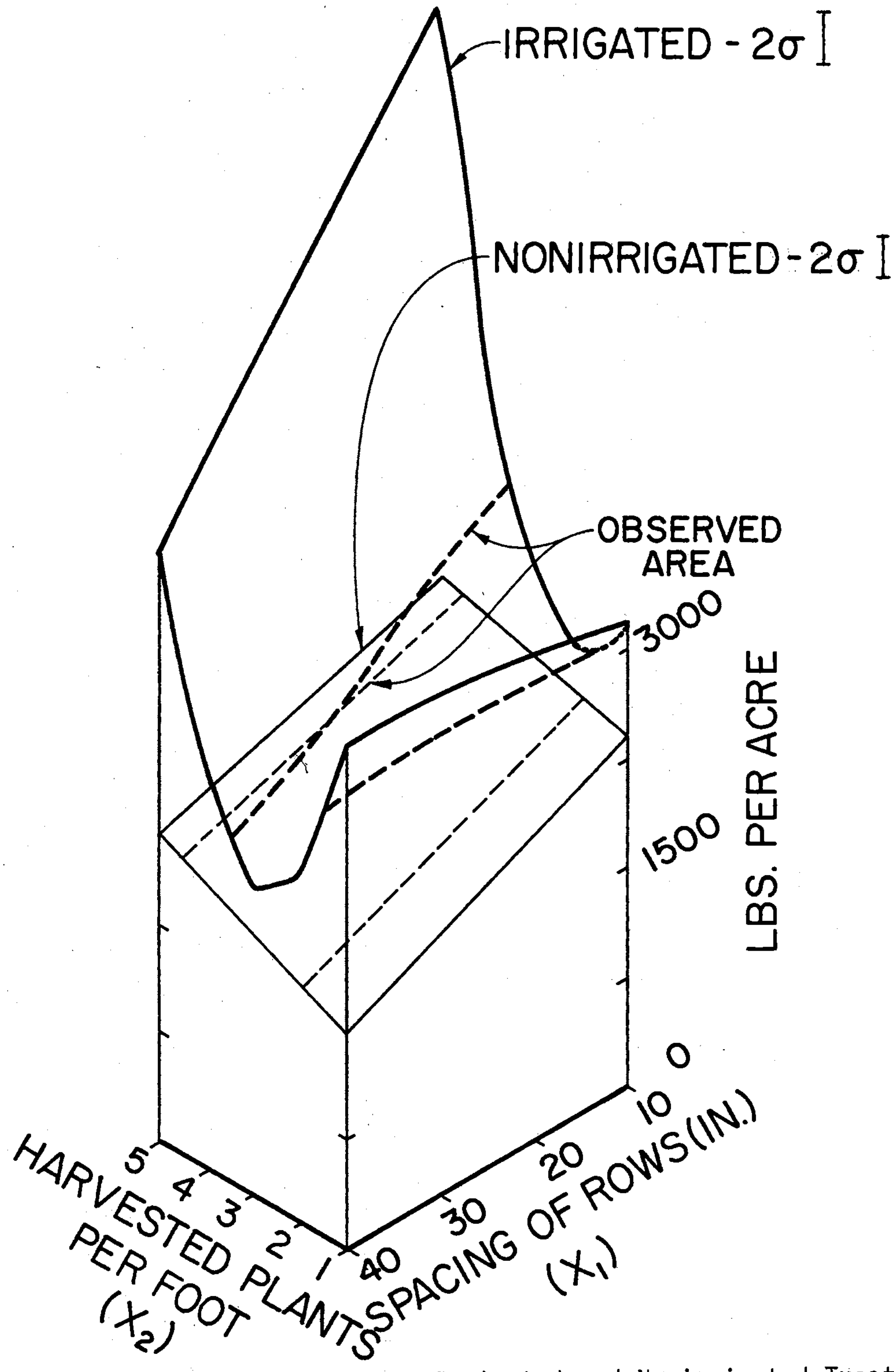

Figure 4. Surface Response for Irrigated and Nonirrigated Treatments for 1964.
$\hat{Y}$ is pounds of unshelled peanuts per acre. The models are:
Irrigated $\hat{Y} = 3966.75 + 49.92X_1 - 0.30X_1^2 - 1400.13X_2 + 421.34X_2^2 - 25.05X_1X_2$.
Nonirrigated $\hat{Y} = 2697.69 - 35.99X_1 + 0.05X_1^2 + 67.03X_2 + 0.39X_2^2 + 2.36X_1X_2$

In contrast to the 1960 data, where 3 to 5 plants on 10 in. rows produced the highest yields, in 1961 (Figure 3) the response was different. Both irrigated and nonirrigated treatments had a somewhat linear response, excluding the extremes of plant spacings. The maximum yield for this year was at the plant spacing of 8 plants per foot on 10 in. row spacing under irrigation, while the minimum yield was at the 1 plant per foot spacing on 40 in. row spacings under nonirrigated conditions.

In 1964, as Figure 4 shows, irrigated conditions gave a response surface which was of a different shape than the preceding two years. The nonirrigated condition gave a flatter response than the 1961 response surface, while the irrigated condition had a greater yield increase with an increase of plant population. Nevertheless, it should be remembered that the upper limit of the observed range was 3.5 and 4.5 plants per foot for the irrigated and nonirrigated treatments, respectively.

Yield Per Plant

Figures 5, 6, 7 and 8 show the surface response surfaces for the three years for grams per plant. The extrapolated surfaces of 1960 and 1961 show that at a high population density, the yield of the plants was unaffected by irrigation on wide rows. Thus in 1960, the surfaces of the irrigated and nonirrigated treatments intersected at about the 6.5 plants per foot level on 40 in. row spacing at 8 plants per foot on about a 35 in. row spacing. In 1961, this intersection occurred at the 6 plants per foot region of the 40 in. row and at about 8 plants per foot on about a 28 in. row spacing. This phenomenon was not observed in the 1964 response, and was not evident in the yield of pounds per acre in 1960 and 1961.

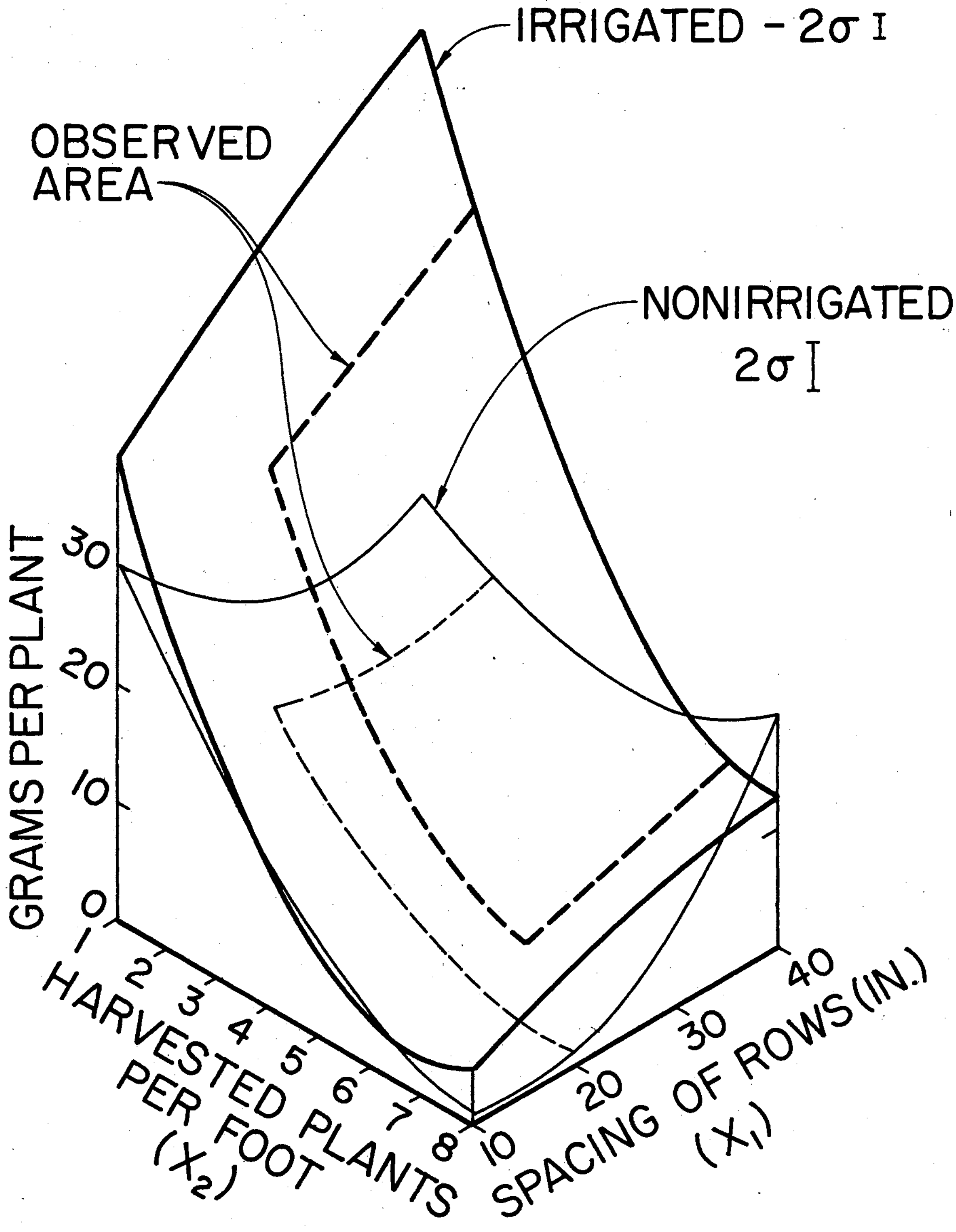

Figure 5. Surface Response for Irrigated and Nonirrigated Treatments for 1960 Where $\hat{Y}$ Is Grams Per Plant

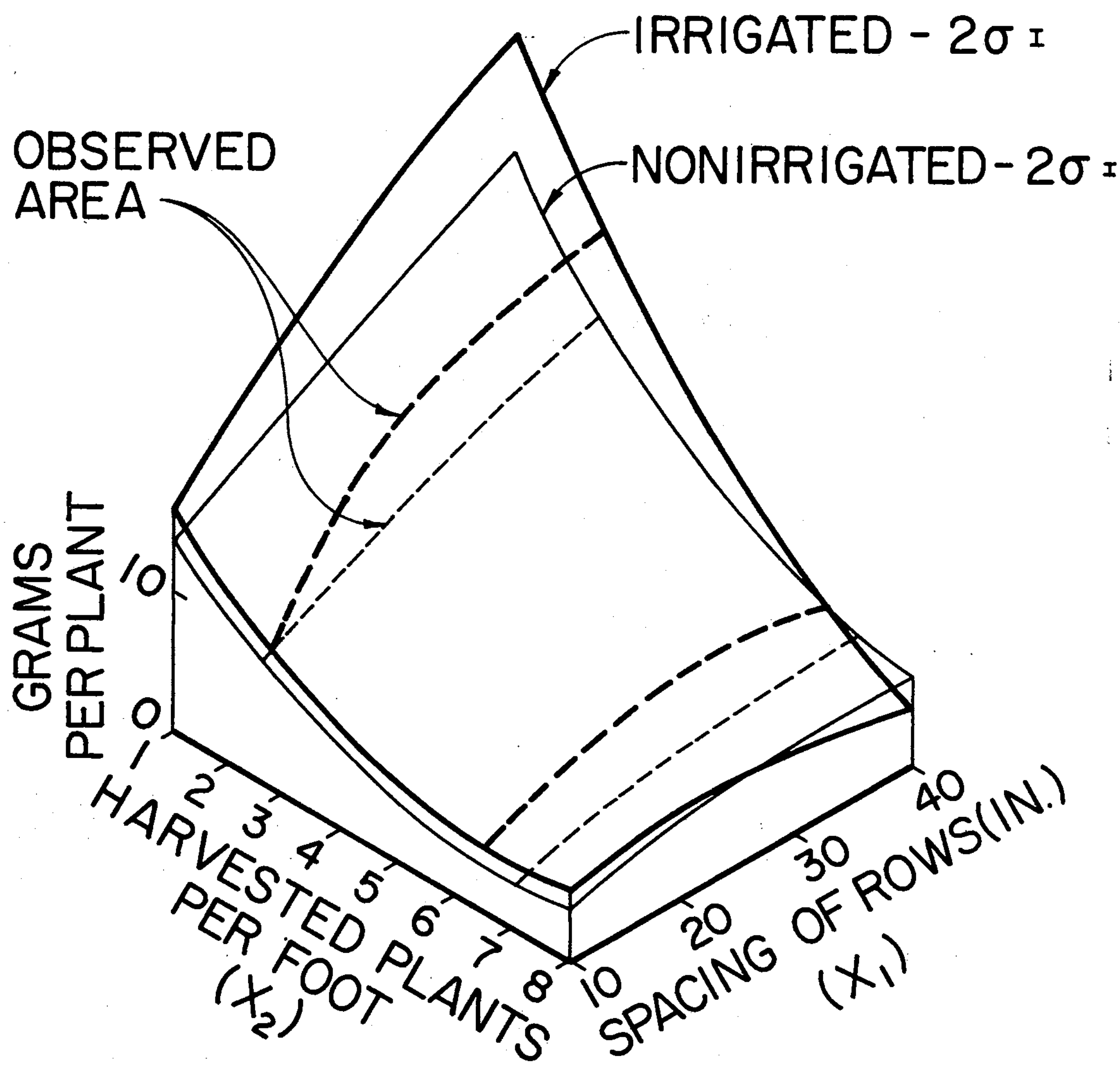

Figure 6. Surface Response for Irrigated and Nonirrigated Treatments for 1961 Where $\hat{Y}$ Is Grams Per Plant

The Models are:

Irrigiated $\hat{Y} = 10.28 + 1.23X_1 - 0.01X_1^2 - 4.19X_2 + 0.40X_2^2 - 0.10X_1X_2$

Nonirrigated $\hat{Y} = 11.72 + 0.73X_1 - 0.01X_1^2 - 4.25X_2 + 0.37X_2^2 - 0.06X_1X_2$

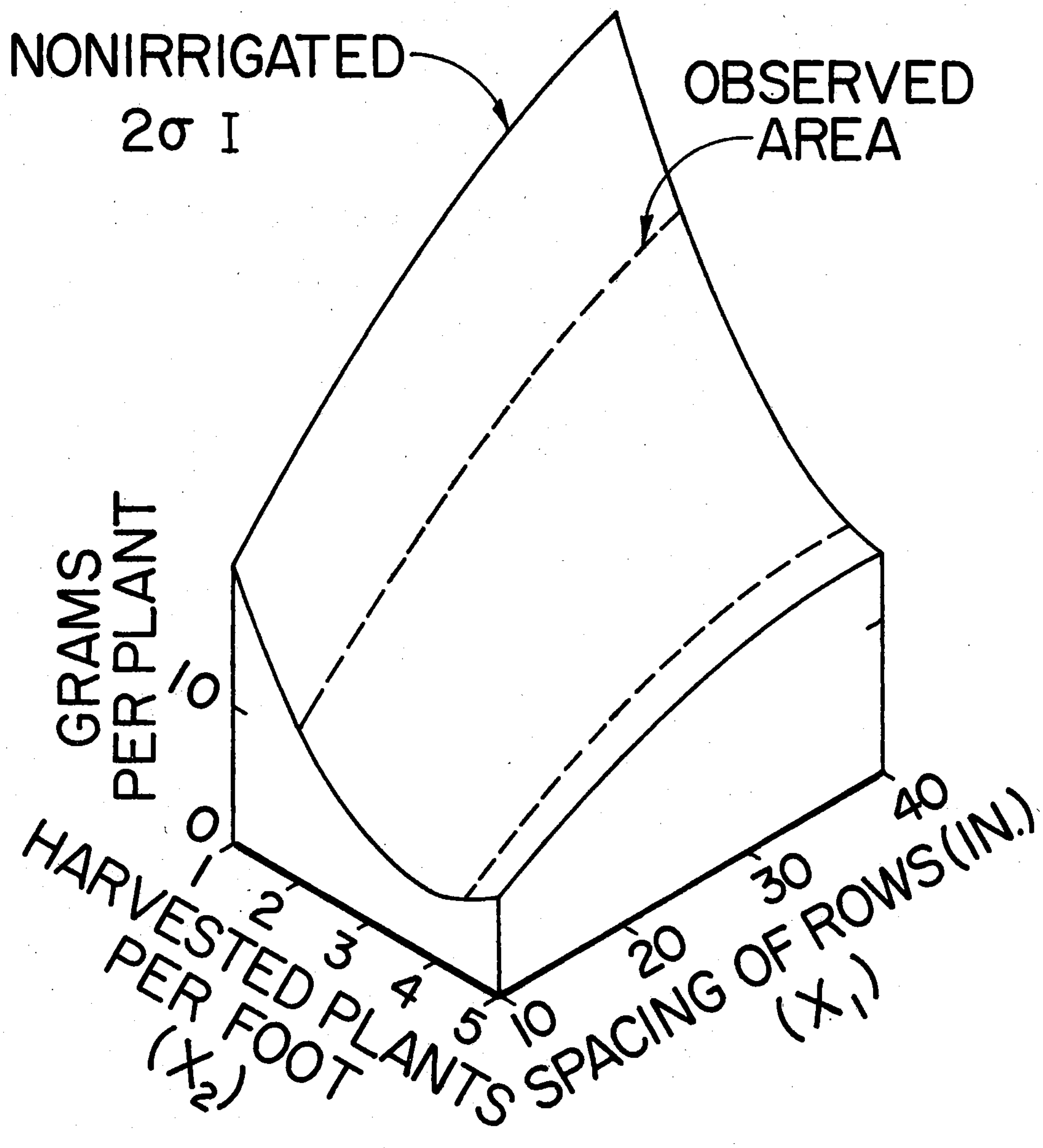

Figure 7. Surface Response for Nonirrigated Treatment for 1964 Where $\hat{Y}$ Is Grams Per Plant

The Model is:

$$\hat{Y} = 17.43 + 1.41X_1 - 0.01X_1^2 - 11.42X_2 + 1.53X_2^2 - 0.11X_1X_2$$

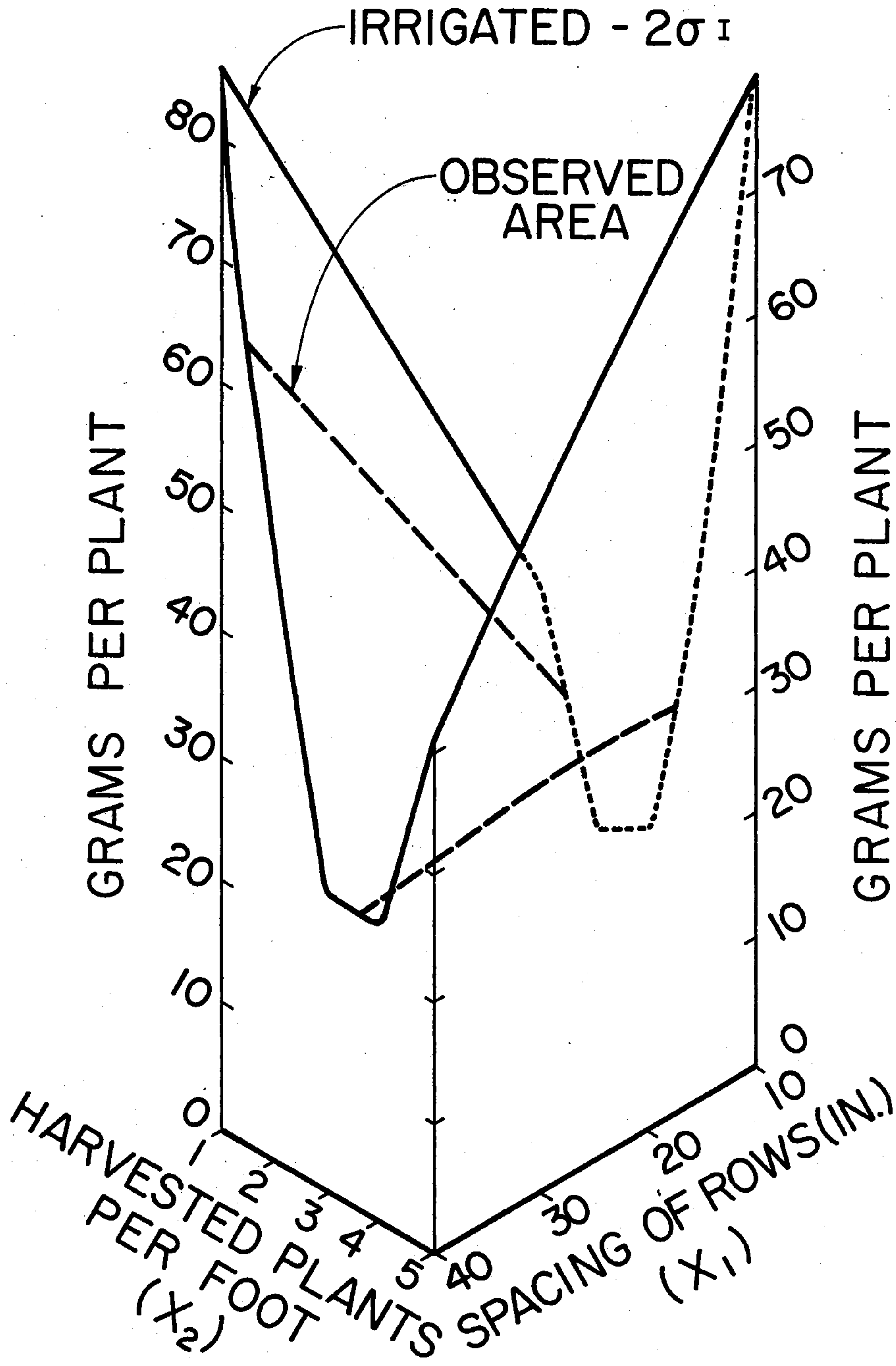

Figure 8. Surface Response for Irrigated Treatment for 1964 Where $\hat{Y}$ Is Grams Per Plant

The Model is:

$$\hat{Y} = 35.92 + 2.85X_1 - 0.01X_1^2 - 37.96X_2 + 9.71X_2^2 - 0.77X_1X_2$$

Figure 5 shows the surface response for both irrigated and nonirrigated treatments of 1960. As the surfaces show, the general tendency for the response was concave upwards. As expected, the maximum grams per plant occurred at the low plant populations, 1 to 2 plants per foot, on wide rows, 40 in. This is seen in both irrigated and nonirrigated treatments. The major difference between the irrigated and the nonirrigated treatments was that the irrigated treatments had a higher production per plant at low populations. Furthermore, the ratio of grams per plant to plant spacing was smaller at the higher plant population than at the lower populations.

Figure 6 shows the 1961 surfaces. At the narrow row spacings the value of the irrigated treatments was slightly higher than that of the nonirrigated, for all plant spacings. The influence of row spacings was greater than that of plant spacings for both treatments at the low population density. Thus the highest value attained by both irrigated and nonirrigated treatments occurred at the 1 plant per foot level on 40 in. row spacings.

Figures 7 and 8 show the response for both irrigated and nonirrigated treatment for 1964. As the figures show, the response of the irrigated treatment was more complex than the nonirrigated, and both more complex than the previous years. One possible explanation for this is that the range of plant spacings which occurred in this year was the smallest encountered. Nevertheless, the general tendency of the preceding years holds true that plants with the largest growing area have the highest yield. The irrigated yield at the 1 plant per foot spacing on 40 in. rows was unrealistic - 83.75 grams. Furthermore, the yield attained by the nonirrigated treatment exceeded that of the irrigated treatment of 1961.

South Mature Kernels

One important characteristic of the quality of the crop is the percentage of sound mature kernels (SMK). This value is determined by the total percentage of undamaged kernels remaining on a 15/64 in. slotted sieve plus sound splits. Since this characteristic is based on size, then it is primarily dependent on the number of days through which the kernels develop or the length of the growing season. The standard deviations obtained from the correlation analysis were too small to be plotted and thus were omitted from the graphs.

In the response surface of 1960 (Figure 9) very little effect of the plant spacing and row spacing is seen on the percent SMK. The percentage of SMK for this year was the highest for the three years studied. In general, increasing the plant population on the 40 in. rows increased the SMK, while on the 10 in. rows increasing the plant population decreased the SMK. This observation was more pronounced under irrigation than on the nonirrigated plots. The range of calculated values was about 69.4% for the nonirrigated 20 in. rows of 6 plants per foot to 73.3% for the same plant spacing on 30 in. rows for irrigated treatment.

Generally, the 1961 surfaces (Figure 10) show that the nonirrigated treatments had a higher percentage of SMK, except at the 6 to 8 plants per foot level across all row spacings. When the plant spacing was between 4 and 5 plants per foot, for both irrigated and nonirrigated treatments, the same percentage of SMK resulted for all row spacings.

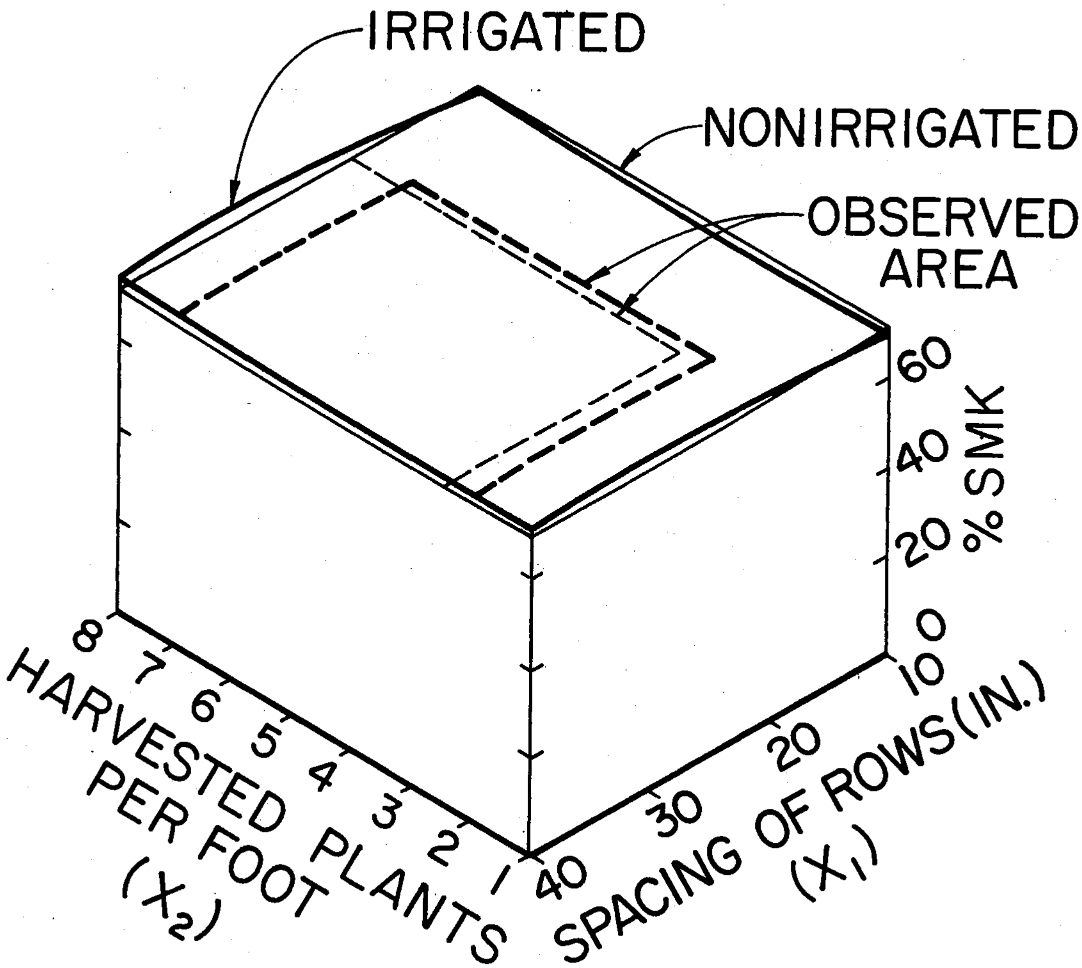

Figure 9. Surface Response for Irrigated and Nonirrigated Treatment for 1960 Where $\hat{Y}$ Is Percent of Sound Mature Kernels

The Models are:

Irrigated $\hat{Y} = 66.18 + 0.52X_1 - 0.01X_1^2 - 0.74X_2 + 0.06X_2^2 + 0.01X_1X_2$

Nonirrigated $\hat{Y} = 74.22 - 0.26X_1 + 0.04X_1^2 - 0.73X_2 + 0.04X_2^2 + 0.01X_1X_2$

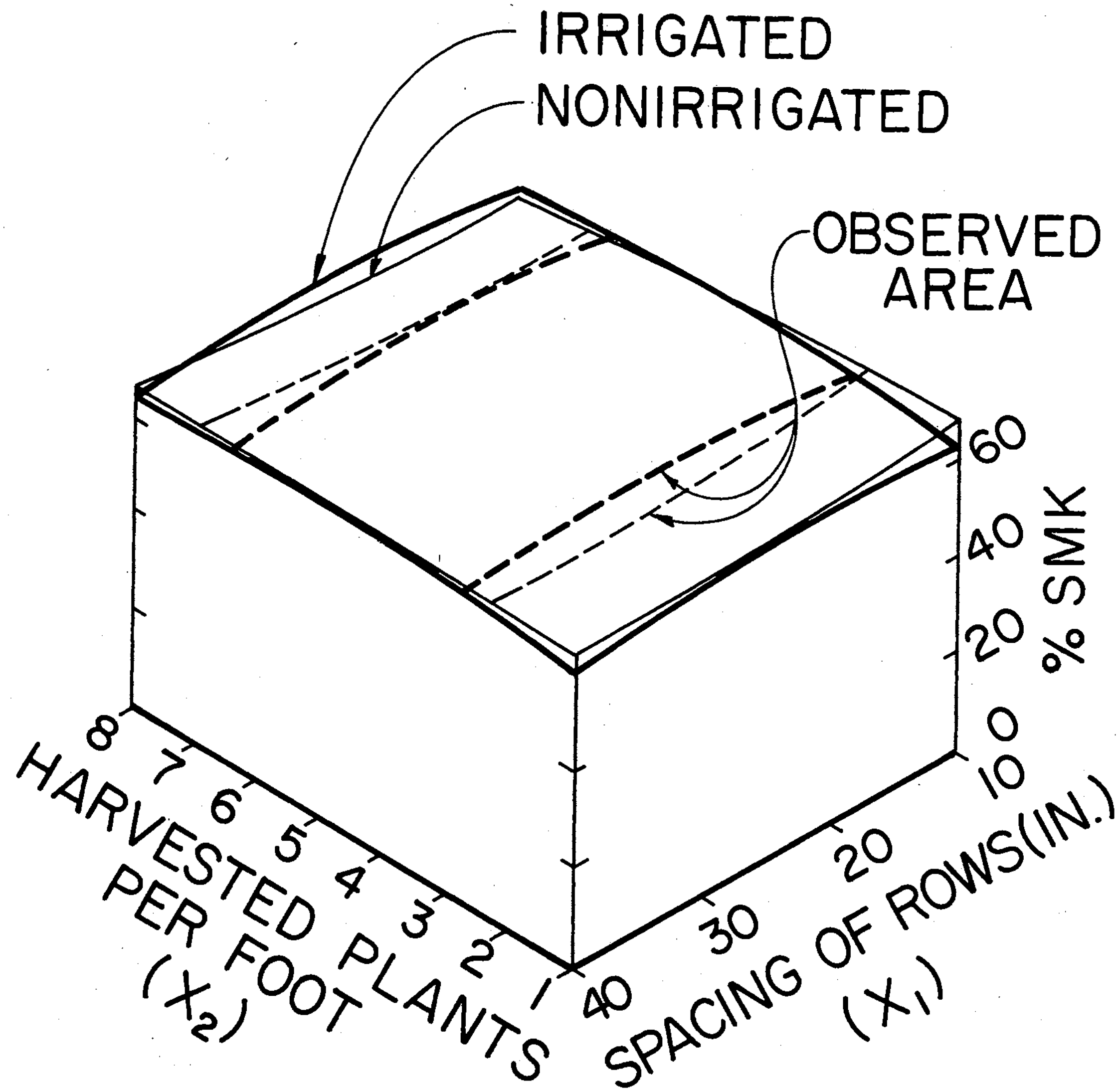

Figure 10. Surface Response for Irrigated and Nonirrigated Treatments for 1961 Where Y Is Percent Sound Mature Kernels

The Models are:

Irrigated $\hat{Y} = 57.16 + 0.46X_1 - 0.01X_1^2 + 2.02X_2 - 0.24X_2^2 + 0.01X_1X_2$

Nonirrigated $\hat{Y} = 74.88 - 0.48X_1 + 0.01X_1^2 - 2.46X_2 + 0.08X_2^2 + 0.05X_1X_2$

This is in contrast to the 1960 study when the percentage of SMK was higher for the irrigated in all but the 10 in. row spacing. The highest and the lowest percentage of SMK was attained by nonirrigation on 10 in. rows and at plant population density of 1 and 8 plants per foot, respectively.

In 1964, the response surface was almost opposite to the preceding years, as seen in Figure 11. In contrast to the relatively flat surfaces of the preceding years, both irrigated and nonirrigated treatments had a response which was slightly concave downwards. The overall percentage of SMK was lower than that of 1960 and wider in range than 1961. The general trend for this year was that as row spacings decreased the percentage of SMK increased under irrigation, but decreased under nonirrigated conditions.

Other Kernels

The final aspect of the quality of the crop which was investigated was the percentage of other kernels (%OK). The percentage OK is the percent of undamaged kernels going through a 15/64 in. slotted sieve. The OK is inferior in price to the SMK, thus a low percentage of OK is desirable. As with SMK, the amount of OK produced by the crop is determined by the length and characteristics of the growing season. Thus like the SMK, the percentage of OK varied from year to year.

In these sets of figures, the magnitude of twice the standard deviation should be noted. The ratios of the 2σ to $\hat{Y}$ were the largest obtained for all the response surfaces obtained in this study. This was expected as the variables used in the correlation model affected

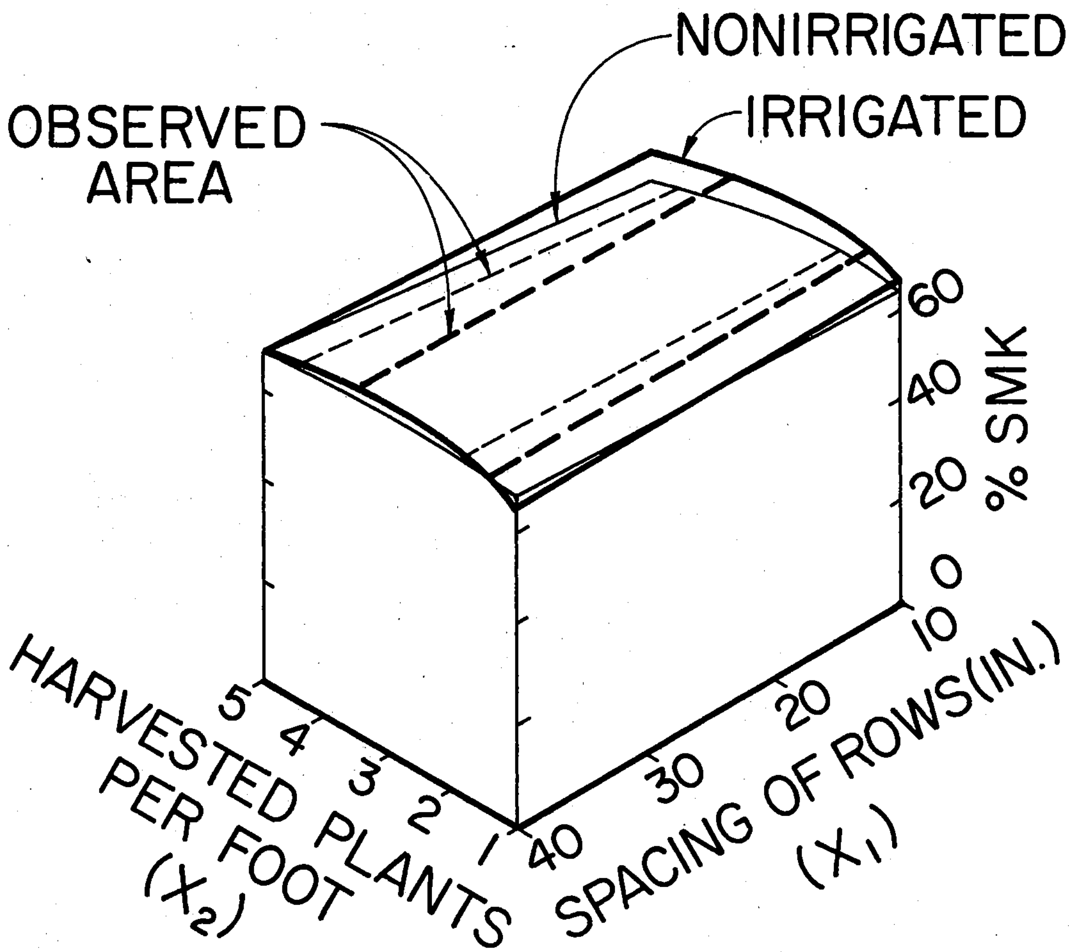

Figure 11. Surface Response for Irrigated and Nonirrigated Treatments for 1964 Where $\hat{Y}$ Is Percent Sound Mature Kernels

The Models are:

Irrigated $\hat{Y} = 63.53 - 0.14X_1 - 0.00X_1^2 + 5.60X_2 - 1.23X_2^2 + 0.06X_1X_2$

Nonirrigated $\hat{Y} = 65.34 - 0.20X_1 + 0.01X_1^2 + 1.29X_2 - 0.68X_2^2 + 0.08X_1X_2$

the final response of the magnitude of the other kernels only to a small degree.

The range of percentage OK encountered in 1960 (Figure 12) was small, ranging from 1.8 percent to 4.1 percent over the observed range and 1.6 to 5.3 percent over the extrapolated range. The nonirrigated treatments had a higher value than that of the irrigated, except for the 8 plants per foot plant spacing on 40 in. rows. The maximum difference which occurred between these two treatments was at the 8 plants per foot level on 10 in. rows. The value of the irrigated treatment was less than a half of the nonirrigated treatment at this plant density. These surfaces also showed that row spacing was more influential on the percentage OK at close plant spacings.

The response of 1961 was different from 1960 (Figure 13). The response for the irrigated treatments became concave upwards while that of the nonirrigated treatments concave downwards. In this year, the irrigated treatments had a higher percentage of OK at about the 1 to 2 plants per foot for all row spacings. The minimum percentage of OK in both treatments was at the 1 plant per foot level on the 10 in. row spacings and the maximum at a plant density of 7 plants per foot on 20 in. rows.

Again, the 1964 surface was different from both 1960 and 1961, as seen in Figure 14. The nonirrigated condition had a higher percentage OK than the irrigated over both row spacings and plant spacings. The projected irrigated treatment for the 5 plants per foot on 10 in. rows was the lowest value in all three years, 0.05 percent OK which is unrealistically low. At this plant density, the nonirrigated treatments had the highest percentage OK, 11.43 percent which is unrealistically high.

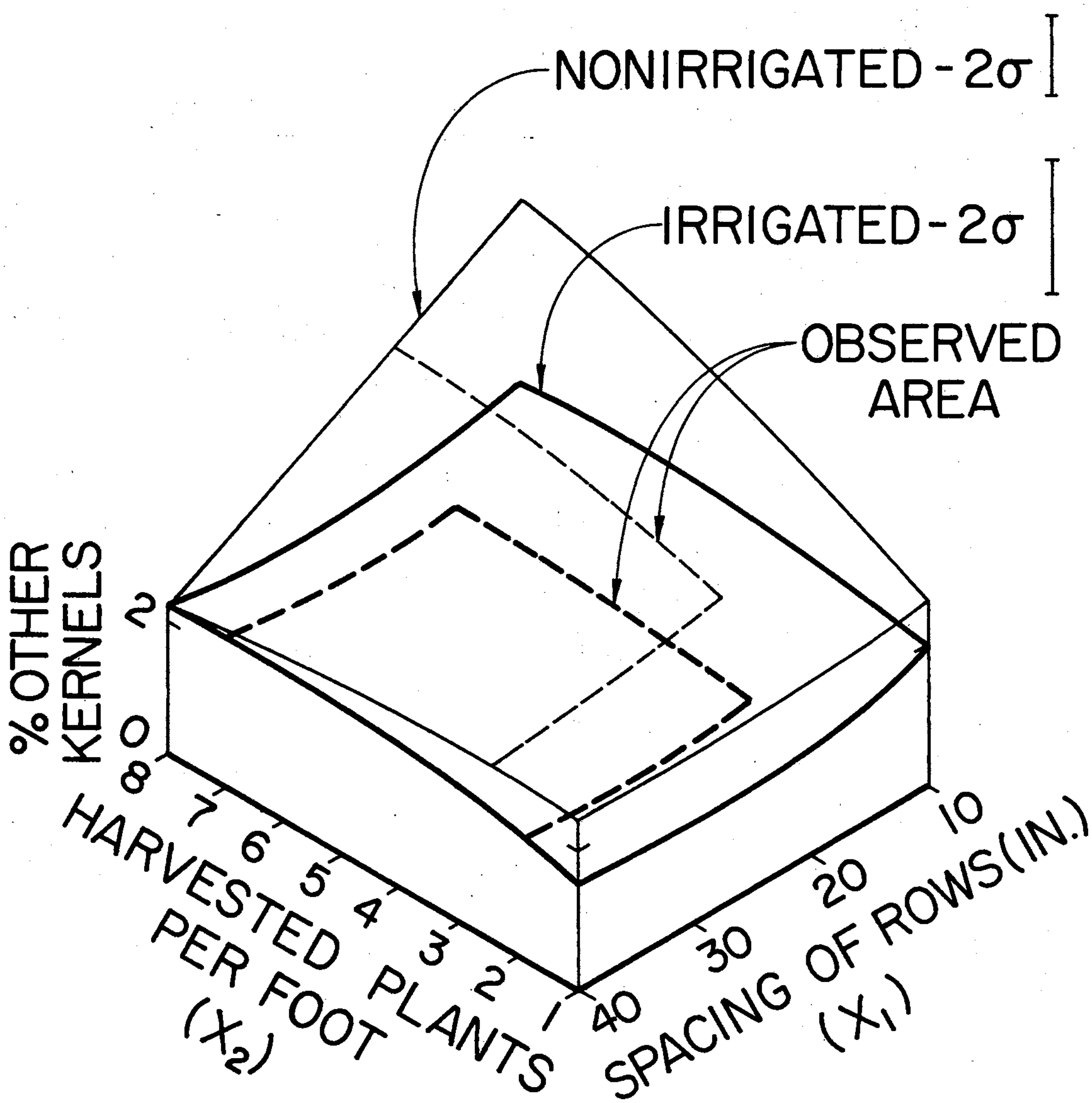

Figure 12. Surface Response for Irrigated and Nonirrigated Treatments for 1960 Where $\hat{Y}$ Is Percent Other Kernels

The Models are:

Irrigated $\hat{Y} = 2.69 - 0.09X_1 + 0.01X_1^2 + 0.20X_2 - 0.02X_2^2 + 0.01X_1X_2$

Nonirrigated $\hat{Y} = 2.47 - 0.02X_1 + 0.01X_1^2 + 0.66X_2 - 0.02X_2^2 + 0.01X_1X_2$

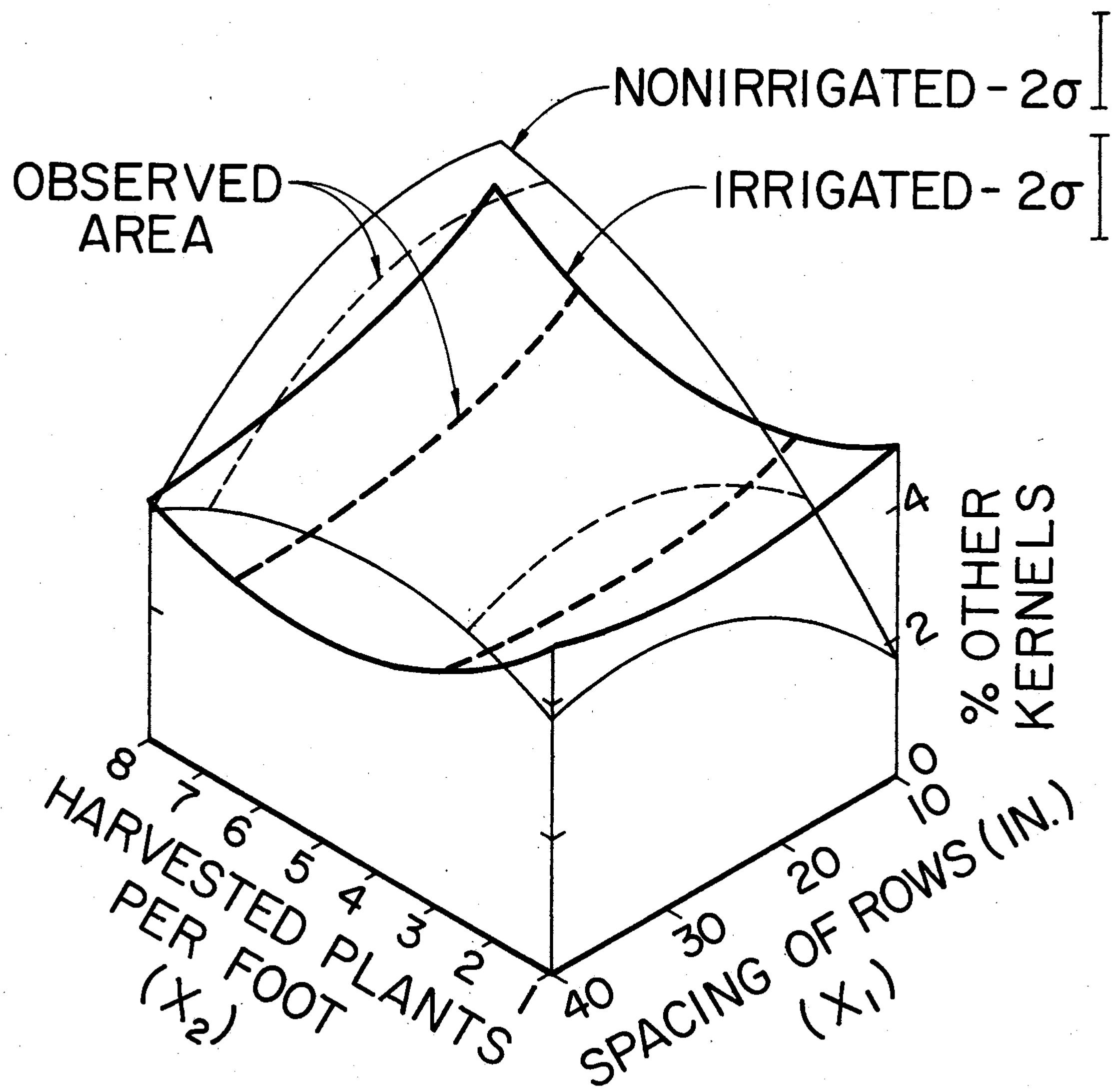

Figure 13. Surface Response for Irrigated and Nonirrigated Treatments for 1961 Where $\hat{Y}$ is Percent Other Kernels

The Models are:

Irrigated $\hat{Y} = 6.45 - 0.09X_1 + 0.01X_1^2 - 0.75X_2 + 0.10X_2^2 - 0.01X_1X_2$

Nonirrigated $\hat{Y} = -2.26 + 0.33X_1 - 0.01X_1^2 + 1.56X_2 - 0.08X_2^2 - 0.02X_1X_2$

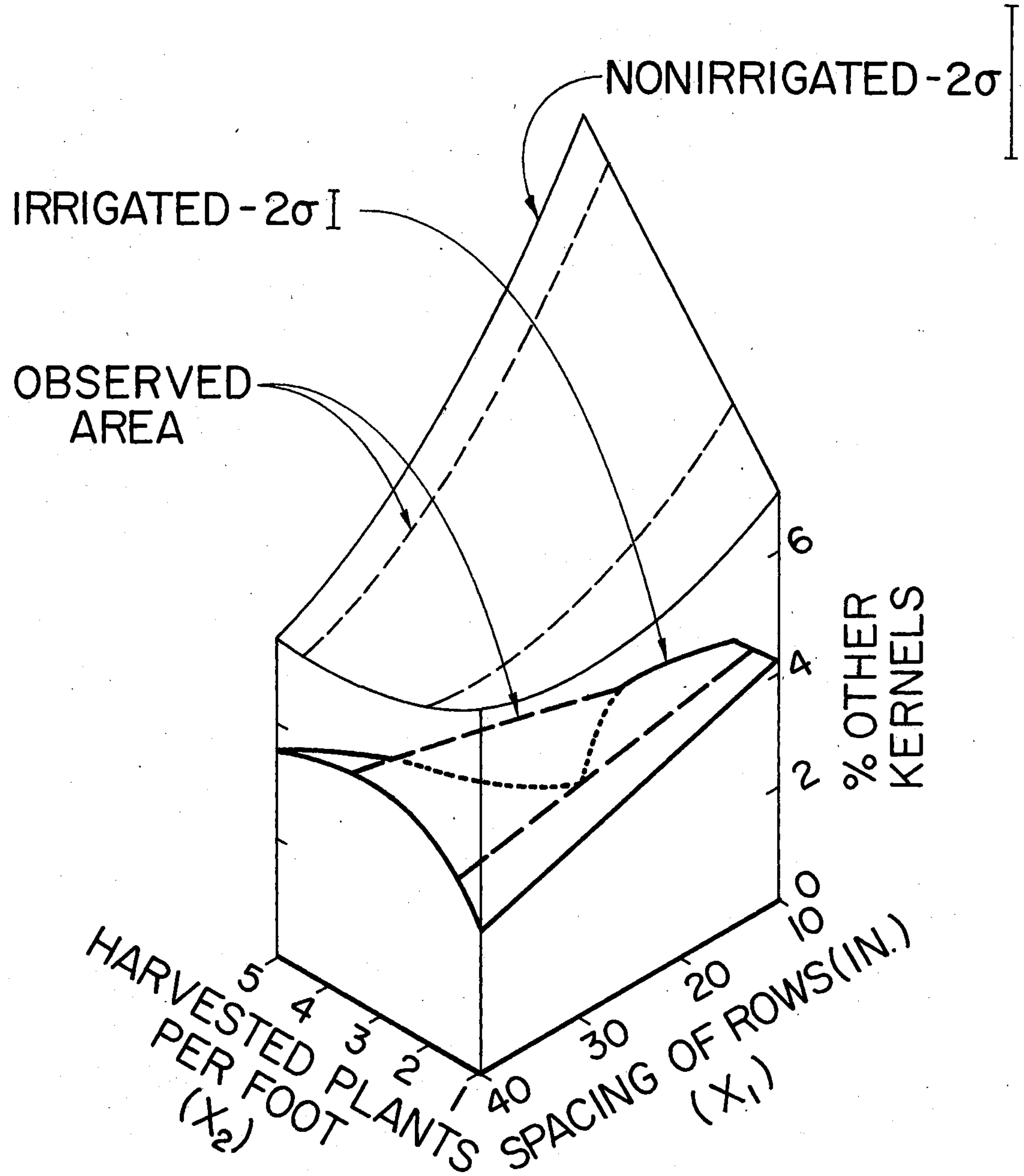

Figure 14. Surface Response for Irrigated and Nonirrigated Treatments for 1964 Where $\hat{Y}$ Is Percent Other Kernels.

The Models are:

Irrigated $Y = 6.45 - 0.09X_1 + 0.01X_1^2 - 0.75X_2 + 0.10X_2^2 - 0.01X_1X_2$

Nonirrigated $\hat{Y} = 7.35 - 0.14X_1 + 0.01X_1^2 + 1.11X_2 + 0.07X_2^2 - 0.04X_1X_2$

Nevertheless, the general trend for the irrigated treatment was an increase in the percent OK across all row spacings at the 1 plant per foot level, and a decrease in the percentage of OK across all row spacings at the 8 plants per foot level. For the nonirrigated treatments, the 40 in. row spacing was slightly affected by the plant spacings, but the 10. row spacing was greatly affected.

Net Value of Crop

An important measure of the success of a crop is the value of the crop or its monetary returns. Figures 15, 16 and 17 are the net values of the crop--gross values minus the seed costs. The computed gross value is the value of the crop in the field and from which no overhead expenses have been deducted. The seed cost value assumes that medium size, certified seed was used in planting and that the seed had 85 percent germination.

Figure 15 shows the 1960 response. Due to the high percentage of SMK and low OK, the surface responses look similar to that of the crop yield. Unlike the yield responses however, the high populations for both irrigated and nonirrigated treatments had a low return. At close row spacings, the gross value realized did not compensate for the costs of additional seed, thus the optimum plant spacing for this year would have been 3 to 5 plants per foot for all row spacings. In comparing irrigated and nonirrigated treatments, the irrigated value ranged from about twice to three-and-a-half times that of the nonirrigated. In both irrigated and nonirrigated treatments, the maximum value attained was on the 10 in. row spacings, with the plant spacing of 1 plant per foot under irrigation and 4 plants per foot under nonirrigated conditions.

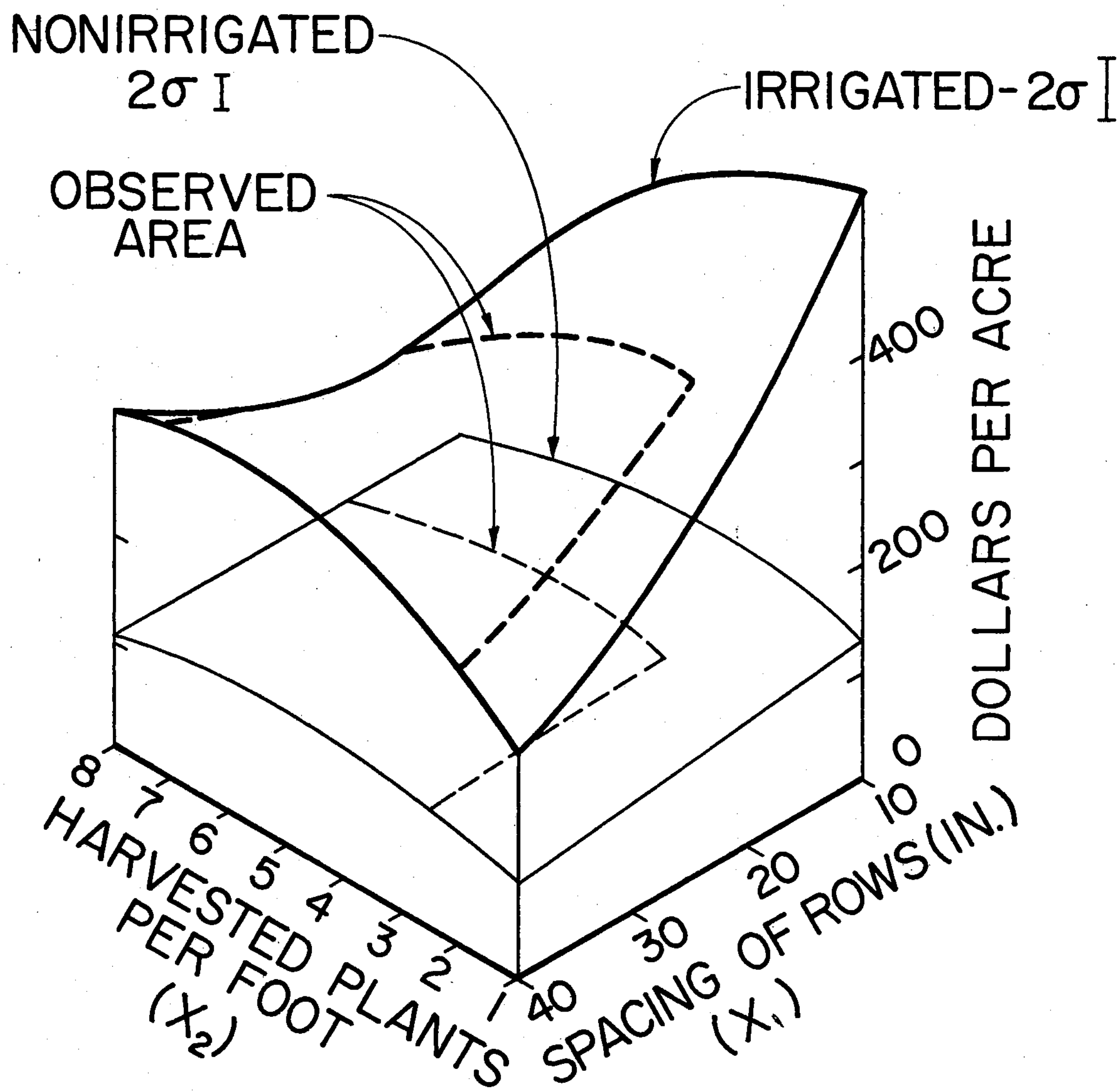

Figure 15. Surface Response for Irrigated and Nonirrigated Conditions for 1960 Where Y Is Dollars Per Acre

The Models are:

Irrigated $\hat{Y} = 764.37 - 23.04X_1 = 0.19X_1^2 - 19.81X_2 - 5.43X_2^2 + 2.09X_1X_2$

Nonirrigated $\hat{Y} = 127.14 - 1.15X_1 - 0.01X_1^2 + 19.53X_2 - 2.84X_2^2 + 0.19X_1X_2$

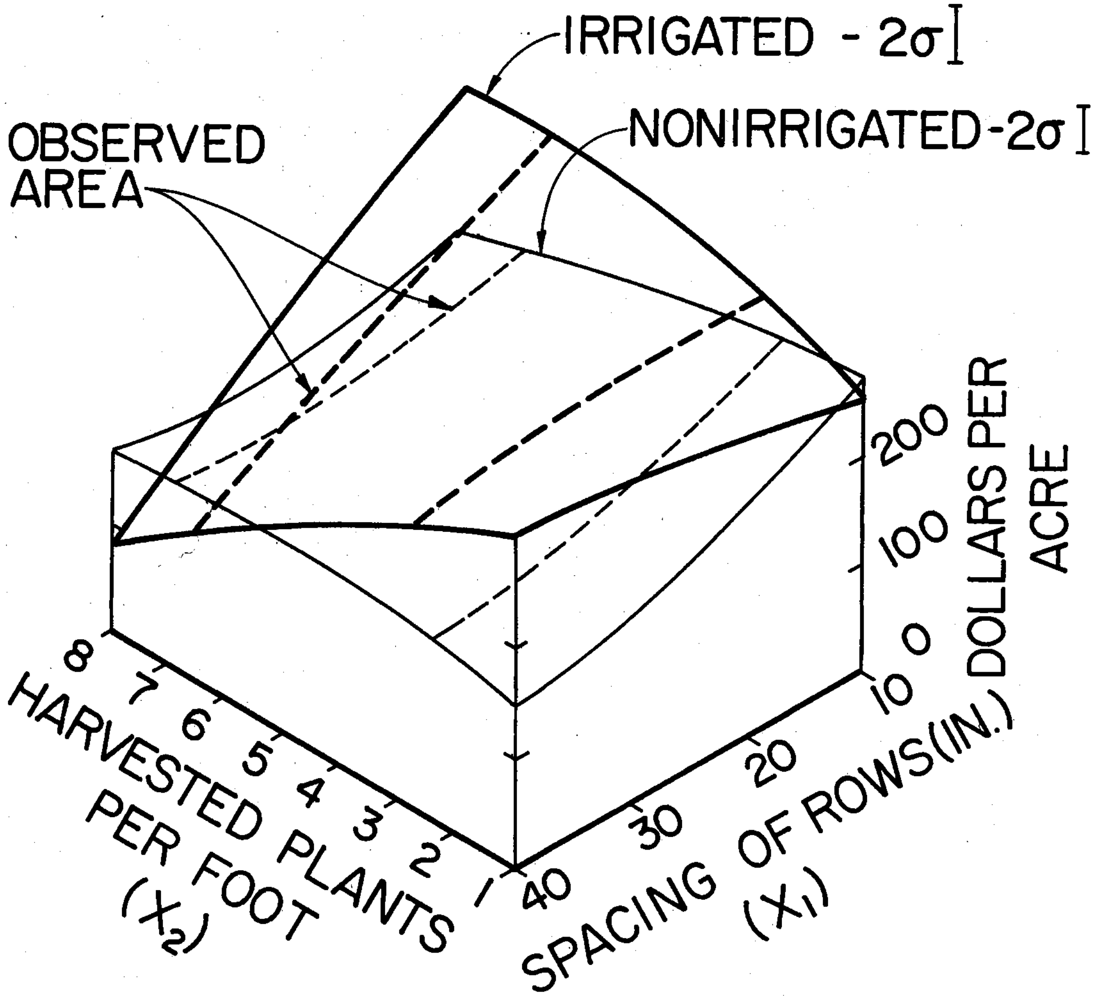

Figure 16. Surface Response for Irrigated and Nonirrigated Treatments for 1961 Where $\hat{Y}$ Is Dollars Per Acre

The Models are:

Irrigated $\hat{Y} = 176.27 + 6.05X_1 - 0.06X_1^2 + 44.97X_2 - 2.33X_2^2 - 1.45X_1X_2$

Nonirrigated $\hat{Y} = 351.08 - 8.00X_1 - 0.07X_1^2 - 8.55X_2 + 1.08X_2^2 + 0.51X_1X_2$

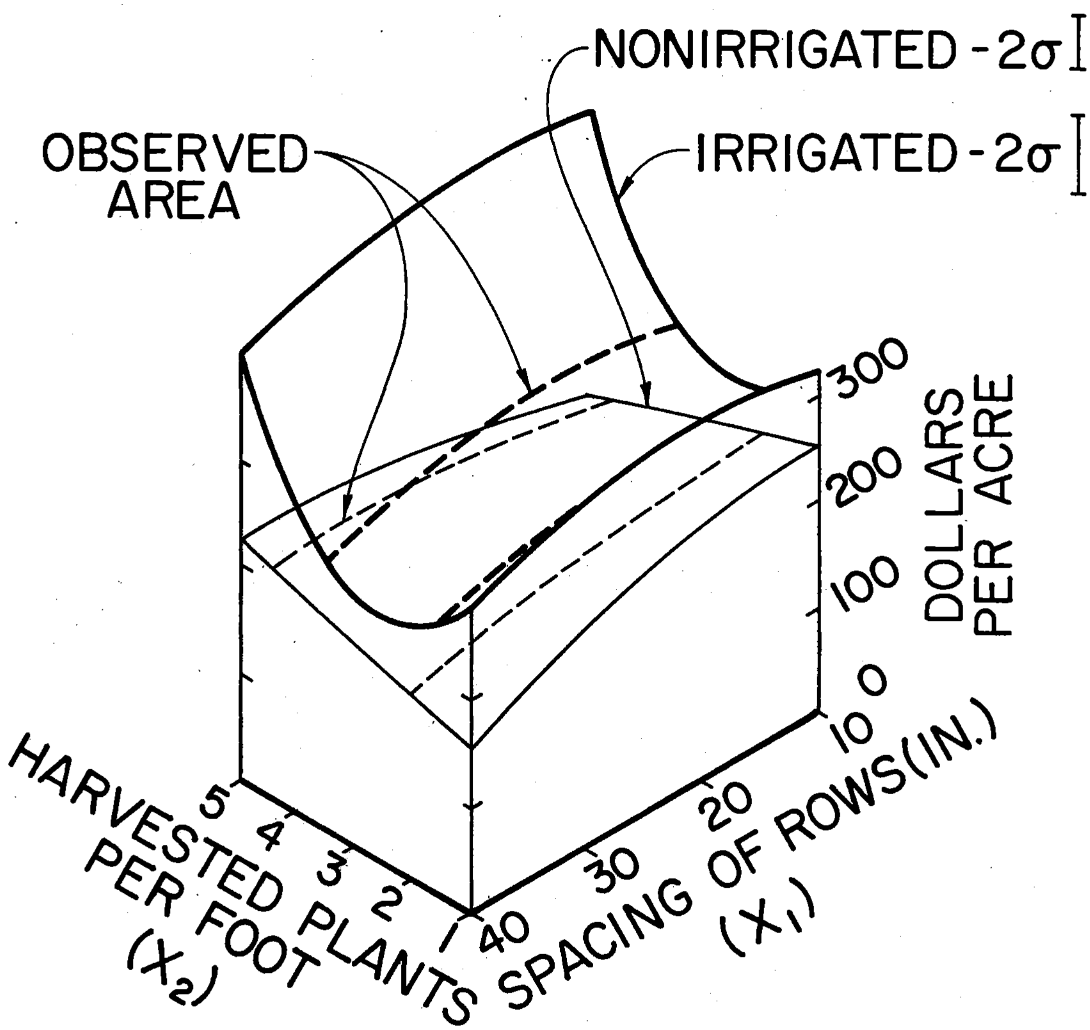

Figure 17. Surface Response for Irrigated and Nonirrigated Treatments for 1964 Where Y Is Dollars Per Acre

The Models are:

$$\text{Irrigated } Y = 410.99 + 4.97X_1 - 0.13X_1^2 - 151.68X_2 + 29.67X_2^2 + 0.04X_1X_2$$

$$\text{Nonirrigated } Y = 292.33 - 1.14X_1 - 0.06X_1^2 - 32.97X_2 + 0.02X_2^2 + 1.22X_1X_2$$

In comparing the 1961 values, as shown in Figure 16, the response surface did not resemble that of the crop yield response. For the irrigated treatments, the relatively high percentage of OK, coupled with the relatively low crop yield on the high plant population made the value of the crop at the high population lower than that of the nonirrigated treatment. Thus the two surfaces intersect from the points 8 plants per foot on 30 in. rows to 5 plants per foot on 40 in. rows. The two surfaces had the widest differences at the lowest plant density. The ideal range of plant population for this year would thus be dependent on the row spacing which was selected.

Figure 17 shows the response surface for the 1964 year. Like the 1960 response, these surfaces resemble that of the crop yield. The value of the nonirrigated treatments was the highest of the three years if conventional plant density was considered. Conventional plant density implied rows of 30 to 40 in. wide and plant spacings of 2 to 4 plants per foot. For the irrigated treatments, the rather high yield coupled with the low percentages of OK and high percentages of SMK enhanced the value of the crop, thereby giving an exceptionally high return.

1968 Study

Table IV shows the average yield and the analysis of variance for yield of 1968. Since this was a latin square design, columns in the table refer to plots in the east-west direction of the experimental area, while rows refer to those in the north-south direction. As the analysis of variance shows, the yield obtained from the various treatments was not statistically significant at levels less than 5 percent.

Nevertheless, the 1,300 pounds of shelled peanuts per acre difference between the 12 in. row spacings of the irrigated versus the nonirrigated treatments seems large.

TABLE IV

1968 YIELD CHARACTERISTICS

Analysis of Variance of Yield of Harvested Area

Source	D.F.	S.S.	M.S.
Total	15	34.09	
Column	3	8.79	2.93
Rows	3	7.70	2.56
Treatments	3	2.30	0.76
Irrigation	1	1.00	
Spacing	1	0.49	
Irrigation X Spacing	1	0.81	
Error	6	15.30	2.55

	Irrigated		Nonirrigated	
	12-in Rows	36-in Rows	12-in Rows	36-in Rows
Yield: Pounds Per Acre	4367	3658	3053	3355
Grams Per Plant	18.57	39.74	15.85	42.03
Plant Density (Plants/Ft)	2.42	3.13	2.35	2.61

1969 and 1971 Studies

Table V shows the results of the 1969 and 1971 studies. Like the 1968 study, the results of the crop yield was not statistically significantly different at levels less than 5 percent, but an actual difference in the yields of the 12 and 36 in. row spacings did exist. Row orientation did not affect the yields of the crop, or the quality of the crop, as measured by the percentage of SMK. Nevertheless, the percentage of SMK was high for the two years, in excess of 70 percent.

In 1971 the plant spacings in the rows was about a third that of the 1969 season, but the plant yield which resulted was less than a third of the yield of the plants of 1969. This is consistent with that which was found in the previous years of study. This difference in plant yield between 1969 and 1971 could account for the difference in yield of the crop for the 1971 year.

Discussion

Table III shows the summary of results for the 1960, 1961 and 1964 studies. In considering the yield of unshelled peanuts per acre, the optimum value was approached in all three years by the 10 in. row spacings of 5 plants per foot. The minimum yields which were obtained were on 40 in. row spacings of 1 plant per foot. Except for annual variation obtained in all instances, no other trends were evident. Planting densities, as noted earlier, varied from year to year and were different from the calculated amount of viable seeds which were planted.

Table VII and Figures 18 and 19 show the climatic conditions which were encountered during the years of the study. Since there were no E.S.S.A. temperature recording stations at either the Perkins Agronomy

TABLE V

1969 AND 1971 CROP CHARACTERISTICS

	1969 Row Spacings				1971 Row Spacings			
	12-in Rows Orientation		36-in Rows Orientation		12-in Rows Orientation		36-in Rows Orientation	
	North-South	East-West	North-South	East-West	North-South	East-West	North-South	East-West
Yield: Pounds Per Acre	3448	3811	3130	3085	3270	3220	2590	2680
Grams Per Pound	29.21	30.46	69.82	70.84	9.46	11.32	19.05	18.89
Plant Spacing (Plants/Ft)	1.26	1.32	1.40	1.37	3.59	3.80	4.23	4.90
Percent Sound Mature Kernels	75.3	72.6	72.3	73.0	71.0	73.0	71.0	71.0

Analysis of Variance

1969 Source	D.F.	S.S.	M.S.	1971 Source	D.F.	S.S.	M.S.
Total	11	17.067		Total	11	13.989	
Reps	2	5.527	2.763	Reps	2	0.671	0.335
Treatments	3	4.667	1.556	Treatments	3	5.790	1.930
Spacing	1	3.853	3.853	Spacing	1	5.740	5.740
Orientation	1	0.334	0.334	Orientation	1	0.007	0.007
Spac x Orien	1	0.480	0.480	Spac x Orien	1	0.043	0.043
Error	6	6.873	1.146	Error	6	7.530	1.255

Research Station or at the Caddo Peanut Research Station, the values which are shown are from the Stillwater and the Carnegie 4ENE stations (25). The Stillwater station is approximately 12 miles north of the Perkins Agronomy Research Station, while the Carnegie 4ENE station is approximately 5 miles west of the Caddo Peanut Research Station. The precipitation data were taken at the respective stations.

The wide variation and extreme temperatures encountered during the growing season are shown in Table VI. Since there is little known about the long term effects of temperature on the growth, yield and quality of the peanut fruit, only qualitative analysis of this data is attempted. Thus whether the number of days about 95 or below 60 affect the final quality and quantity of the crop is speculative. Nevertheless, climate does affect the yield and quality of the fruit.

TABLE VI

PERCENT OF MAXIMUM NET VALUE ATTAINED BY TWO PLANTS PER FOOT

	Treatment							
	Irrigated				Nonirrigated			
	Row Spacings (in.)							
Year	40	30	20	10	40	30	20	10
1960	70.49	79.63	87.56	94.30	48.78	58.55	75.62	100.00
1961	59.46	67.89	81.41	100.00	88.57	90.95	89.95	85.5
1964	69.75	82.00	89.45	91.83	49.99	58.77	61.80	59.09

TABLE VII

SUMMARY OF CLIMATOLOGICAL DATA DURING THE SIX YEARS OF STUDY

Location	Year	Month	Monthly Average		Temp. Range (°F)		Number of Days		
			High	Low	High	Low	<95°F	>60°F	>50°F
Stillwater	1960	May*	83.6	58.1	89-69	67-50	-	9	-
		June	89.0	65.3	99-51	81-51	5	2	-
		July	89.7	67.8	99-76	76-56	9	2	-
		Aug.	91.7	67.7	99-85	72-57	6	1	-
		Sept.	88.2	61.1	94-80	70-48	-	9	2
		Oct.	79.1	51.1	92-64	66-30	-	23	12
	1961	May*	80.4	56.0	88-72	69-41	-	11	-
		June	85.6	63.3	97-75	73-51	1	7	-
		July	90.0	67.3	97-82	74-57	5	4	-
		Aug.	89.7	66.4	98-77	73-51	9	3	-
		Sept.	81.5	59.8	98-67	79-44	2	16	5
		Oct.	75.8	50.7	86-64	68-28	-	23	17
Carnegie 4ENE	1964	May*	85.4	60.5	95-68	67-52	-	4	-
		June	91.9	64.0	100-76	74-45	12	5	2
		July	101.5	72.3	108-91	85-59	30	1	-
		Aug.	96.9	68.6	113-84	78-59	16	1	-
		Sept.	85.6	61.5	101-71	71-42	10	15	1
		Oct.	75.6	46.4	92-68	55-29	-	31	16
	1968	May*	80.1	56.5	91-73	67-44	-	13	3
		June	89.3	65.5	100-74	76-57	8	5	-
		July	91.1	69.1	98-82	79-60	9	-	-
		Aug.	94.5	69.2	101-77	76-54	18	2	-

	Sept.	85.0	57.4	96-70	71-45	2	18	5
	Oct.	77.9	50.3	90-62	69-34	-	24	14
1969	May*	85.5	62.2	95-74	72-53	1	6	-
	June	89.8	65.9	105-74	80-52	11	7	-
	July	100.2	72.9	106-91	80-60	29	-	-
	Aug.	94.2	69.5	109-82	75-61	14	-	-
	Sept.	84.6	63.1	96-71	74-49	2	8	1
	Oct.	68.5	47.3	88-47	67-31	1	25	17
1970	May*	87.3	59.2	76-95	49-71	1	8	-
	June	93.2	68.4	87-100	61-75	12	-	-
	July	96.8	71.2	81-105	55-78	19	2	-
	Aug.	89-3	65.3	78-102	54-75	5	1	-
	Sept.	84.7	62.0	58-97	41-76	5	12	3
	Oct.	76.3	52.0	66=82	36-68	-	25	11

*For the month of May, the values are from May 15 to May 31.

Dates of first freeze are:

1960 - October 20
1961 - October 26
1964 - October 20
1968
1969 - October 14
1971

In assessing the role of climate on peanuts, the work of Davis (6) will be mentioned. Under controlled environmental conditions, he found that the minimum time that the Argentine variety of peanut would bloom was 28 days. The temperature in which this occurred was 86 , and which temperature can be regarded as the optimum temperature. Under this condition, the plant reached a peak blooming frequency 4 days after blooming commenced with about 5 flowers per plant per day. Furthermore, his results showed that 87% of the physiologically mature and immature pods were produced from this period. 96% of the crop was produced from the first 22 days of pegging.

Smith (24) showed that under field conditions, Improved Spanish variety required 50 to 60 days from flowering to the formation of mature pods. In combining the data of Smith and Davis, under ideal conditions, 110 days would be needed for the formation of 96% of the crop. Nevertheless, when competition between plants exists, as exemplified by close planting densities, no information can be found with peanuts. Direct information does exist only with soybeans (13).

Implied information is available under greenhouse conditions for close planting densities of peanuts. Using seeds of the Schwartz 21 variety, Bolhuis planted 2 and 3 seeds per pot (3). His results showed that 3 plants per pot produced an average number of flowers higher than that of 2 plants per pot. The flowering difference was attributed to a longer period of flowering of the 3 plants per pot. The fruiting percentages between the 2 and 3 plants per pot was the same, with the major difference being that the 2 plants per pot had a higher amount of ripe pods than the 3 plants per pot. Thus this work would imply that denser plant population would have a lower percentage of mature kernels than less dense plant population, and in this study, the higher percentages of other kernels which were encountered at the high population densities.

Under high plant population density, the fruiting habit of the plant magnifies the importance of the first blooming cycle. The closeness of the plants force the growing portion to become upright, thereby increasing the distance between the gynophore and the soil surface. Pickett (23) has estimated that the maximum distance in which the gynophore will grow and remain viable is about 6 in. Thus flowers which are produced higher than 6 in. above the soil surface could be regarded as being nonproductive. But, flowers which are produced less than 6 in. above the soil surface become farther away from the photosynthetically active portion of the plant, thereby maturing late. Thus the low yield, in terms of grams per plant, which was observed in the high plant population densities could be the resultant of fewer gynophores reaching the surface of the soil, or the gynophores which reach the soil surface being 'starved' by the distance of the photosynthetically active portion of the plant. Under wide row conditions, more lateral growth of the plant is possible thus a lower amount of flowers are produced 6 inches, or farther, from the surface of the soil. This could account for the high grams per plant attained by the wide row spacings. Furthermore, in combining the information by Bolhuis with this, a more uniform crop could be expected in high plant population densities.

Beside the flowering pattern of the plant, another aspect of the plant environment which should be considered is that of the effects of moisture, or water, on the plant. Figures 18 and 19 show the precipitation pattern for the years in which the studies were undertaken. Since supplemental water was provided late in the growing season,

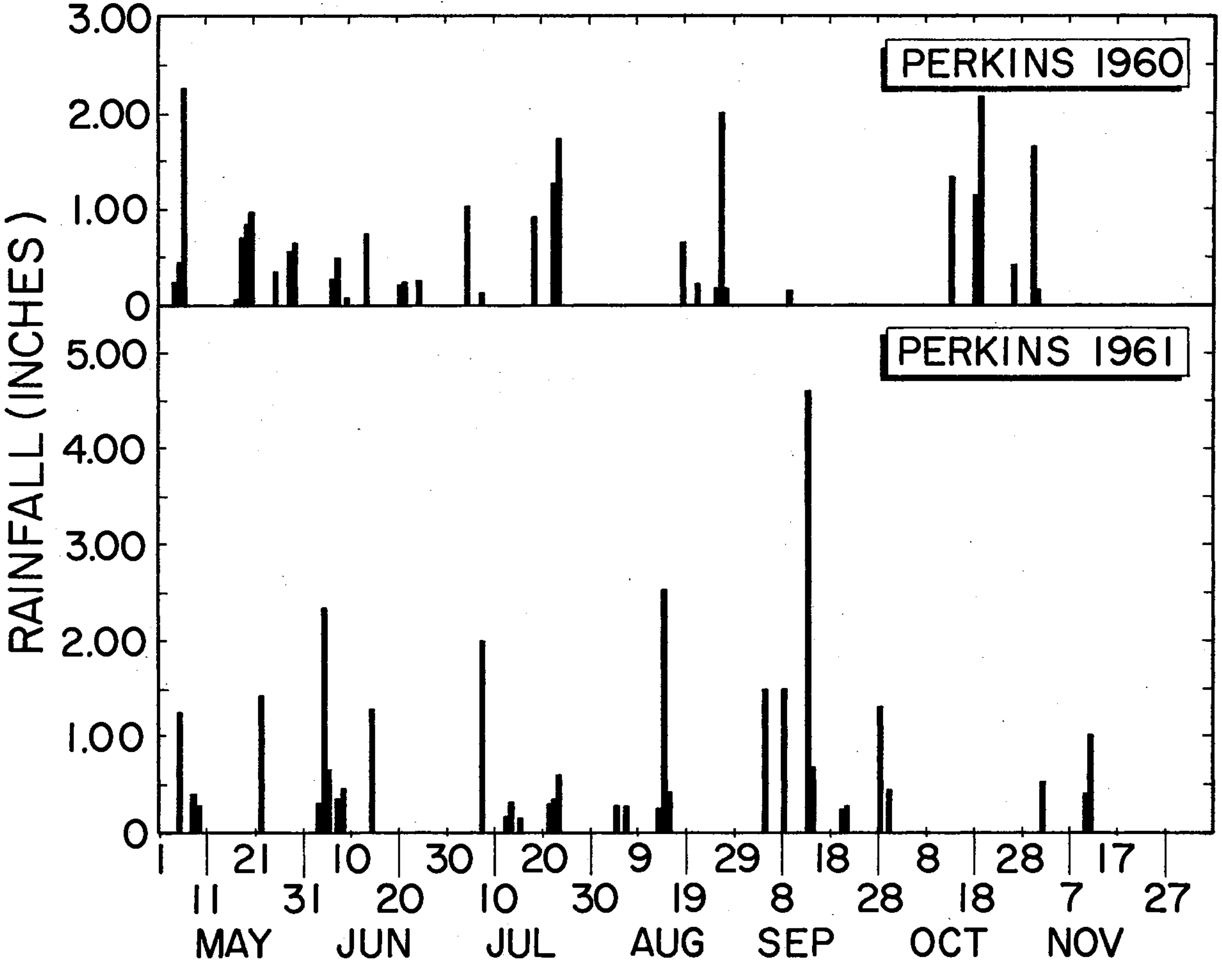

Figure 18. Precipitation Pattern, Perkins: 1960-1961

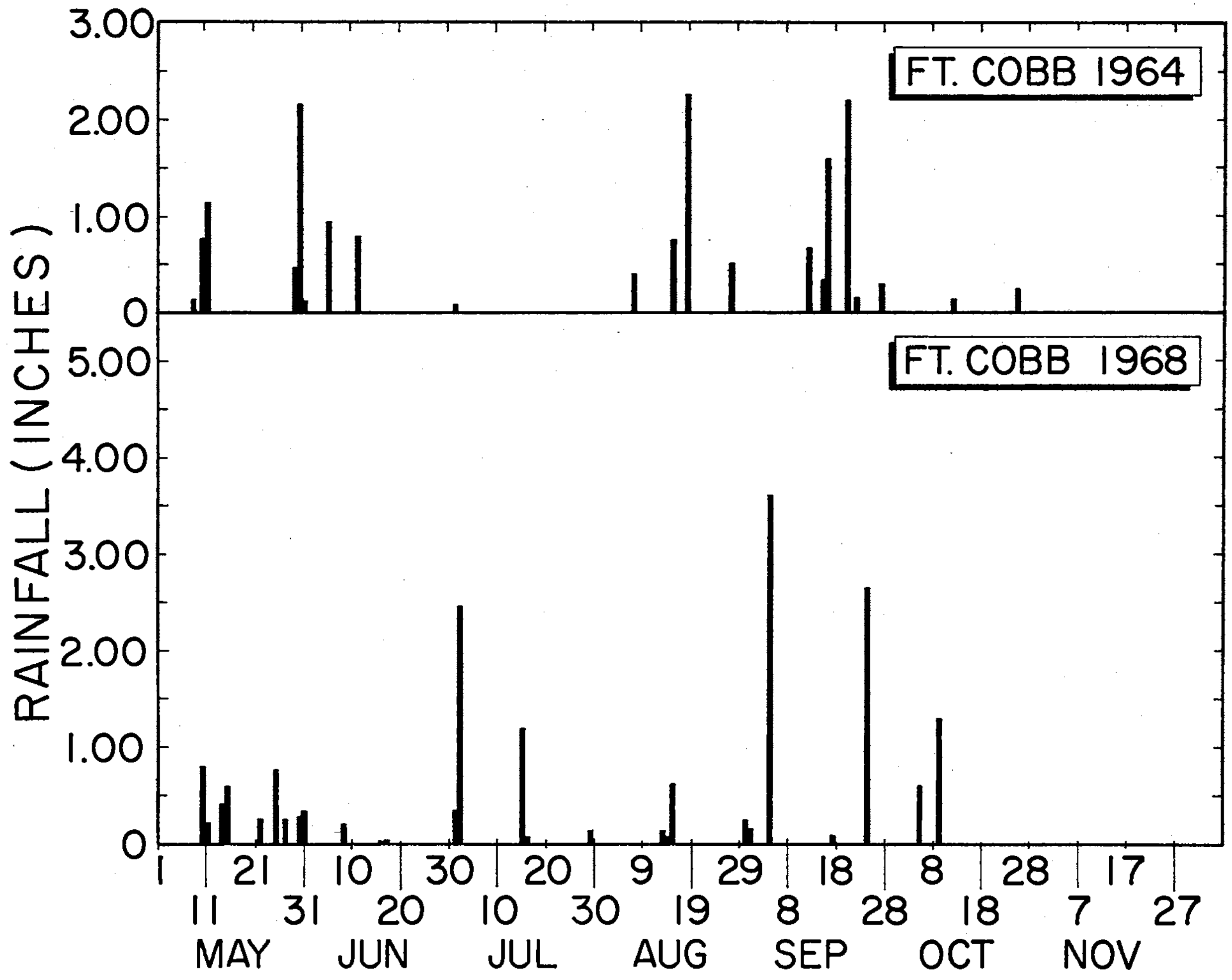

Figure 19. Precipitation Pattern, Ft. Cobb: 1964, 1968

precipitation becomes important in the early part of the growing season for the germination, development and the flowering of the plant. Again, flowering becomes important because dryness in the early part of the growing season affects the flowering response by causing slow and late flowering (9).

An example of moisture on the overall welfare of the plant is seen in 1961. The high amount of precipitation which was observed in September (Figure 18) could have caused germination of the mature fruits which were on the plants. This is probably a reason why the observed plant densities was greater than those which were planted in all row spacings, except the 10 in. This germination factor would also affect the quality of the fruit which was harvested, as the mature fruits had germinated, thus the percentage SMK was the lowest of all years studied. The gross aspect of the effect of water on the production of fruits by the plant is borne out by the large differences in yield by the irrigated and the nonirrigated treatments. Under irrigation not only was the yield affected but also the quality of the crop as seen in the high percentages of SMK which resulted in the irrigated treatments. The irrigated treatments also had the lowest percentages of OK in all years. This confirmed earlier works (17, 18).

In looking at the comparison of narrow versus wide rows, with respect to monetary returns, Table III shows that narrow rows, whether irrigated or not, gave the highest returns. Narrow rows of higher population density consistently outyielded lower population densities. Table VI shows a comparison of wide versus narrow rows, for both irrigated and nonirrigated treatments, in terms of monetary return for the 1960, 1961 and 1964 seasons. In this table, the percentage of maximum return refers to the percent the 2 plants per foot--plant spacing attained relative to the maximum value achieved by any planting density for that year and treatment.

Thus the yield and quality, and hence the value of the crop, obtained in this study was found to be conditioned by the environment of the crop. The climate in the early part of the growing season had an important role in the final yield, as it affected flowering. Interaction between plants, as shown by the high plant population densities, also seemed to have affected yield, since in no year did the yield increase proportionate to the increase in plant population. High plant population densities, achieved by close row spacings and a high plant population within these rows, produced less fruit per plant, but the economic return realized seemed to make such culture profitable although an increase in seed cost was incurred.

Water Requirement

Results

Although water was applied uniformily over the entire area, runoff was not measured, and no attempt was made to determine the water budget on accretion. Thus instead of using the total amount of water applied in the estimation of evapotranspiration (ET), the depreciation of soil moisture following water input was used to gauge evapotranspired water.

Selection of periods between neutron determination which were free from rainfall excluded a large part of the growing seasons. Figures 18 and 20 show the precipitation patterns and attest to this. Thus the analysis was modified to the selection of periods when the soil moisture content of any 6-in. increment of the top 36-in. of the soil profile

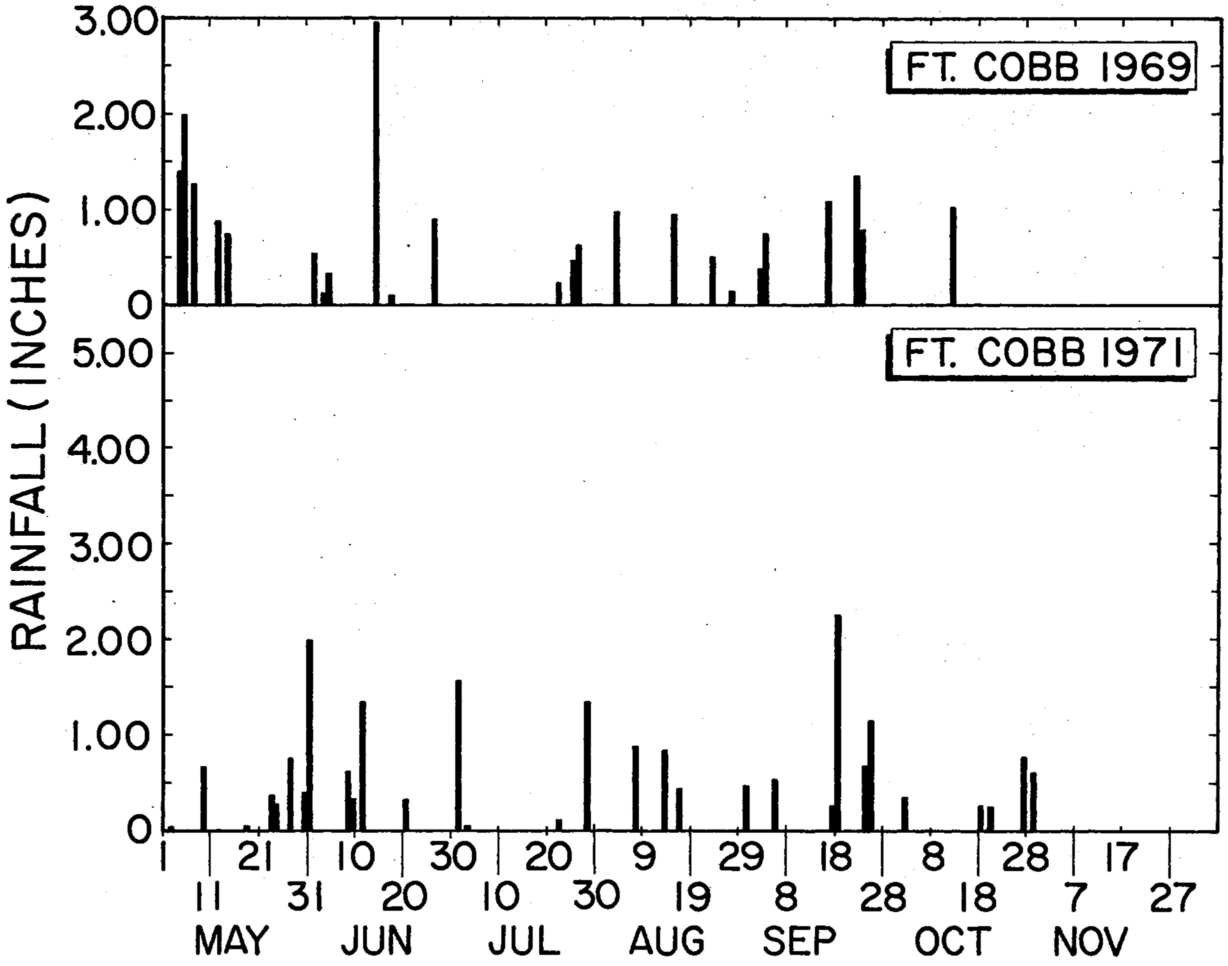

Figure 20. Precipitation Patterns, Ft. Cobb: 1969, 1971

did not exceed the value of the preceding determination made after irrigation. The value of ET obtained by this method is thus an estimate of actual ET.

1961 Study

Figure 21 shows the soil moisture content of the growing season for 1961. As pointed out in the Materials and Methods section, the difference of water content for all treatments at the beginning of the monitoring period was about 0.5 in. and at the end of this period, the spread was about 2 in. Inspection of the individual soil profiles of the treatments showed that the increase of water content of the narrow rows was mainly in the top 36 in. of the soil profile. Thus the higher water contents of the narrow row spacings, for both irrigated and nonirrigated treatments, which was encountered in the latter part of the growing season was an actual accumulation of moisture in the root zone.

In looking at some of the changes of water contents, as detected by neutron determination, Table XII shows that the rate of moisture loss by the narrow rows between July 24 and 31 and between August 21 and 28 was greater than that of the wide rows. Since there was no knowledge as to the amount of water which was lost by drainage from the profile, the estimate of the ET rate is probably too large.

In this year, there was 14.23 in. of water by precipitation and 7.7 in. of water by irrigation.

1968 Study

Figure 22 shows the water content of the soil profile by neutron determination. A high soil water content, plus timely precipitation,

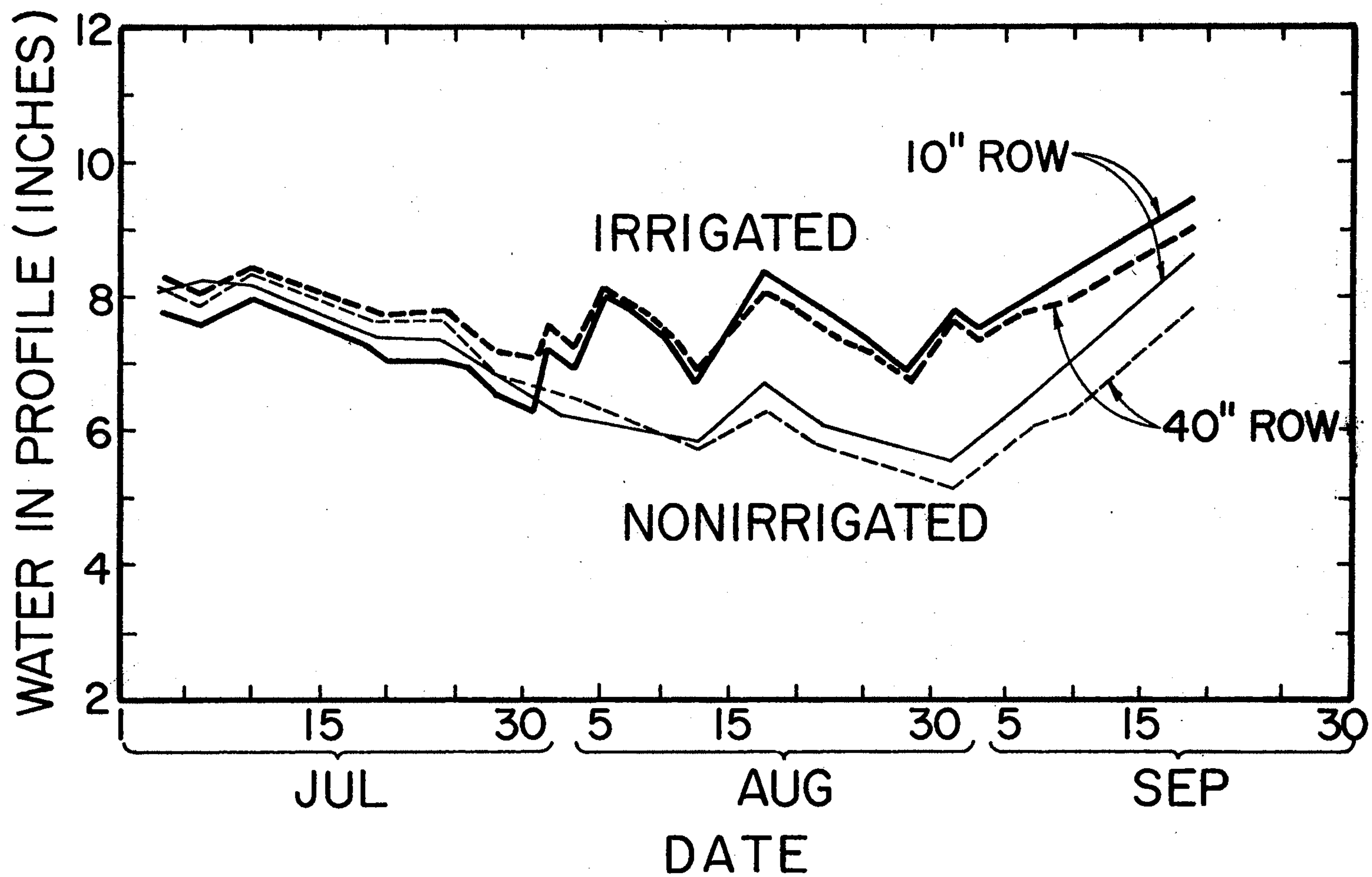

Figure 21. 1961 Neutron Determined Soil Moisture Content for the Growing Season

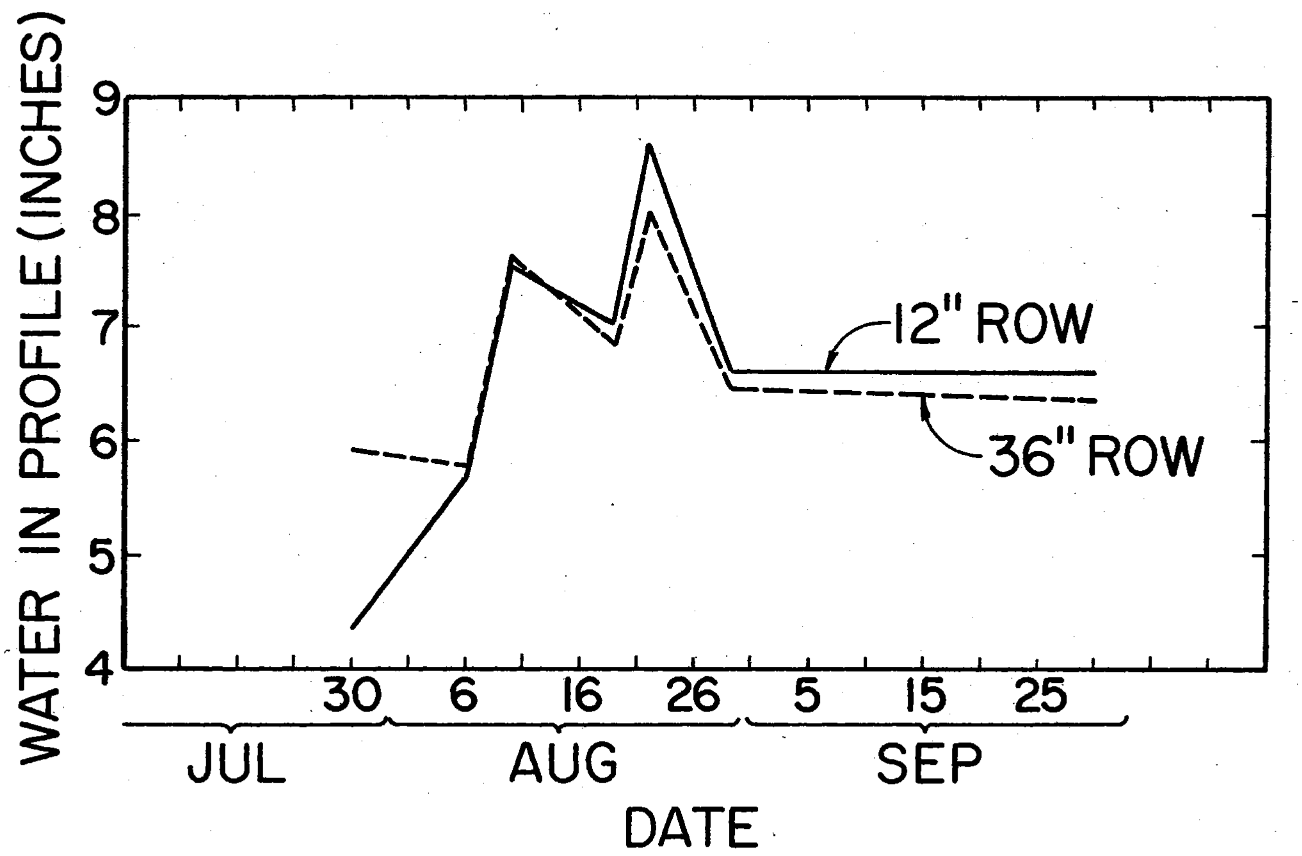

Figure 22. 1968 Neutron Determined Soil Moisture Content for the Growing Season

necessitated only 2 irrigations this year. On the graph, the value of July 30 for the narrow rows can be disregarded as this point represented only one plot, the neutron access tube in the other plots being filled with water when the tubes were installed and had not completely drained.

Of note in Figure 22 is that the narrow row spacings had a lower rate of water loss between August 9 and 19 than the wide rows, but the inch of precipitation which occurred between August 15 and 16 negates any ET calculation.

1969 Study

The 1969 growing season was characterized by a very wet June and August (Figure 20). Between June and October, the precipitation totalled 13.5 in. and with 10 in. of supplemental water, a total of 23.5 in. of water reached the plots during the growing season.

Figure 23 shows the soil moisture content, by neutron determination, for the growing season. As can be seen in this figure, the phenomenon of the water content of the close row spacing surpassing that of the wide row spacing was far less than 1961. Nevertheless, intersection of the curves did occur, e.g. the 12 in. north-south oriented rows intersected with that of similar orientation of 36 in. row spacing on several occasions, but did not surpass it until September 10. The close row spacing curve for the east-west orientation did not exceed, or intersect, that of the wide row spacings.

Table VIII shows the tensiometric readings for the plots at the 4 and 5 ft. depth. As can be seen from the potential gradients, after August 7, the movement of water in the close row spacings, regardless of orientation, was in the upward direction in this zone of the soil

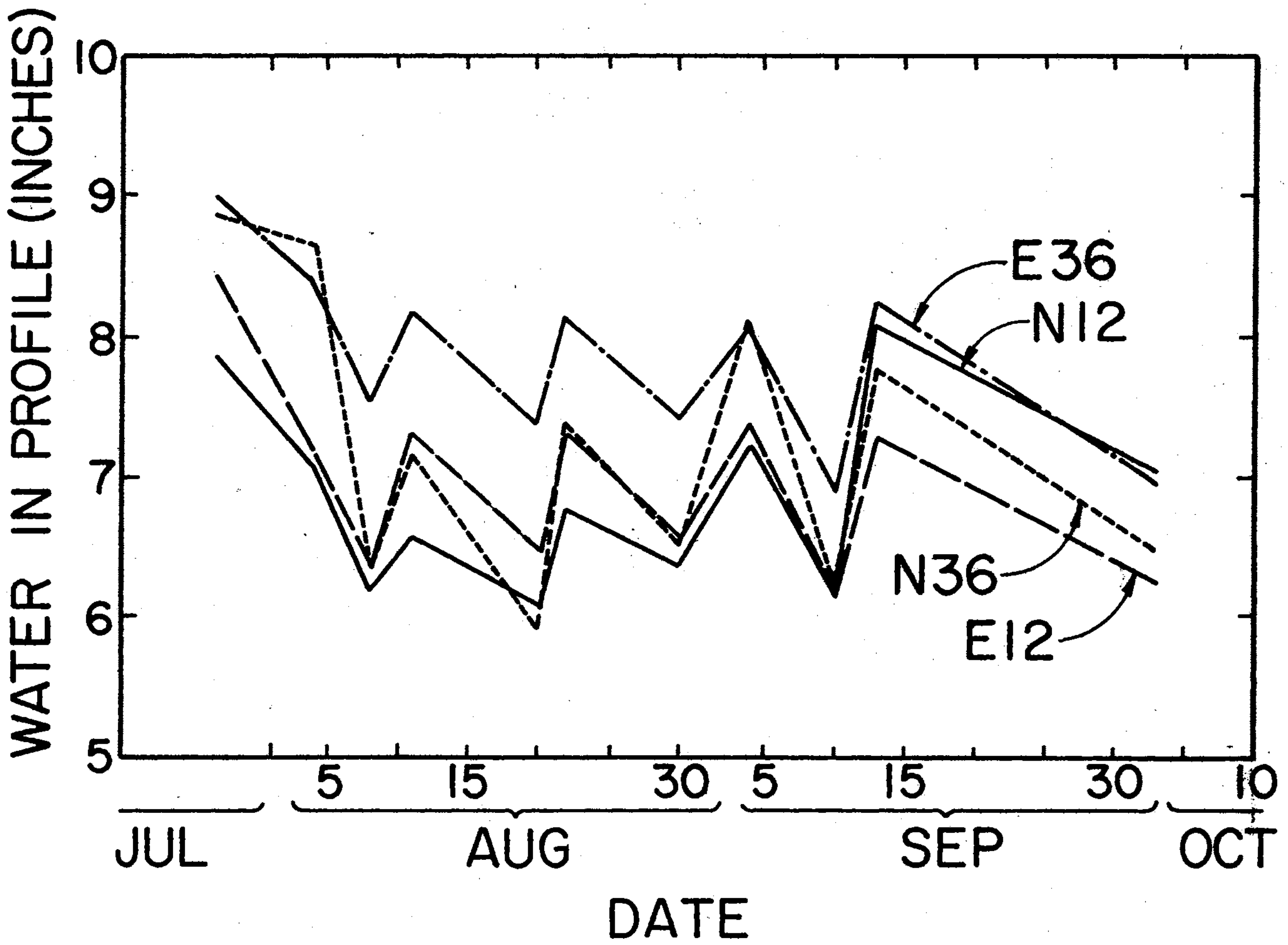

Figure 23: 1969 Neutron Determined Soil Moisture Content of the Growing Season

TABLE VIII

TENSIOMETRIC DATA AT THE 4TH AND 5TH FT. DEPTH (TOTAL HEAD, CM WATER SUCTION)

	1N12		1E12		1N36		1E36		2N12		2E12		2N36		2E36		3N12		3E12		3N36		3E36	
	4 ft	5 ft	4 ft	5 ft	4 ft	5 ft	4 ft	5 ft	4 ft	5 ft	4 ft	5 ft	4 ft	5 ft	4 ft	5 ft	4 ft	5 ft	4 ft	5 ft	4 ft	5 ft	4 ft	5 ft
July 24	205	207	227	243	186	210	213	221	197	202	238	238	218	273	174	201	204	247	-	-	-	-	247	277
25	219	217	235	246	283	234	220	226	203	203	244	243	227	280	177	207	226	256	-	-	-	-	261	279
26	211	210	222	243	179	229	218	223	199	197	242	241	223	276	173	201	219	255	-	-	-	-	257	277
30	230	223	244	251	184	234	224	227	203	203	262	256	228	281	176	207	241	261	247	346	258	259	258	282
August 1	221	214	242	250	187	234	223	226	202	202	253	251	232	280	176	202	241	257	326	294	260	259	260	282
4	227	213	247	251	187	234	224	226	205	205	257	252	247	281	176	204	253	259	341	297	262	262	262	272
5	231	223	251	254	189	236	224	228	205	205	262	250	229	283	178	205	263	262	347	303	262	261	260	286
7	241	222	257	254	190	236	228	228	184	209	265	257	236	285	179	206	275	266	385	309	268	264	272	291
8	251	224	261	256	190	236	229	230	213	213	269	260	238	288	179	205	286	272	433	311	272	267	276	293
9	250	224	246	259	190	236	233	233	212	210	274	261	246	285	181	206	291	269	411	312	270	264	271	291
10	254	224	270	260	193	232	230	230	212	210	277	265	247	288	182	207	309	270	430	316	273	266	275	294
12	213	212	272	260	194	237	232	232	213	212	280	267	247	288	181	205	328	279	483	331	280	267	277	296
13	265	223	275	340	195	234	233	232	214	212	285	267	247	290	186	206	363	277	605	333	283	271	281	300
14	279	228	284	603	197	239	237	235	217	214	294	273	252	291	188	211	458	297	750	339	286	272	291	303
15	264	232	292	248	199	239	240	236	223	219	304	273	267	297	191	210	518	412	612	-	296	274	295	299
18	302	-	291	271	203	230	237	233	227	220	305	263	272	298	192	211	420	289	693	-	296	275	298	302
20	314	-	304	280	203	240	245	237	238	224	330	320	283	305	196	212	560	560	682	-	327	276	308	307
21	289	-	302	276	204	241	247	238	237	227	355	283	288	301	198	211	615	294	813	-	313	277	308	307
22	-	-	307	284	215	242	248	236	240	223	357	286	294	308	203	216	584	300	812	-	313	277	316	311
25	347	-	304	289	217	245	255	240	290	232	350	292	307	315	209	217	590	300	440	376	323	281	328	-
27	329	-	306	291	218	247	257	242	247	233	335	292	308	313	207	217	454	437	508	366	320	284	326	316
29	362	-	310	293	222	250	259	240	247	235	350	291	314	315	211	217	558	319	686	366	326	254	333	316
30	372	-	314	296	225	251	260	241	288	238	367	293	319	440	212	220	688	312	687	376	331	286	340	316
September 2	425	-	325	306	232	252	269	243	299	240	378	296	326	306	219	221	749	320	843	384	347	289	356	321
4	434	-	325	308	234	254	272	242	298	238	369	297	341	321	223	222	683	310	826	378	341	290	361	322
8	501	-	350	306	245	259	280	247	303	245	350	306	357	326	228	216	808	336	836	447	376	291	390	320
10	710	-	482	345	247	256	292	247	305	260		315	376	333	467	249	806	351	852	481	411	294	431	332
13	800	-	361	356	254	262	297	247	300	245	-	-	394	341	-	214	798	352	845	459	465	316	428	333
15	725	-	360	354	262	266	299	262	307	250	-	-	404	337	-	226	779	376	827	447	452	295	422	336
17	517	-	360	359	264	266	310	253	378	252	-	-	400	328	-	227	790	340	741	434	426	299	421	336
19	575	-	361	350	269	259	310	253	287	254	-	-	400	335	-	230	618	337	738	446	451	324	415	322
22	817	-	361	360	279	270	318	253	283	253	-	-	357	340	-	231	640	341	872	443	482	301	425	338
24	737	-	357	360	279	295	320	255	288	259	-	-	432	340	-	230	746	340	961	436	490	301	428	338
October 3	812	-	382	338	297	275	354	260	308	273	-	-	473	370	-	235	795	350	835	484	701	307	500	353

profile. Hence, these rows did not lose any water by drainage after August 7. On the other hand, the wide row spacings, i.e. 36 in., had water draining through this portion of the soil profile as late as September.

Tensiometers were used to characterize potential gradients. Since matric suction is related to the soil water content, tensiometer readings should follow at least the major changes in soil water content, and many workers have used them for this purpose. However, in this study there were many instances of disagreement between tensiometers and neutron readings.

Table IX shows a comparison of tensiometric and neutron determination of water contents at the three and four ft. depth. Almost in all plots, the tensiometers did not respond to an increase of water content which was detected by the neutron method. In plot 2E36, a relationship between the water content, as detected by the neutron method, and pressure head can be observed, but the water content of the soil decreased throughout the season.

Thus, because of this difficulty in establishing the water content-pressure head relationship for the calculation of the hydraulic conductivity, a new assumption was made. Since the downward flux of water in the 4 and 5 ft. zone was extremely small, less than 0.1 cm^3/cm^2/day (5) when the matric suction was greater than 100 cm water; and since the matric suction which was observed in the field often exceeded this matric suction value in the early part of the growing season, then the amount of water which was lost by drainage could be considered to be negligible. In support of this assumption, Table X shows calculation of soil-water

TABLE IX

COMPARISON OF TENSIOMETRIC VALUES (PRESSURE HEAD, CM. WATER SUCTION) AND WATER CONTENT DETERMINATION BY THE NEUTRON METHOD FOR THE 1969 DATA AT THE 3RD AND 4TH FT. DEPTH OF THE SOIL PROFILE

Plot Number	Depth (ft)	Moisture Deter-mined by	July	August						September			October
			28	4	8	11	20	22	30	4	10	13	3
1N12	3	Neutron	13.0	10.4	10.2	9.8	10.0	9.0	9.5	9.3	9.4	9.5	-
		Tensiometer	171	429	590	703	685	689	538	685	726	716	-
	4	Neutron	13.2	12.0	12.5	11.1	11.9	10.5	11.2	10.5	10.6	10.4	10.1
		Tensiometer	97	107	131	113	194	-	252	314	590	680	692
1E12	3	Neutron	14.0	13.1	12.3	11.7	11.4	10.8	10.8	10.5	10.6	10.7	-
		Tensiometer	150	228	323	419	654	670	699	720	723	717	-
	4	Neutron	19.0	13.9	13.6	12.9	12.8	13.1	12.2	12.5	11.6	11.3	11.0
		Tensiometer	119	127	141	151	184	187	194	205	362	241	262
1N36	3	Neutron	-	-	15.0	13.2	12.8	12.1	12.3	11.7	11.6	11.8	-
		Tensiometer	80	88	97	111	165	181	233	256	243	-	-
	4	Neutron	-	-	19.1	19.9	19.6	17.6	16.7	16.7	16.3	15.9	15.3
		Tensiometer	67	67	70	74	83	95	105	114	127	134	177
1E36	3	Neutron	15.1	13.0	15.6	14.2	13.1	13.0	13.4	12.4	13.4	12.6	-
		Tensiometer	139	150	165	176	313	444	481	564	713	724	-
	4	Neutron	17.8	15.9	17.2	16.7	16.4	16.9	17.0	16.5	13.6	15.7	14.4
		Tensiometer	107	104	109	111	125	128	140	152	172	177	234
2N12	3	Neutron	11.8	11.5	10.0	10.1	8.8	8.1	7.9	7.8	7.6	7.5	-
		Tensiometer	147	227	310	471	-	-	-	-	-	-	-
	4	Neutron	21.1	20.3	19.6	18.9	18.2	17.0	16.6	12.6	15.3	14.9	15.3
		Tensiometer	83	85	93	92	118	120	168	178	185	180	188
2E12	3	Neutron	-	13.9	12.7	11.8	10.6	10.5	10.4	10.6	10.3	10.1	-
		Tensiometer	222	436	702	739	715	715	702	726	724	726	-
	4	Neutron	-	15.6	15.0	14.4	12.8	12.6	12.6	12.9	12.6	11.7	11.3
		Tensiometer	134	137	149	158	235	237	247	249	-	-	-
2N36	3	Neutron	22.5	21.6	17.3	19.4	15.3	15.4	15.6	14.6	15.6	15.4	-
		Tensiometer	141	164	193	209	472	537	637	693	718	732	-
	4	Neutron	18.3	18.8	15.9	17.9	14.5	16.4	15.6	15.6	15.6	15.4	15.6
		Tensiometer	108	127	118	127	163	174	199	221	256	274	353
2E36	3	Neutron	11.8	11.3	11.0	10.9	10.0	9.5	9.4	9.2	8.9	8.7	-
		Tensiometer	70	78	84	95	154	178	230	282	380	384	-
	4	Neutron	15.4	16.1	13.6	13.7	15.6	12.4	12.3	11.8	11.5	11.6	10.7
		Tensiometer	54	56	59	61	76	89	92	103	347	-	-
3N12	3	Neutron	23.4	22.3	20.9	19.8	17.6	17.7	17.3	18.9	18.5	18.8	-
		Tensiometer	189	511	499	594	686	693	739	730	725	706	-
	4	Neutron	23.7	23.5	23.1	21.5	18.8	17.9	17.9	17.8	15.9	16.1	16.8
		Tensiometer	111	133	166	199	440	464	568	563	686	678	675
3N12	3	Neutron	20.4	17.6	16.5	16.0	15.5	15.1	14.7	15.7	15.1	14.7	-
		Tensiometer	-	476	496	-	456	502	679	734	751	745	-
	4	Neutron	27.6	22.7	22.3	21.1	18.6	17.9	18.0	18.9	16.9	16.8	16.5
		Tensiometer	-	221	313	336	562	692	567	706	732	725	715
3N36	3	Neutron	-	-	10.7	10.0	8.8	9.2	8.9	8.5	8.1	8.0	-
		Tensiometer	175	199	217	225	309	305	319	339	365	371	-
	4	Neutron	11.9	-	10.1	10.0	9.4	9.3	8.9	8.6	8.3	8.0	7.5
		Tensiometer	132	142	152	156	207	193	211	231	291	345	581
3E36	3	Neutron	19.3	16.8	18.1	16.5	15.2	14.6	14.4	19.3	14.0	13.3	-
		Tensiometer	177	242	322	429	701	709	762	745	745	732	-
	4	Neutron	20.6	20.8	19.0	18.2	17.9	18.7	17.7	16.2	17.6	17.9	17.7
		Tensiometer	136	143	156	156	188	196	220	241	311	308	380

TABLE X

CALCULATION OF WATER FLUX AT THE 4TH AND 5TH FT. DEPTH USING TENSIOMETRIC DATA OF AUGUST 4TH AND 12TH, 1969

Plot No.	Date	North Side[1]			South Side[2]		
		θ	K	v	θ	K	v
1N12	4	0.217	1.352	-0.631	0.266	0.727	-0.339
	12	0.227	2.098	-0.070	0.271	0.878	-0.029
1E12	4	0.166	0.143	0.019	0.240	0.273	-0.036
	12	0.154	0.084	-0.034	0.230	0.187	-0.075
1N36	4	0.242	4.095	6.359	0.272	0.912	1.429
	12	0.225	1.911	2.739	0.267	0.756	1.083
1E36	4	0.214	1.182	0.079	0.260	0.578	0.038
	12	0.214	0.761	-*	0.254	0.463	-*
2N12	4	0.240	3.695	-*	0.279	1.185	-*
	12	0.227	2.099	-0.070	0.272	0.912	-0.030
2E12	4	0.162	0.120	-0.020	0.237	0.244	-0.040
	12	0.149	0.068	-0.029	0.225	0.155	-0.067
2N36	4	0.150	0.071	0.080	0.228	0.174	0.197
	12	0.148	0.065	0.088	0.226	0.161	0.220
2E36	4	0.266	11.642	10.865	0.292	2.315	2.161
	12	0.268	12.734	10.187	0.290	1.788	1.430
3N12	4	0.174	0.203	0.041	0.247	0.356	-0.071
	12	0.136	0.038	-0.038	0.213	0.099	-0.162
3E12	4	0.127	0.131	-0.192	0.206	0.076	-0.111
	12	-+	-	-	-+	-	-
3N36	4	0.156	0.092	-*	0.234	0.195	-*
	12	0.149	0.068	-0.029	0.225	0.155	-0.067
3E36	4	0.150	0.071	0.023	0.227	0.167	0.055
	12	0.138	0.042	-0.026	0.216	0.111	-0.070

*No flux of soil water
+Matric suctions too large for water-content estimation

[1]These calculations were based on the soil-water characteristics determined on the north side of the experimental area, where:
θ - averaged volumetric water content of the 4th and 5th ft. depth
K - hydraulic conductivity of the 120-150 cm zone of the soil profile, estimated from: $K = 9.63 \times 10^{-5}\, e^{43.98\theta}$
v - soil water flux, cm^3/cm^2 day, computed:

$$v = \frac{\text{Total Head (150 cm)} - \text{Total Head (120 cm)}}{(150 - 120)\text{ cm}}$$

Negative sign denotes upward flux.

[2]These calculation were based on the soil-water characteristics determined on the south side of the experimental area. θ, K and v, same as above, but K being computed as $K = 3.267 \times 10^{-5}\, e^{37.622\theta}$

flux for August 4 and 12, using the tensiometric data with the available water release curve.

Table XI shows the calculation of water flux, summed over the period of August 11-20. The values for the hydraulic conductivity were the same as those used in Table X. Gross difference in the fluxes of plots 1N36 and 2E36 can be seen when the soil water-matric suction characteristics of the north portion of the field (denoted as Point A in Figure 1) and the south portion (Point B in Figure 1) are compared. In both plots, the amount of water calculated to be lost by drainage exceeded the loss of water from the profile detected by the neutron method. The magnitude of upward fluxes obtained for several plots also seemed too large to be acceptable.

Except for plots 1N12, 1N36 and 2E36, the magnitude of the flux values were generally of the order of 0.1 cm per day, in both the upward and downward directions. In plot 1N12, the magnitude of the upward flux was deemed too large to be creditable. Similarly, the magnitude of the downward fluxes for plots 1N36 and 2E36 were too large to be valid when the pressure gradients were considered. The discrepancy of the magnitude for fluxes probably lies in the moisture release curve, i.e., the relationship between the matric suction and water content.

Table XIII shows the calculation of ET from changes of neutron determined water content. As the table shows, in the early part of August, the 12 in. row spacing of north-south orientation had the lowest daily loss of moisture. This value was about half of that of the east-west oriented rows of similar spacings. In the later part of August, the 12 in. north-south oriented rows continued to be the lowest in ET, but the ET rate for the east-west oriented 36 and 12 in. rows

TABLE XI

CUMULATIVE FLUX (IN. WATER) FOR AUGUST 11-20, 1969, USING THE HYDRAULIC CONDUCTIVITIES DETERMINED AT THE NORTH AND SOUTH PORTIONS OF THE EXPERIMENTAL AREA

	1N12	1E12	1N36	1E36	2N12	2E12	2N36	2E36	3N12	3E12	3N36	3E36
North	*	0.02	12.98	-0.34	-1.04	-0.18	0.98	20.64	*	*	-0.13	0.05
South	*	-1.60	4.63	-0.16	-0.45	-0.44	0.65	3.23	*	*	-0.66	0.13

*No value assigned due to a) missing data within period or b) the values of the matric suction obtained within this period for these plots exceeded the lower limit of the water desorbtion versus matric suction relationship found in the lab, thus water content could not be otained.

NOTE: Negative sign denotes upward flux

were about the same. In early September, the ET rate for all but the 36 in. north-south oriented rows were about the same.

1971 Study

At the start of the growing season, the soil profile was exceedingly dry due to the deficiency of precipitation in the preceding winter. This is evidenced by the low water contents of the plots, by neutron determination, and by the high matric suction shown by the tensiometers, Figure 24 and Table XI, respectively.

Figure 24 shows the water content of the plots during the growing season. Accumulation of moisture by the narrow rows was evident only for a small part of the growing season by the north-south oriented rows, and only for a several day period for the east-west oriented rows. The 36 in. east-west oriented rows showed a high accumulation of moisture on August 16, but this point of the graph represented only one neutron determination as there was water ponding on the surface of the soil in the vicinity of the other access tubes.

In the calculation of ET, as shown in Table XIII, only two periods could be selected. In the early part of August, the 12 in. north-south oriented rows had the lowest ET in agreement with what had been found the previous year of study. In the other period of calculation, the ET rate was higher than that of the previous year of the same date.

In looking at the tensiometric data, Table XII, there was a large amount of missing data. Problems were encountered in the field this year by rodents gnawing at the nylon tubing which connected the tensiometers with the mercury manometers. Also, several tensiometers malfunctioned at the end of the growing season. Nevertheless, where data were

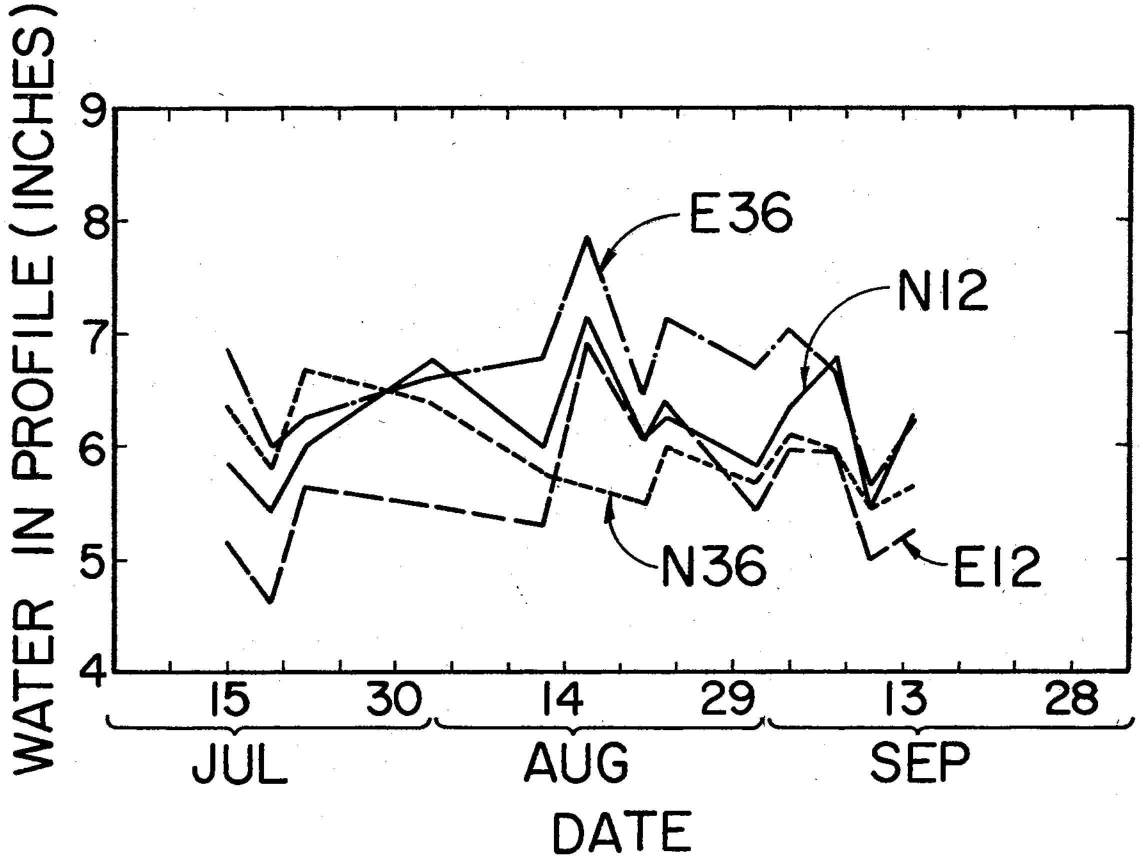

Figure 24. 1971 Neutron Determined Soil Moisture Content of the Growing Season

TABLE XII

1971 TENSIOMETRIC DATA AT THE 4TH AND 5TH FT. DEPTH (TOTAL HEAD, CM WATER SUCTION)

Plot:	1N12		1E12		1N36		1E36		2N12		2E12		2N36		2E36		3N12		3E12		3N36		3E36	
Depth:	4 ft	5 ft	4 ft	5 ft	4 ft	5ft	4 ft	5 ft	4 ft	5 ft	4 ft	5 ft	4 ft	5 ft	4 ft	5 ft	4 ft	5 ft	4 ft	5 ft	4 ft	5 ft	4 ft	5 ft
July 14	-	448	244	444	488	362	319	352	599	501	565	421	323	363	196	105	363	335	-	550	381	458	-	-
15	-	-	-	-	534	380	370	373	659	558	629	327	345	336	-	-	374	295	-	557	480	477	174	201
16	-	-	-	-	539	388	409	383	720	657	292	327	-	-	-	-	-	-	-	552	525	476	204	238
19	-	-	-	-	-	385	490	387	779	638	351	435	324	383	-	-	-	-	-	602	696	486	-	-
21	182	513	313	455	667	342	477	-	-	-	380	421	-	-	-	-	-	-	-	539	632	442	-	-
22	-	573	369	405	-	-	535	367	789	495	441	423	328	355	-	-	-	-	-	589	677	467	-	-
23	-	586	397	425	-	-	554	368	805	466	464	382	339	356	-	-	-	-	-	586	673	477	-	435
26	-	-	452	353	-	-	578	358	-	-	534	342	340	351	-	-	-	-	-	586	663	470	-	-
27	170	473	414	-	-	-	-	-	-	-	524	422	-	-	312	338	-	-	-	550	384	463	-	410
28	254	565	483	530	-	-	587	-	-	-	597	435	345	370	-	-	-	-	-	590	491	476	-	420
29	263	445	-	-	282	347	-	-	-	-	579	431	321	331	-	-	383	274	-	561	495	453	-	401
August 2	303	562	318	503	367	360	-	-	-	-	676	442	357	354	-	-	395	310	-	593	681	463	-	406
4	342	487	365	507	-	-	-	-	-	-	638	425	364	432	-	-	-	312	-	568	582	444	-	404
5	378	479	-	-	-	-	-	-	-	-	644	431	375	355	-	-	414	-	-	574	644	458	-	-
10	339	430	369	504	-	-	-	-	-	-	-	433	457	-	-	-	349	327	-	590	-	-	-	-
11	-	456	359	-	-	-	-	-	-	-	-	436	475	-	-	-	358	330	-	592	-	-	-	-
16	-	516	495	510	-	-	-	-	-	-	727	-	498	-	-	-	378	335	-	-	-	-	-	-
17	-	535	510	516	-	-	-	-	-	-	-	-	433	-	-	-	360	331	-	-	-	-	-	-
18	320	533	524	516	-	-	-	-	-	-	480	442	485	-	-	-	366	336	-	-	-	-	-	-
19	-	538	-	-	-	-	-	-	-	-	523	446	504	-	-	-	372	336	-	-	-	-	-	-
24	-	546	-	-	-	-	-	-	-	-	630	455	582	-	-	-	388	335	-	-	-	-	-	-

TABLE XIII

CALCULATION OF EVAPOTRANSPIRATION FOR 1961, 1969 AND 1971, BASED ON NEUTRON DETERMINATION

Year	Date	No. of Days	Treatment	Total ET for Period (In. Water) Row Spacing 10"	40"
1961	July 24-31	7	Irrigated	0.84	0.70
	July 24-28	4	Nonirrigated	1.00	0.76
	August 21-28	7	Irrigated	1.00	0.70
	August 21-31	10	Nonirrigated	0.56	0.63

Year	Date	North-South Oriented Rows 12"	36"	East-West Oriented Rows 12"	36"
1969	August 11-20	0.48	1.22	0.81	1.36
	August 22-30	0.38	0.85	0.75	0.72
	September 4-10	1.04	1.86	1.25	1.18
1971	August 2-12	0.56[1]	0.67[1]	0.82	-
	August 16-21	0.85	1.47[1]	1.04	1.39

[1]Value from 1 tube

available, only two plots did not show an upward flux of water before July 26. The matric suction in the plots was higher than that of 1969.

Discussion

In considering the relationship between the water content of the soil, as determined by the neutron method, versus the matric suction, as indicated by tensiometric response, the sampling volume characteristic of the respective instruments, along with water conductivity of the nonhomogeneous soil is important. For example, the entire area was irrigated on August 10, 1969. The time lag for the tensiometers to reflect this pulse of water at the 4 ft. depth varied from August 12 (plots 1N12, 1N36, 2N36 and 3E36) to August 18 (plots 1N12, 1E36, 2N12 and 2E12). Using the neutron method, however, an increase of water content was detected at the 4 ft. depth two days after irrigation in all plots. It would have been desirable to compare conductivities in the above plots between the 1969 and 1971 data. In 1971, insufficient tensiometric data prohibited this comparison. This is unfortunate in that such comparisons could have established whether further sampling for water content versus matric suction relationship need be established for the nonconforming portions of the field.

Table XIV shows the calculated ET values, expressed as a percentage of the maximum ET obtained for each period. Two definite relationships can be seen in this table. The first is that the north-south oriented rows had the extremes in ET. Hence, the 12 in. row spacings had the lowest ET for all treatments, while (except for the August 11-20 period) the 36 in. row spacings had the highest. The second relationship is that except for the early part of September, 1969, the 12 in.

TABLE XIV

EVAPOTRANSPIRATION OF 1969 AND 1971 ON A PERCENTAGE BASIS*

Year	Date	North-South Oriented Rows		East-West Oriented Rows	
		12"	36"	12"	36"
1969	August 11-20	35	90	60	100
	August 22-30	45	100	86	91
	September 4-10	55	100	66	62
1971	August 2-12	29	100	73	-
	August 16-21	58	100	70	95

*100 Percent Being Assigned to the Highest Value Within a Given Period

east-west and north-south oriented rows had a lower ET than the 36 in. rows of similar orientations.

Because no micrometerological measurements were made during this study, no explanation can be offered for this phenomenon. Yao and Shaw (27, 28) found that in 42 in. rows, the net radiation of east-west oriented corn crop was higher than the north-south oriented rows. The authors concluded that this higher net radiation contributed to a more "efficient water usage" by the north-south oriented rows. In this study, the only time that the north-south wide rows had a lower ET than the east-west oriented rows was during the period of August 11-20, 1969. Thus, the observations by these workers may be valid for tall crops, where the soil surface has a better chance of being exposed to diffuse sunlight, but not for peanuts.

Lysimetry is the accepted method in obtaining accurate determination of ET. The depth of most lysimeters is about 3 ft. Mantel and Goldin (16) estimated that 20 percent of the water extracted by peanut plants from the soil during the growing season is extracted from about the 4 ft. depth. Thus a lysimetric study would probably be not reflective of the extraction pattern of the rooting zone of the plant. The solution is to employ field scale studies and either account for the water flux at the bottom of the rooting zone or determine water budget during periods of zero flux. The problems encountered in field approach are obvious in these results.

CHAPTER V

SUMMARY AND CONCLUSIONS

In experiments which were conducted in the field for 6 years, bunch peanuts, planted in narrow rows (10 or 12 in.) consistently yielded higher than 36 or 40 in. rows.

In three of six years, plant population varied from 2 to about 7 plants per foot on 20, 30 and 40 in. rows. A regression model was used to relate row spacing and plant spacing to several dependent variables. The dependent variables were: yield, in terms of pounds of unshelled peanuts per acre and also in terms of grams per plant; percentage of sound mature kernels; percentage of other kernels, and net value of the crop. The regression model accented the year effect on production by resulting in different response surfaces within dependent variables and between years. The model fitted all the data for the dependent variables except that of percent other kernels.

Two to four plants per foot was found to be the ideal plant spacing within row spacings. For row spacings, the row spacing which consistently gave the highest yields was the 10 in. For nonirrigated crops, closer row and plant spacings seemed to enhance the yield, both qualitatively and quantitatively.

In comparing the irrigated and nonirrigated treatments, irrigation was found to enhance both yield and quality of the crop, regardless of plant spacings. In some years, the yield of the irrigated treatments doubled that of the nonirrigated treatments.

By altering the geometry of the crop, through the orientation of the rows with respect to the wind direction and by close row spacings, the amount of water lost by the ET process was reduced. A higher amount of water was conserved in the soil profile when the orientation of the 12 in. rows were in the north-south direction. In practical terms, this study showed that the north-south oriented narrow row spacings had a decrease of the amount of water lost by ET without being detrimental to the quality of quantity of the peanut crop for the two years of study. A water budget analysis was used in the calculation of ET.

LITERATURE CITED

(1) Beattie, J. H., C. J. Hunn, F. E. Miller, R. E. Currin and E. D. Kyzer. 1927. Effect of planting distances and time of shelling seed on peanut yield. U.S.D.A. Dept. Bul. 1478 (1:4).

(2) Bennett, R. L. 1889. Yield of spanish peanuts planted at different distances. Arkansas Agr. Exp. Sta. Bul. 58:101-102.

(3) Bolhuis, G. G. 1958. Observations on the flowering and fruitification of the groundnut, Arachis hypogaea. Netherlands Jour. Agr. Sci. 6:18:23.

(4) Cox, F. R. and P. H. Reid. 1965. Interaction of plant population factors and level of production on the yield and grade of peanuts. Agron. Jour. 57:455-457

(5) Davidson, J. M., L. R. Stone, D. R. Nielsen and M. E. Larue. 1969. Field measurement and use of soil-water properties. Water Resour. Res. 5:1312-1321.

(6) Davis, W. B. 1968. The effect of light, temperature and time of planting on the yield, grade and maturation of the spanish peanut. Unpubl. Master's Thesis, Oklahoma State University, pp. 1-63.

(7) Duke, G. B. and M. Alexander. 1964. Effects of close row spacings on peanut yield and on production equipment requirement. U.S. Agr. Prod. Res. Rept. 74:1-14.

(8) Funchess, M. J. and H. B. Tisdale. 1924. Peanut spacing test. Alabama Agr. Exp. Sta. Thirty-fifth Ann. Rept. No. 6.

(9) Fortanier, E. J. 1958. Control of flowering in Arachis hypogaea, L. Netherlands. Agr. Sci. Jour. 6:69-70.

(10) Goldberg, S. D., B. Gornat and D. Sadan. 1967. Relation between water consumption of peanuts and Class A pan evaporation during the growing season. Soil Sci. 104:289-296.

(11) Gray, Fenton and Clyde Stahnke. 1967. Detailed Soil Survey, Caddo Peanut Research Station, Ft. Cobb, Oklahoma. Okla. Agr. Exp. Sta. Processed Ser. P-569.

(12) Killinger, G. G., W. E. Stokes, F. Clark and J. D. Warner. 1947. Peanuts in Florida. Fla. Agr. Exp. Sta. Bul. 432:1-47.

(13) Lin, C. S. and J. H. Torrie. 1968. Effect of plant spacing within a row on the competitive ability of soybean genotypes. Crop Sci. 8:585-588.

(14) McClelland, C. K. 1931. The peanut crop in Arkansas. Ark. Agr. Exp. Sta. Bul. 263:1-15.

(15) ________. 1944. Peanut production experiments, 1931-1941. Ark. Agr. Exp. Sta. Bul. 448:1-27.

(16) Mantel, A. and E. Goldin. 1964. The influence of irrigation frequency and intensity on the yield and quality of peanuts, (Arachis hypogaea, L.). Isral. Jour. Agr. Res. 14:203-210.

(17) Matlock, J. W. 1961. Effects of plant population, planting date and irrigation on the yield and grade of two peanut varieties. Unpubl. Master's Thesis. Oklahoma State University, pp. 1-49.

(18) Matlock, R. S., J. E. Garton and J. F. Stone. 1961. Peanut irrigation studies in Oklahoma, 1956-1959. Okla. Agr. Exp. Sta. Bul. B-580.

(19) Meredith, R. M. 1964. The effects of planting density and manuring on the yields of bunch-type groundnuts. Emp. Jour. Exp. Agr. 32:136-140.

(20) Nelson, W. L. 1948. North Car. Agr. Exp. Sta. Res. and Farm., Seventy-first Ann. Rept., No. 17.

(21) Parkham, S. A. 1942. Peanut production in the Coastal Plains of Georgia. Georgia Coastal Plains Exp. Sta. Bul. 24:27-29.

(22) Perrier, E. R. and D. D. Evans. 1961. Soil moisture evaluation by tensiometers. Soil Sci. Soc. Am. Proc. 25:173-175.

(23) Pickett, T. A. 1950. Composition of developing peanut seed. Plant Physiol. 25:210-224.

(24) Smith, Ben W. 1954. Arachis Hypogaea, reproductive efficiency. Am. Jour. Bot. 41:607-616.

(25) U.S. Weather Bureau Climatological Data, National Summary. U.S. Dept. of Commerce, Environment Science Services Administration.

(26) West, H. O. 1942. Peanut production. Miss. Agr. Exp. Sta. Bul. 366:1-67.

(27) Yao, A. Y. M. and R. H. Shaw. 1964. Effect of plant population and planting pattern of corn on water use and yield. Agron. Jour. 56:147-152.

(28) Yao, A. Y. M. and R. H. Shaw. 1964. Effect of plant population and planting pattern of corn on the distribution of net radiation. Agron. Jour. 56:165-169.

(29) York, E. T., B. M. Cannon, W. E. Cooper and R. O. Ritcher. 1952. Triple your peanut yield. Research and Farming. North Car. Agr. Exp. Sta. No. 6.

VITA

Edward W. Chin Choy

Candidate for the Degree of

Doctor of Philosophy

Thesis: THE EFFECTS OF PLANT POPULATION AND GEOMETRY ON YIELD AND WATER UTILIZATION BY PEANUTS (ARACHIS HYPOGAEA, L.)

Major Field: Soil Science

Biographical:

Personal Data: Born in Kingston, Jamaica, April 27, 1941, the son of Edward and Lillian Chin Choy.

Education: Graduated from St. George's, Kingston, Jamaica in 1957; received the Bachelor of Science Degree from the University of Southwestern Louisiana, Lafayette, Louisiana in June, 1965; received the Master of Science Degree from Oklahoma State University, Stillwater, Oklahoma in July, 1967; completed the requirements for the Doctor of Philosophy Degree in May, 1972.

Experience: Graduate assistant, Department of Agronomy, Oklahoma State University, 1965 to 1972.

Member: Sigma Xi (Associate); Alpha Zeta.