

CORN (Zea mays L.) YIELD AND WATER USE AS
INFLUENCED BY IRRIGATION LEVEL, NITROGEN
FERTILIZATION, AND PLANT POPULATION

by

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B.S., National University of ZAIRE, 1973

A MASTER'S THESIS

Submitted in partial fulfillment of the
requirements for the degree

MASTER OF SCIENCE

Department of Agronomy

Kansas State University
Manhattan, Kansas

1981

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ACKNOWLEDGEMENTS

I thank professors Loyd R. Stone, Clyde Wassom, and Arthur Dayton for their guidance, inspiration, and advice during this study.

I also thank the Government of ZAIRE Republic for the financial support throughout this study.

My thanks to CIMMYT for making this study and our stay in the U.S. possible and enjoyable.

To the ET Lab. staff, students, and workers, I express my gratitude for their help in the field and in preparation of this thesis.

A special thanks goes to my wife BAMANGA NTOTO, my children ZEYIMO BAKELANA and MAMPASI BAKELANA for their love, understanding, daily encouragement, and help during this study.

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INTRODUCTION

Irrigation is practiced by farmers to increase crop yields, especially in arid and semi-arid regions where rainfall is not sufficient to support high yields.

In 1979, irrigated corn in the southwest district of Kansas yielded an average of 8,455 kg/ha; nonirrigated corn yielded 3,293 kg/ha. The average corn grain yield per hectare for Kansas in 1979 was 87% higher than that obtained in 1919 (Kansas State Board of Agriculture, 1979). Corn grain yield increase in Kansas until the mid-1970's was obtained through a continuous improved technology but also with an abundant and relatively inexpensive water supply before energy costs rose (Report of Governor's Task Force on water resources, 1977). Prolonged, intense irrigation is depleting the groundwater supplies and farmers now must pump water from deeper depths which requires more energy. Groundwater study of western Kansas indicated that the water table declined in the range of 3 m to 30 m between 1950 and 1975, and that 10 to 50% of the stored water has been depleted (Report of Governor's Task Force on water resources, 1977). The groundwater decline was estimated at 0.5 m in 1977; precipitation was 10% below normal and withdrawals averaged 14 times the natural recharge (Final report of the Governor's Task Force on water resources, 1978). The 1977 groundwater study of western Kansas predicted that if the groundwater withdrawals continue at that rate to year 2,000, farmers will not have enough water to irrigate their crops. Therefore, groundwater must be carefully managed if risks of water shortage are to be diminished. With increasing energy prices, the costs of cropping are increasing and the irrigation profit picture is changing.

Corn grain yield is most sensitive to water deficits at tasseling, silking, and early ear growth. Water stress during those critical growth stages will reduce grain yields considerably (Robins and Domingo, 1953; Denmead and Shaw, 1960; Claassen and Shaw, 1970; Stewart et al., 1975). Supplying water only during the critical growth stages would reduce the amount of water pumped and use less energy. Maximum yields will likely not be obtained with limited irrigation but yields will be improved by proper timing of limited irrigation amounts (Stone et al., 1978; Siebert, 1978).

Use of the proper source of nitrogen in adequate amounts and restricting nitrogen losses from overwatered soil profiles would improve corn yields (Stevenson and Baldwin, 1969; Jung et al., 1972; Rehm and Wiese, 1975; Whitaker et al., 1978).

Plant population also has a significant influence on corn yields. Research has shown corn yield increasing as plant population increases to a given point, but beyond that population yields decrease (Brown et al., 1970; Elshahookie, 1976; Siebert, 1978). Therefore, growing corn under optimum plant populations will improve yields.

Even without developing varieties that require less water, one might ask "Do proper amounts of nitrogen fertilization and proper plant populations, with their interaction, improve corn water use efficiency and maintain profitable production under limited irrigation?"

This study was conducted to measure the effects of limited irrigation, nitrogen fertilization rate, plant population, and their interactions on: (1) corn dry matter yield, (2) corn grain yield, and (3) corn water use and water use efficiency.

LITERATURE REVIEW

Available water in the soil is of great importance during the growth of corn. Water used by corn comes from soil water in storage at planting, rainfall, and/or irrigation.

Corn will complete its vegetative and ear filling stages only if the necessary amount of water is available during all the growing season. Wright et al. (1980) found that the daily water use for corn grown on sandy soil was: 0.2 cm/day during the first 40 days of growth, 0.4 cm/day from day 40 to tasseling, and 0.6 cm/day from tasseling to maturity. Total water use for corn from planting to maturity was about 42 cm. They stated that water requirements for corn will vary with soil type and atmospheric conditions.

Paulsen (1980) found that the monthly conditions of rainfall for top corn yields are: 9 cm of rain in May, 9 cm in June, 11 cm in July, 11 cm in August, and warm dry weather in September to hasten ripening and drying of the grain.

In arid and semi-arid regions, rainfall does not always supply sufficient water needed by corn during the critical stages of growth. If available soil water is not sufficient for growth, moisture stress conditions will result and corn yields will be reduced.

A short stress during the vegetative stage delayed tasseling and silking, resulting in a reduction of grain yield (Claassen and Shaw, 1970). Maranville and Paulsen (1970) found that a stress shortly after emergence decreased the starch and chlorophyll content of seedlings. In a study of crop responses to water at different stages of growth, Salter and Good (1967) found that stress during the vegetative stage had little effect on final corn grain yield.

Most stress which reduces grain yield in corn occurs during tasseling, silking, and early ear growth. Stewart et al. (1975) in a 3-year evapotranspiration (ET) deficit study, obtained greatest yield when little or no ET deficit occurred during pollination. They found no yield improvement with vegetative and late-season irrigations and noted yield fell by 59% when ET deficit developed during pollination and ear growth. Denmead and Shaw (1960) reported yield reductions of 25, 50, and 21% when stress occurred at vegetative, silking, and ear growth stages, respectively. Robins and Domingo (1953) found no significant yield difference between plots where all available soil water was removed seven weeks following tasseling and plots which had ample soil water until the corn was harvested. Plots reaching the wilting point at tasseling gave less yield than plots which had ample soil water until the corn was harvested.

Water stress in the late vegetative stage stunted growth of corn plants (Downey, 1971). According to Eik and Hanway (1966), grain yield reduction was greatest when water stress reduced leaf area index below 3.3.

Gard et al. (1961) showed that 10 cm of irrigation water on a silt loam soil during early tasseling and early ear growth (a 5 cm irrigation at early tasseling and a 5 cm irrigation 14 days later) resulted in economically desirable corn grain yield compared to the use of 5 cm irrigations applied weekly from the 7th through the 12th week after corn planting.

Irrigation in the late ear growth stage does not improve corn grain yield sufficiently to be economical. Siebert (1978) obtained a yield reduction of 19% compared to full-season irrigation when irrigation was operated only during flowering. A 45% yield reduction on dryland, compared to full-season irrigation, was also obtained. Stone et al. (1978) found that corn irrigated at the silking stage only produced yields lower than corn which received three

irrigations, but yields did not decrease as much as water applied.

The amount of water used by corn varies with stage of development. Early in the season, loss of water is primarily due to evaporation from the soil as seedlings do not cover the soil surface. As the season proceeds, crop cover increases and most of the water is lost by transpiration. Peters and Russel (1959) found that of total water loss from field corn, 50 to 70% was lost by evaporation from the soil surface and 30 to 50% by transpiration from the corn. Harrold et al. (1959) found that of 39 cm total evapotranspiration from 1 May to 9 September, 56% was evaporation and 44% was transpiration. The lack of significant leaf area from 1 May to 5 June caused seasonal evaporation to be higher than transpiration. As corn leaf area increased, evaporation decreased relative to transpiration.

Peters (1960) found that water loss of corn was higher at an atmospheric relative humidity of 40% than at 95%. At 40% atmospheric relative humidity, corn roots grew less and plants wilted during the day compared to corn grown at 95% relative humidity.

The increase of ET to a peak use rate in July followed by a gradual decrease to grain maturity was reported by Doss et al. (1962). They found that the rate of ET was generally higher immediately after irrigation than immediately before. DeBoer et al. (1977) reported an average daily ET of 0.54 cm/day during 15 June to 1 August with corn grown on a Great Bend silt loam. Steiner (1979) found that the average daily ET of corn was about 0.5 cm/day in June, 0.8 cm/day in July, and 0.5 cm/day in the first week of August.

Water use by corn is also influenced by plant population. At a very low plant population, water use is low. As plant population increases, water use increases up to a point and then changes slowly with increasing

plant population (Olson, 1971). He obtained an increase in water use as plant population increased from 35,000 to 45,000 plants per hectare, but plant population of 70,000 plants per hectare did not significantly increase water use.

Temperature also has a great influence on corn growth. High air temperatures increase the water requirement of corn by increasing corn transpiration and water evaporation from the soil surface. Under these conditions the plant might be unable to take up enough water to replace that lost by transpiration.

Soil temperatures also affect corn growth. Shaw (1971) found that low soil temperatures in late spring delayed seed germination. Alessi and Power (1971) studied corn emergence in relation to soil temperature and seeding depth. They found a delay of one day in seed germination for each 2.6 cm increase in depth of planting. But, soil temperatures are not as important as high air temperatures during the corn growing season.

Pierre et al. (1966) showed that the optimum monthly average air temperature is 22°C in June, 23°C in July, and 22°C in August during normal rainfall conditions. Yield declines appreciably as average monthly air temperature rises above 24°C in August. As air temperature rises, the rate of respiration of the plant increases and there is less storage of the photosynthate. Most of the photosynthate product of the plant is utilized by the plant itself rather than storing it in the seed.

Paulsen (1980) stated that the monthly average air temperatures for optimum corn growth are 22°C in May, 22°C in June, 23°C in July, and 23°C in August; with warm and dry weather needed in September.

High temperatures are harmful to corn plant during the tasseling stage. Pierre et al. (1966) reported that a period of one or two weeks with above

32°C during summer, particularly after mid-July, may cause such high demands of water that the plants wilt during the day, though rainfall for the period is normal.

Temperatures in the range of 38°C - 40°C caused plants to burn, to turn nearly white, and later to die at the top (Aldrich et al., 1975). High air temperatures decrease photosynthesis, destroy proteins, and affect pollination by blasting tassel so that no pollen is shed or if it is, the pollen is killed before fertilization and consequently the overall yield of corn declines (Paulsen, 1980).

Although high corn yield has been obtained with nitrogen application, time and method of application must be considered to maintain the effectiveness of nitrogen fertilization for high yields. Applying certain types of nitrogen fertilizer on the soil surface has found not to be very effective in grain yield increase because of N losses on the soil surface. Olson et al. (1964) found that broadcast fertilizer on Crete silty clay loam was less effective at increasing corn yield than sidedress applied fertilizer. Chaudhary and Prihar (1974) compared banded and broadcast applied fertilizer and found that banded applied nitrogen increased grain yield by 55% more than broadcast applied nitrogen. Whitaker et al. (1978) found nitrogen losses about twice as much with broadcast as with banded nitrogen beside the row. Corn grain yield increased when 25% of N was banded at planting and 75% was sidedressed.

Nitrogen application after planting and during root development might provide yield increases due to root activity. According to Jung et al. (1972), applications during the 7th and 8th weeks after planting resulted in higher corn grain yield than later applications. Corn grain yield increased as N increased to 168 kg/ha with no further yield increase as N increased to 224 kg/ha. A late nitrogen application does not allow enough time for plants to accumulate protein in the vegetative tissue before grain formation begins.

Wright et al. (1980) found that delaying nitrogen on irrigated corn until three weeks after planting increased corn grain yield but further delay drastically reduced corn grain yield. Anderson (1978), splitting the application of nitrogen fertilizer to corn, found that preplant applied nitrogen on Eudora silt loam was as effective as split applied nitrogen.

Differences in corn yields due to nitrogen application can also be attributed to the source of nitrogen. Stevenson and Baldwin (1969) reported that anhydrous ammonia applied to corn gave much greater response than ammonium nitrate or urea. Because of the low degree of hydrolyzation, all ammonium nitrate was not used by corn at the right time and a part of the urea was rapidly lost by volatilization and leaching. Nelson and McGregor (1973) detected a superior response from ammonium nitrate compared to urea when applied spring surface and sidedress.

Most of the time, corn yield response to nitrogen applied is less than maximum because of nitrogen losses. Moe et al. (1968) reported that total N loss from ammonium nitrate was higher than from urea in all plots, and N losses were greater in sod plots than in fallow plots. They said that because of its high ionization, ammonium nitrate would be adsorbed and held near the surface of the soil. But the non-ionized urea would be carried further down into the soil with the first increment of rainfall and would, therefore, be less subject to surface runoff loss.

Rehm and Wiese (1975) stated that for a sandy soil with no accumulation of fine textured material, the application of N with the irrigation water increased corn grain yield. Smika et al. (1977) found that the average annual total dry matter production was negatively correlated to $\text{NO}_3\text{-N}$ percolating to the 150-cm depth ($r=-0.99$), showing that production of dry matter was highly related to $\text{NO}_3\text{-N}$ loss.

Residual soil nitrogen from substantial amounts of fertilizer nitrogen applied to corn may be carried over from year to year and have an effect on grain yield of the future crop. Claassen (1979) reported that zero nitrogen plots with previous N rates of 73 kg/ha produced corn grain yields not differing significantly from those in plots receiving a continuous application of 34 kg N/ha. A similar effect of residual soil-nitrogen on corn grain yield has been reported by Mulliner and Frank (1975) and Anderson (1978).

Pierre et al. (1977) established a relationship between yield of corn and percentage nitrogen content in the grain. According to that relationship, the percentage of nitrogen content in the grain is 1.52% at the maximum yield. Jung et al. (1972) found that the percentage of N in grain of corn grown on sandy soil increased with increasing rate of applied nitrogen.

Another factor which influences corn yield is the plant population. In most of the cases when corn is planted at a plant population below 40,000 plants per hectare, the average corn grain yield is low compared to grain yield obtained from 50,000 to 60,000 plants per hectare. At low plant population with greater spaced plants and less leaf area, plants do not utilize the maximum of nutrients and they photosynthesize less. At a very dense plant population (above 80,000 plants per hectare), plant competition for nutrients and shading decrease dry matter and grain yield.

According to Brown et al. (1970) the average corn grain yield increased when corn was planted at 55,000 plants per hectare compared to corn grain yield obtained with the stand of 24,000 plants per hectare. Corn grain yield decreased as plant population further increased to 100,000 plants per hectare. Elsahookie (1976) and Siebert (1978) obtained similar trends of yield increase with increases in plant population to a point beyond which corn grain yield decreased.

Grain yield decline at higher plant populations was also explained by

its relationship with leaf area index, kernel dry weight, lodging, and the dry weight that a plant can produce. Williams et al. (1968), Yamagushi (1974), and Poneleit (1979) obtained a decrease in ear number per hectare, kernel dry weight, and dry weight per plant when the plant population was increased.

MATERIALS AND METHODS

This study was conducted on the Ashland Agronomy Research Farm located 5 km southwest of Manhattan, Kansas.

The research soils are Muir silt loam (Stone et al., 1978) and Eudora silt loam (Anderson, 1978). Muir silt loam is a fine-silty, mixed, mesic, Pachic Haplustoll, developed from alluvium. The Eudora silt loam is a coarse-silty, mixed, mesic, Fluventic Hapludoll, developed in coarse silty alluvium on a high flood plain along the Kansas River.

Corn was grown on the Muir soil (Muir Experiment) in 1979 and 1980, and on the Eudora soil (Eudora Experiment) in 1980.

Three irrigation treatments were used: (1) full irrigation, intended to minimize water stress throughout the corn growing season; (2) limited irrigation, corn irrigated to minimize water stress during tasseling, silking, and early ear growth; and (3) no irrigation.

Nitrogen fertilization rates of 100, 225, and 350 kg N/ha were applied to the Muir soil in 1979. In 1980, the rates of N fertilizer applied to the Muir soil were 140, 225, and 350 kg N/ha.

A rate of 215 kg N/ha was applied to the entire Eudora area in 1980.

Urea (45% N) applied using a drill and ammonium nitrate (34% N) applied by hand were the sources of nitrogen in 1979. A urea-ammonium nitrate solution (28% N) and ammonium nitrate (34% N) applied by hand were the sources of nitrogen in 1980.

Three plant populations of approximately 43,000; 57,000; and 86,000 plants per hectare were established by thinning. Rows were 76 cm apart. *Prairie Valley 76S* was the corn variety used.

The design of the Muir Experiment was split-split plot. The design of

the Eudora Experiment was completely randomized block for each irrigation level.

In the Muir Experiment, irrigation treatments provided the main plot effect, nitrogen rates provided the subplot effect, and plant populations gave the sub-subplot effect. The experiment was replicated three times.

Plant population was the main treatment in each Eudora irrigation level. Treatments were replicated three times.

Figures 1 and 2 show the dimensions of the research plots and the plot scheme. Each plot in the Muir and Eudora experiments contained 11 and 15 rows, respectively.

The land was fall plowed and disked in spring. A preplant herbicide of 4.7 liters/ha of Bladex and 4.7 liters/ha of Lasso was applied in 1979.

A preplant herbicide of 2.24 kg/ha of Bladex and 4.7 liters/ha of Lasso was applied in 1980. The lowest nitrogen rate was applied to the entire area. The additional amounts of nitrogen needed by the intermediate and higher rates were applied by hand.

Corn was planted in rows 76 cm apart on 8 May 1979, and 29 April 1980, at a plant population of approximately 178,000 plants per hectare and thinned to the desired plant populations four weeks after planting.

Corn was treated with 2.8 kg/ha of Sevin 80% by weight of active ingredient to control chinch bugs in 1979 and chinch bugs and grasshoppers in 1980 as needed.

Corn grain yield was determined by hand harvesting the center 3 m length of the five center rows of each plot and adjusting to a water content of 15.5% on a wet weight basis. Also at harvest, total plants, total lodged plants, and total ears in the 15 m were recorded. Percentage of grain water content was determined in the laboratory by oven drying grain samples at

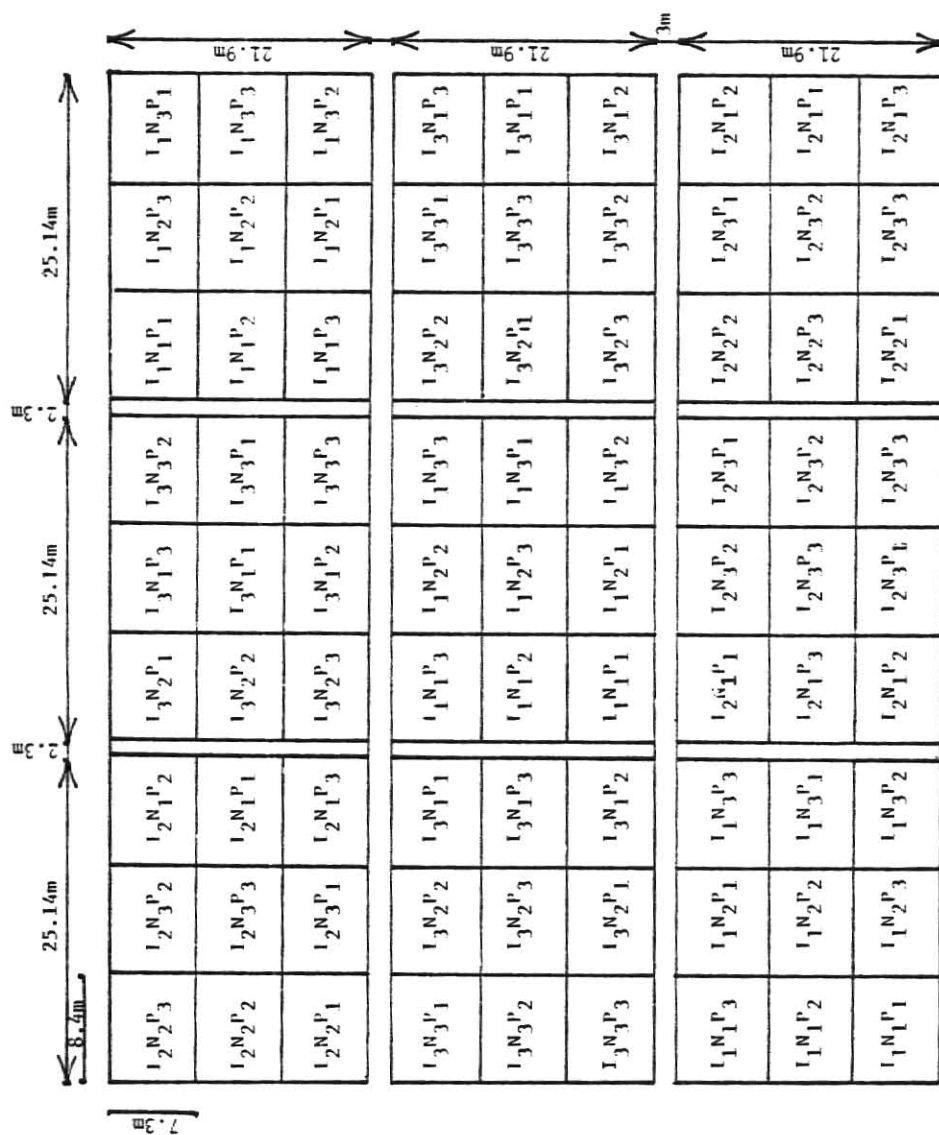


Figure 1. Diagram of the corn experiment conducted in 1979 and 1980 on the Muir silt loam soil.

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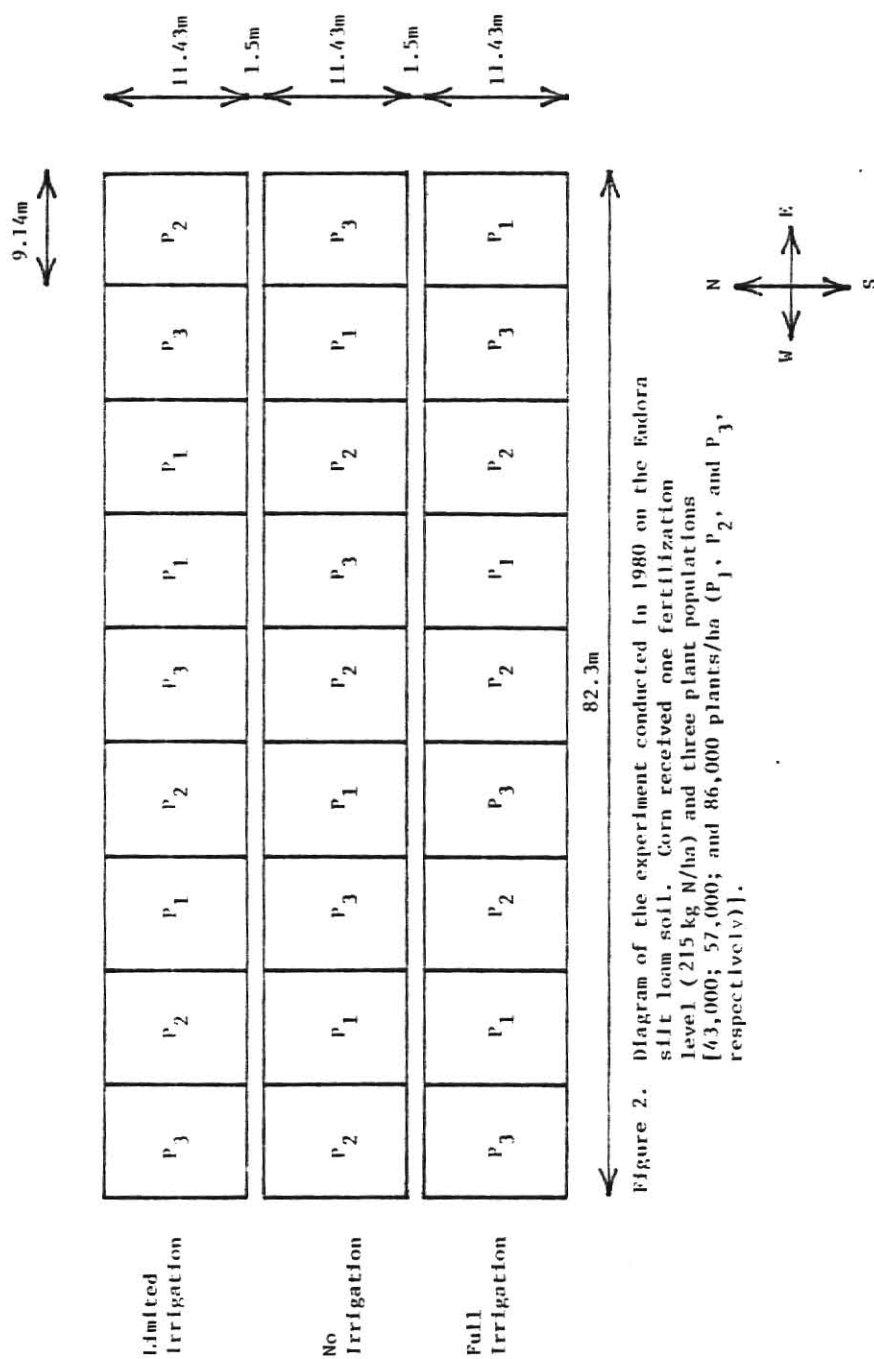


Figure 2. Diagram of the experiment conducted in 1980 on the Eudora silt loam soil. Corn received one fertilization level (215 kg N/ha) and three plant populations [43,000; 57,000; and 86,000 plants/ha (P₁, P₂, and P₃, respectively)].

105°C for four days. Yield components were calculated as follows.

$$(1) X = \frac{D}{1-0.155} \times \frac{10,000 \text{ m}^2 \text{ per hectare}}{11.43 \text{ m}^2 (\text{harvested area})}$$

X = grain yield (kg/ha) at 15.5% water content.

D = grain dry wt. per plot sample = $\frac{\text{grain wet wt. in 15 m}}{1+W}$

W = $\frac{\text{grain wet wt. in 15 m} - \text{grain dry wt. in 15 m}}{\text{grain dry wt. in 15 m}}$

W = grain water content

$$(2) \text{Yield per plant (g)} = \frac{\text{grain yield (g/11.43 m}^2\text{) at 15.5\% water content}}{\text{Total plants in 15 m}}$$

$$(3) \text{Number lodged plants/ha} = \frac{\text{total lodged plants in 15 m} \times 10,000 \text{ m}^2}{11.43 \text{ m}^2 (\text{harvested area})}$$

$$(4) \text{Number ears/ha} = \frac{\text{total ears in 15 m} \times 10,000 \text{ m}^2}{11.43 \text{ m}^2 (\text{harvested area})}$$

$$(5) 100 \text{ kernel wt. (g/100) at 15.5\% water content} = \frac{\text{OD wt.}}{1-0.155}$$

OD wt. = oven dried 100 kernel wt.

Percentage of nitrogen in the grain was determined by the Soil Testing Laboratory, Kansas State University.

Rainfall data was obtained throughout the corn growing season and is summarized in Table 1. The summer of 1979 was wet and cool while that of 1980 was dry and hot. Fig. 3 represents air temperatures during 1979 and 1980 seasons.

Table 1. Monthly rainfall amounts at the Ashland Agronomy Research Farm.

Month	1979	1980	1941-1970 Mean [*]
	cm		
April	5.2	3.3	7.6
May	4.5	5.4	11.0
June	8.9	5.1	14.8
July	14.5	3.2	11.2
August	3.6	7.2	9.1
September	4.2	3.4	10.1

^{*}(Stone et al., 1978)

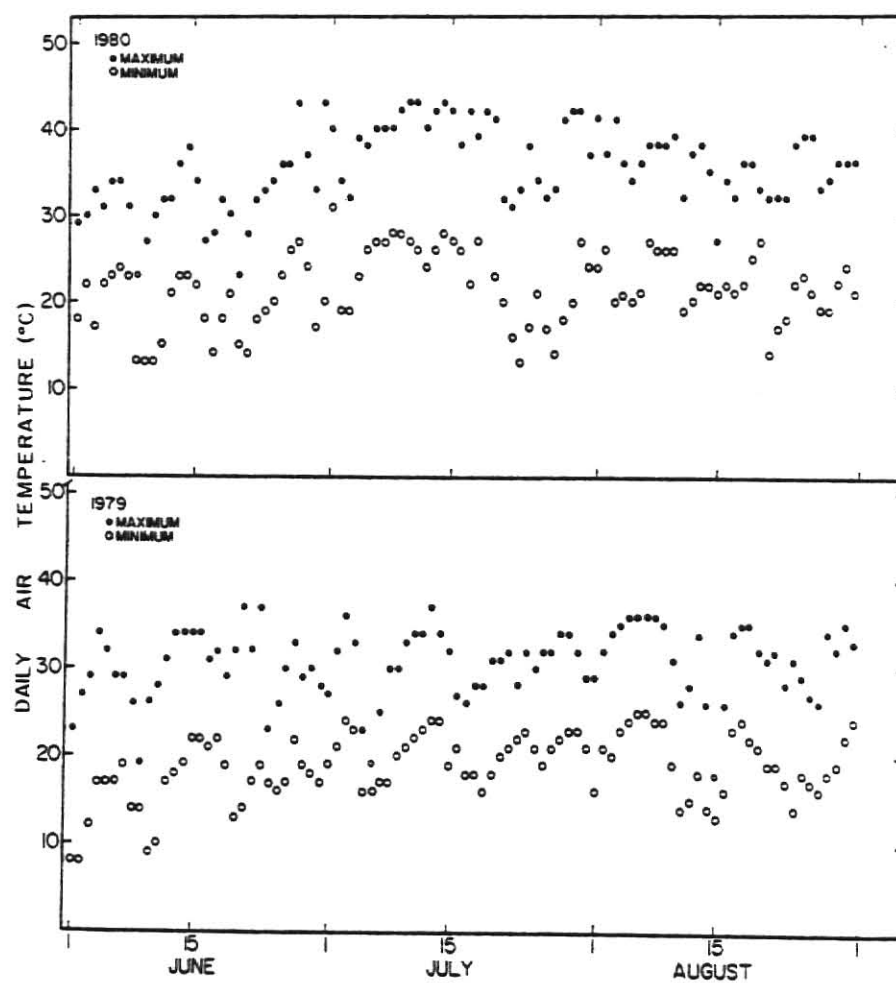


Fig. 3. Air temperature during the 1979 and 1980 corn growing seasons.

Corn received furrow irrigations with water supplied through gated pipe. A ridge placed at the end of each plot prevented runoff from the furrows.

Tables 2 and 3 list the amounts and dates of irrigations.

Table 2. Amounts of water applied to the 1980 Muir Experiment and dates of application.

Date	No irrigation	Limited irrigation	Full irrigation
		cm water	
30 June	0	0	9.9
11 July	0	11.4	8.2
18 July	0	0	6.3
25 July	0	5.9	4.7
1 August	0	0	6.1
8 Auguts	0	0	4.2
Total	0	17.3	39.4

Table 3. Amounts of water applied to the 1980 Eudora Experiment and dates of application.

Date	No irrigation	Limited irrigation	Full irrigation
		cm water	
30 June	0	0	4.1
11 July	0	4.8	3.6
18 July	0	0	3.4
25 July	0	3.9	3.6
1 August	0	0	2.3
8 August	0	0	3.1
Total	0	8.7	20.1

Soil water content was determined in the profile by neutron thermalization and gravimetric methods. An aluminum access tube was placed in the center row

of each plot. Water content readings were taken in the 15- to 150-cm soil profile at 15-cm depth increments. The following formula was used to compute soil water content by volume:

$$\theta = 0.457 (CR) - 0.0348$$

where CR is the count ratio (CPM reading/CPM standard) and θ the soil water content by volume.

Water content by weight in the upper layer (0 to 15 cm) was determined by the gravimetric method. The moist soil sample including the can was weighed, oven dried at 105°C for 48 hours, and weighed again. The empty can weight was recorded. The water contents by weight and by volume were obtained using the following formulas (Hillel, 1971).

$$(1) \quad W = \frac{M-D}{D}$$

W = water content by weight

M = the moist mass of the total sample minus the weight of the can

D = the dry mass of the total sample minus the weight of the can

$$(2) \quad \theta = \frac{W \times \rho_b}{\rho_w}$$

θ = the volumetric water content

ρ_b = the soil dry bulk density

ρ_w = the density of water (1 g/cm³)

Corn growth stages are described according to Hanway (1971) in Table 4. Stages of growth before silking were identified in the field by counting the number of leaves that were fully emerged (with the collar visible) from the whorl. Grain filling stages were timed by repeated observation of kernel development during ear growth. Tasseling or silking stage was recorded when 50% of the corn plants in the field bore tassels or silks. In this study tasseling stage occurred at 16 leaf stage.

Table 4. Corn growth stage development with date of observance.

Growth stage		Date	
Stage number	Description	1979	1980
	Planted	8 May	29 April
0.0	Emergence	18 May	22 May
0.5	2 Leaf	26 May	26 May
1.0	4 Leaf	5 June	2 June
1.5	6 Leaf	12 June	12 June
2.0	8 Leaf	19 June	22 June
2.5	10 Leaf	26 June	28 June
3.0	12 Leaf	1 July	4 July
3.5	14 Leaf	8 July	9 July
4.0	16 Leaf	14 July	11 July
5.0	Silk Emergence	18 July	16 July
6.0	Blister	28 July	25 July
7.0	Dough	8 August	2 August
8.0	Beginning dent	15 August	11 August
9.0	Dent	26 August	20 August
10.0	Physiological maturity	5 September	2 September

To estimate total above-ground corn dry matter yield, plots were sampled on three dates in 1979 and on two dates in 1980 by referring to the method used by Johnson (1966). Eight plants were cut at the ground level and taken from each plot. The eight plants were chopped, dried in a forced air drier at 55°C - 60°C for 14 days or more, and weighed. The strip length left by the sampled plants was measured for dry matter conversion to a hectare basis.

Seasonal evapotranspiration (or water use) of corn was calculated from the following formula:

$$\text{Seasonal ET} = (\text{TW1} - \text{TW2}) + \text{I} + \text{P}$$

where TW is total soil water content of the 150-cm soil profile at beginning

(TW1) and ending (TW2) of the growing season; I and P are water received by irrigation and precipitation, respectively.

Research data were analyzed using the Kansas State University Computing Facilities.

Because of the above-normal rainfall in July 1979 (Table 1), irrigation was not needed and the Muir silt loam experiment was reduced to a split-plot design. The 1980 Muir silt loam experiment was analyzed as a split-split plot design and the Eudora silt loam experiment as a completely randomized block design for each irrigation level.

Means between irrigation treatments, nitrogen fertilizer rates, and plant populations were compared using Duncan's Multiple Range Test. Means with the same letter are not statistically different at the significance level of 0.05.

RESULTS AND DISCUSSIONS

Tables 5, 6, and 7 present the mean amount of water within the 150 cm soil profiles during 1979 and 1980.

In each year, soil water content measured in the Muir silt loam was not influenced by nitrogen fertilizer rate. Soil water content was influenced by plant population in 1979 and by irrigation and plant population in 1980. In both years, plant population significantly influenced soil water content on the Muir silt loam from one week before tasseling (mid-July) to physiological maturity (Tables 5 and 6). Profile soil water content decreased as plant population increased. Plant population in no, limited, and full irrigation did not influence soil water content on the Eudora silt loam (Table 7).

An analysis of variance of soil water content determined for both years showed a significant effect among blocks. This is an indication of variability in the two soil types.

Profile water content in the Muir silt loam and Eudora silt loam progressively decreased during the growing seasons (Fig. 4). Profile water content in the Muir silt loam at no time during the growing seasons approached the permanent wilting point (175 mm at -15.0 bars soil water potential). Profile soil water content in the Eudora silt loam was less than in the Muir silt loam (Fig. 4). Due to structural and textural differences the Eudora silt loam holds less water than the Muir. The Eudora holds 380 and 115 mm of water at soil water potentials of -0.2 and -15.0 bars, respectively. The Muir holds 477 and 175 mm of water at soil water potentials of -0.2 and -15.0 bars, respectively.

Table 5. Profile soil water content (mm water/150 cm soil depth) in Muir silt loam during the 1979 corn season as influenced by nitrogen fertilizer rate and plant population.

Treatment	21 May [†]	9 June [†]	11 June [†]	20 June	3 July	12 July	1 Aug.	7 Aug.	21 Aug.	1 Sept.	11 Sept.
	mm water/150 cm soil depth										
<u>Nitrogen rate</u> (kg N/ha)											
100	443	421	467a [*]	453a	454a	460a	421a	384a	343a	313a	333a
225	443	421	481a	466a	464a	468a	430a	385a	349a	324a	346a
350	443	421	483a	470a	471a	473a	440a	400a	360a	326a	350a
			0.232	0.288	0.262	0.419	0.257	0.388	0.387	0.509	0.469
			<u>Significance level</u>								
<u>Population</u> (plants/ha)											
44,943	443	421	479a	466a	466a	475a	441a	404a	368a	334a	354a
57,808	443	421	476a	464a	462a	465ab	430ab	387b	347b	316b	335b
78,384	443	421	476a	458a	460a	461b	421b	377b	336b	314b	336b
			0.748	0.205	0.516	0.028	0.008	0.001	0.001	0.002	0.011
			<u>Significance level</u>								

*Means within a column for N rate and for population followed by the same letter are not different at the 0.05 significance level according to Duncan's Multiple Range Test.

†Gravimetric sampling on 21 May and 9 June. Neutron sampling on 11 June and throughout remainder of season.

Table 6. Profile soil water content (mm water/150 cm soil depth) in Muir silt loam during the 1980 corn season as influenced by irrigation, nitrogen fertilizer rate, and plant population.

Treatment		29 May [†]	10 June	18 June	25 June	8 July	14 July	24 July	29 July	5 Aug.	12 Aug.	21 Aug.	4 Sept.
		mm water/150 cm soil profile depth											
<u>Irrigation</u>													
None Limited Full	*	475a	462a	439a	446a	376a	345b	318b	310b	301c	282b	298b	296b
		494a	485a	461a	464a	401ab	426a	372ab	401a	365b	334b	337b	327b
		491a	475a	456a	464a	443b	443a	420a	435a	429a	413a	406a	379a
		<u>Significance level</u>											
		0.384	0.327	0.369	0.417	0.062	0.026	0.018	0.012	0.011	0.011	0.022	0.022
<u>Nitrogen</u> (kg N/ha)													
140 225 350		483a	468a	448a	457a	400a	394a	363a	377a	359a	341a	344a	331a
		487a	475a	451a	455a	407a	404a	368a	379a	362a	340a	344a	334a
		489a	479a	456a	462a	413a	415a	379a	389a	374a	349a	353a	337a
		<u>Significance level</u>											
		0.799	0.551	0.765	0.783	0.590	0.276	0.478	0.625	0.381	0.714	0.710	0.867
<u>Population</u> (plants/ha)													
42,578 55,410 73,588		488a	476a	457a	462a	417a	419a	384a	400a	380a	361a	360a	348a
		487a	476a	451a	459a	405ab	400b	364b	377b	360b	336b	342b	326b
		484a	470a	447a	453a	399b	395b	361b	372b	355b	332b	339b	327b
		<u>Significance level</u>											
		0.602	0.458	0.138	0.358	0.023	0.003	0.003	0.004	0.001	0.001	0.008	0.001

*Means within a column for irrigation, for N rate, and for population followed by the same letter are not different at the 0.05 significance level according to Duncan's Multiple Range Test.

[†]Neutron sampling throughout season.

Table 7. Profile soil water content (mm water/150 cm soil depth) in Eudora silt loam soil during the 1980 corn season as influenced by plant population and three irrigation levels.

Treatment		mm water/150 cm soil depth												
Irrigation Pop. (plants/ha)		28 May [†]	12 June	19 June	25 June	7 July	14 July	25 July	30 July	5 Aug.	12 Aug.	22 Aug.	6 Sept.	
None	44,911	318a	308a	277a	289a	218a	179a	160a	148a	150a	136a	147a	157a	
	52,493	275b	268a	261a	259a	206a	160a	138a	134a	139a	127a	140a	140a	
	53,952	280b	269a	241a	260a	197a	181a	172a	164a	165a	157a	156a	167a	
		Significance level												
Limited	48,702	0.056	0.365	0.557	0.545	0.754	0.525	0.340	0.332	0.559	0.315	0.762	0.352	
	60,367	335a	320a	305a	314a	239a	269a	189a	220a	197a	156a	161a	153a	
	87,489	347a	336ab	315a	325a	236a	245a	198a	207a	206a	165a	175a	174a	
		322a	302b	281a	301a	214a	268a	188a	233a	194a	157a	155a	158a	
		Significance level												
Full	44,328	0.184	0.055	0.214	0.496	0.419	0.219	0.867	0.364	0.872	0.937	0.604	0.735	
	56,285	366a	316a	303a	304a	290a	266a	230a	246a	250a	248a	242a	226a	
	81,073	305a	283a	269a	279a	241a	219a	181a	189a	202a	206a	191a	168a	
		353a	328a	304a	315a	293a	272a	241a	260a	273a	265a	248a	221a	
		Significance level												
		0.481	0.468	0.652	0.642	0.350	0.425	0.365	0.238	0.358	0.391	0.387	0.424	

*Means within a column for each irrigation level followed by the same letter are not different at the 0.05 significance level according to Duncan's Multiple Range Test.

[†] Neutron sampling throughout season.

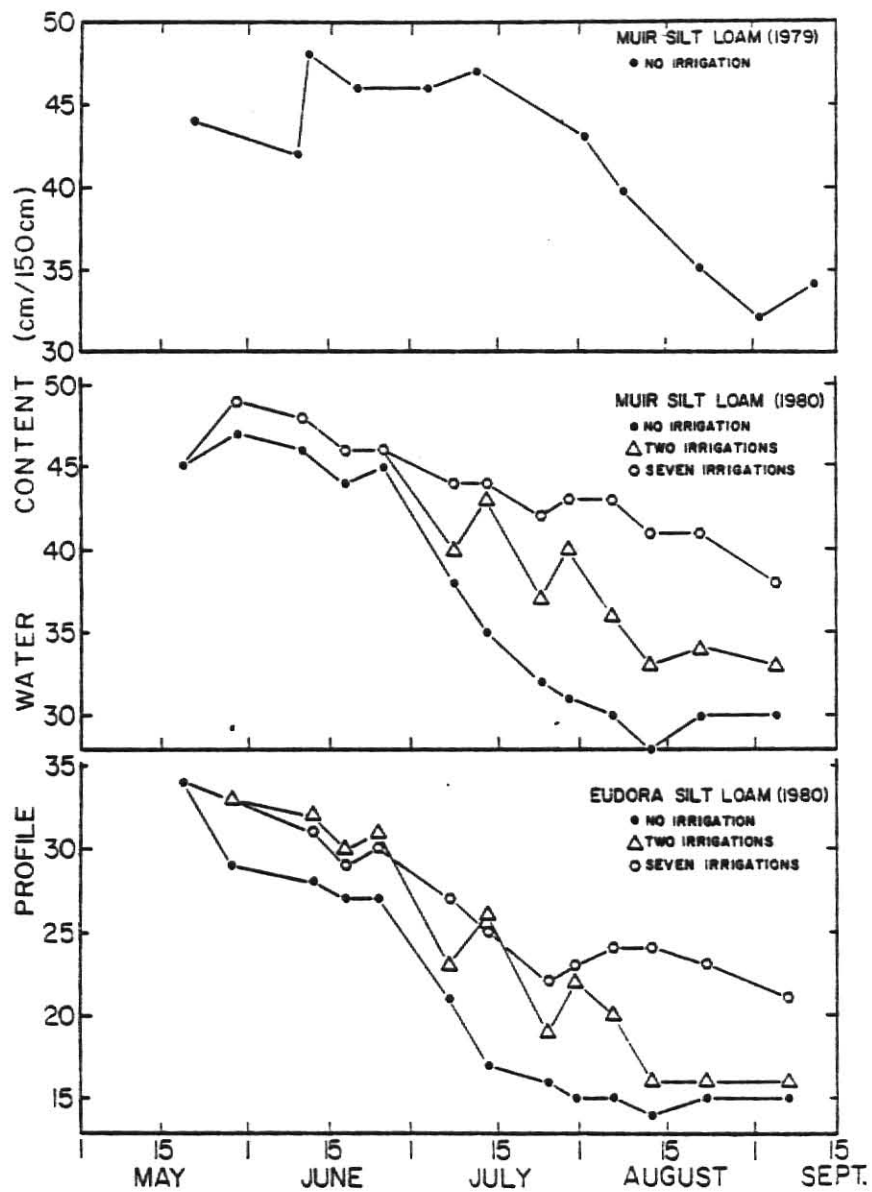


Fig. 4. Profile water content throughout the corn growing season in 1979 and 1980.

Mean corn dry matter yields are presented in Tables 8, 9, and 10.

The analysis of variance of 1979 corn dry matter yield indicated dry matter yield was significantly influenced by plant population but not by nitrogen rate (Table 8). The highest plant population of 75,357 plants per hectare on the Muir silt loam produced the significantly greatest dry matter yield at the 8-leaf and silking stages; and statistically the same amount as the medium population at beginning dent (Table 8). Greater competition and shading at the highest plant population might decrease dry matter production in the late season. Tanaka and Yamagushi (1972) stated that in the late season, corn plants at the highest population cover the soil surface, light transmission from the top to the bottom of the maize canopy decreases and the lowest plant leaves synthesize less than the top leaves, therefore, total dry matter yield decreases.

Plant population on the Eudora silt loam soil did not significantly influence dry matter yield (Table 10). Nitrogen fertilizer rate did not influence dry matter production in 1979 (Table 8). But, dry matter production at dent stage was significantly influenced by nitrogen fertilizer rate in 1980. The rate of 350 kg N/ha produced significantly greater dry matter than the 140 kg N/ha rate (Table 9).

Nonirrigated, limited, and full irrigation conditions on Muir and Eudora silt loam significantly influenced dry matter production at blister and dent stages (Tables 9 and 10). Full irrigation on both soil types yielded the highest dry matter. Dry matter yield of nonirrigated and limited irrigation corn on Muir silt loam at dent stage was 47 and 87%, respectively, of the full irrigation corn dry matter yield (Table 9). On the Eudora silt loam, using the mean from all populations, nonirrigated and limited irrigation corn yielded 29 and 63%, respectively, as much dry matter as full irrigation

Table 8. Dry matter yield (kg/ha) at three stages of corn development in 1979 on Muir silt loam soil as influenced by nitrogen fertilizer rate and plant population.

Treatment	8 Leaf stage (20 June)	Silking stage (20 July)	Beginning dent stage (22 August)
<u>kg/ha</u>			
<u>Nitrogen rate</u> (kg N/ha)			
100	853a*	7,369a	14,902a
225	824a	7,871a	15,709a
350	764a	7,800a	15,553a
		<u>Significance level</u>	
	0.311	0.382	0.331
<u>Population</u> (plants/ha)			
44,055	623a	6,681c	14,271b
56,731	775b	7,661b	15,744a
75,357	1,035c	8,699a	16,148a
		<u>Significance level</u>	
	0.001	0.001	0.004

*Means within a column for N rate and for population followed by the same letter are not different at the 0.05 significance level according to Duncan's Multiple Range Test.

Table 9. Dry matter yield (kg/ha) at two stages of corn development in 1980 on Muir silt loam soil as influenced by irrigation, nitrogen, fertilizer rate, and plant population.

Treatment	Blister stage (22 July)	Dent stage (18 August)
kg/ha		
<u>Irrigation</u>		
None	4,688b [*]	5,353c
Limited	6,771a [†]	10,011b
Full	7,108a [†]	11,455a
	<u>Significance level</u>	
	0.031	0.001
<u>Nitrogen (kg N/ha)</u>		
140	6,129a	8,554b
225	6,020a	8,912ab
350	6,417a	9,554a
	<u>Significance level</u>	
	0.198	0.011
<u>Pop. (plants/ha)</u>		
42,648	5,939a	8,631a
56,346	6,001b	8,945a
74,232	6,633b	9,245a
	<u>Significance level</u>	
	0.017	0.308

*Means within a column for irrigation, for N rate, and for population followed by the same letter are not different at the 0.05 significance level according to Duncan's Multiple Range Test.

†Prior to blister stage, corn had received one and two irrigations in the limited and full irrigation plots, respectively.

corn at dent stage (Table 10).

The three interacting factors (irrigation, nitrogen fertilizer rate, and plant population) had no significant influence on dry matter yield in the 1980 Muir study area. Also, the interaction between nitrogen fertilizer rate and plant population did not influence dry matter yield in 1979.

Mean corn grain yields and yield components are shown in Tables 11, 12, 13, 14, and 15.

The Duncan's Multiple Range Test indicates no significant differences in grain yield due to nitrogen fertilizer rate in the 1979 Muir study (Table 11). Anderson (1978) reported a similar finding, he found that nitrogen fertilizer rate applied on corn had no significant affect on grain yield. However, grain yield for corn grown on the Muir soil was significantly influenced by nitrogen fertilizer rate in 1980 (Table 12). Grain yield was only significantly different between the 140 and 350 kg N/ha rates according to Duncan's Multiple Range Test. Corn receiving the 350 kg N/ha rate produced the most grain.

Grain yield in 1979 was significantly influenced by plant population on the Muir silt loam (Table 11). Grain yield from the medium and highest plant populations were not significantly different. The highest grain yield was obtained with plant population of 57,808 plants per hectare.

A multiple regression analysis for nitrogen rate and plant population was performed on 1979 grain yield. The stepwise-forward procedure applied to tested levels of nitrogen and plant population (independent variables), generated a final equation which indicated that grain yield was a quadratic function of plant population at $p = 0.001$ level (Fig. 5). Grain yield increased to a maximum of 9,615 kg/ha as plant population increased to 68,910 plants per hectare. Grain yield decreased with further increases in

Table 11. Mean corn grain yield, yield per plant, 100 kernel weight, grain nitrogen content, number ears per hectare, number ears per plant, lodging, water use, and water use efficiency as influenced by nitrogen fertilizer rate and plant population in the Mulr 1979 study. All grain weights are reported at water content of 15.5% on a wet weight basis.

Treatment	(grain yield (kg/ha)	Yield per plant (g)	100 kernel weight (g/100)	Grain nitrogen (%)	Ear number (ears/ha)	Ear number (ears/plant)	Lodging (plants/ha)	Water use (mm)	Water use efficiency (kg/ha cm ⁻¹)
<u>Nitrogen rate</u> (kg N/ha)									
100	9,196a*	160a	32.9a	1.39c	58,358a	0.98a	3,759b	464a	199a
225	9,160a	158a	32.7a	1.48b	58,168a	0.98a	7,064a	467a	197a
350	9,200a	161a	33.0a	1.52a	58,391a	0.98a	6,707a	465a	198a
Significance level									
	0.975	0.740	0.897	0.001	0.790	0.957	0.041	0.931	0.875
<u>Population</u> (plants/ha)									
44,943	8,705b	194a	35.0a	1.52a	45,267c	1.00a	1,977c	456b	191b
57,808	9,593a	166b	33.5b	1.43b	56,867b	0.98b	5,185b	470a	204a
78,384	9,259a	119c	30.2c	1.44b	73,782a	0.94c	10,369a	469a	198ab
Significance level									
	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.012	0.013

*Means within a column for N rate and for population followed by the same letter are not different at the 0.05 significance level according to Duncan's Multiple Range Test.

Table 12. Mean corn grain yield, yield per plant, 100 kernel weight, lodging, number of ears per hectare, number of ears per plant, water use, water use efficiency, and grain nitrogen content as influenced by irrigation level, nitrogen fertilizer rate, and plant population in the Muir 1980 study. All grain weights are reported at a water content of 15.5% on a wet weight basis.

Treatment	Grain yield (kg/ha)	Yield per plant (g)	100 kernel weight (g/100)	Lodging (plants/ha)	Ear number (ears/ha)	Ear number (ears/plant)	Water use (mm)	Water use efficiency (kg/ha/cm)	Grain nitrogen (%N)
<u>Irrigation</u>									
None									
Limited	44c*	1c	25.5c	4,277a	2,268c	0.05b	355c	1b	2.03a
Full	3,030b	56b	27.7b	1,944b	44,069b	0.78a	520b	59a	1.80b
	4,389a	79a	29.1a	1,944b	48,313a	0.85a	687a	64a	1.71c
<u>Significance level</u>									
	0.001	0.001	0.001	0.031	0.001	0.001	0.001	0.001	0.002
<u>Nitrogen rate (kg N/ha)</u>									
140	2,186b	41b	28.3a	2,754a	30,718a	0.56a	520a	36b	1.73b
225	2,500ab	44ab	27.9a	2,819a	31,690a	0.55a	522a	41ab	1.79ab
350	2,777a	51a	28.2a	2,592a	32,241a	0.58a	520a	47a	1.81a
<u>Significance level</u>									
	0.017	0.108	0.570	0.840	0.524	0.502	0.945	0.014	0.046
<u>Population (plants/ha)</u>									
42,578	2,486a	58a	27.8b	1,329b	29,033b	0.68a	508b	43a	1.84a
55,410	2,699a	48b	29.1a	2,074b	31,885ab	0.57b	530a	44a	1.76b
73,588	2,278a	30c	27.5b	4,763a	33,732a	0.47c	524a	36a	1.71b
<u>Significance level</u>									
	0.318	0.001	0.005	0.001	0.049	0.001	0.001	0.221	0.001

*Means within a column for irrigation, for N rate, and for population followed by the same letter are not different at the 0.05 significance level according to Duncan's Multiple Range Test.

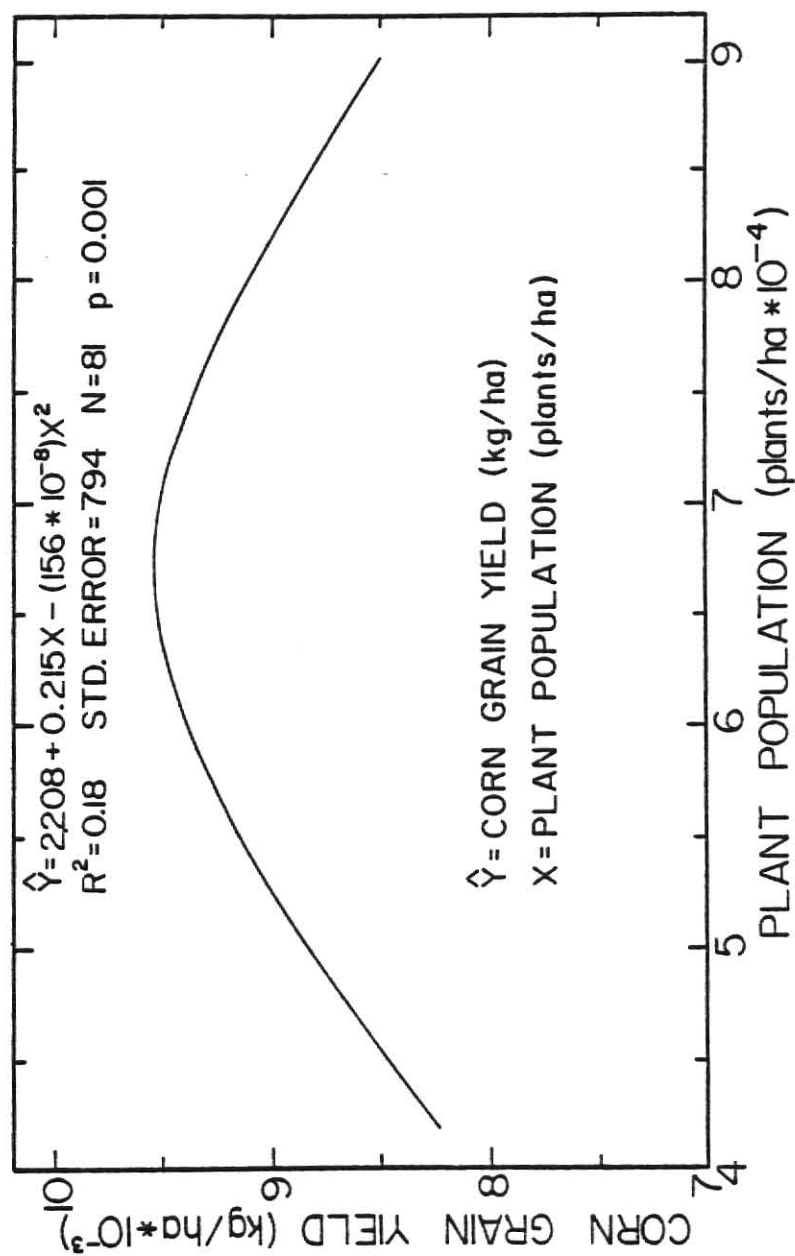


Fig. 5. Corn grain yield as influenced by plant population in 1979.

plant population. This finding is in agreement with those of Brown et al. (1970), Siebert (1978), and Elsayhokie (1978). They all found that the average grain yield increased as plant population increased to a given point, but beyond that population grain yield was not improved. Buren et al. (1974) attributed yield reduction at higher plant populations to a higher percentage of barren plants.

Irrigation level had a significant influence on corn grain yield in 1980 (Table 12). Grain yield was 69 and 1% in plots receiving limited irrigation and no irrigation, respectively, of the yield from full irrigation plots. Siebert (1978) obtained a corn grain yield reduction of 19% compared to full-season irrigation when irrigation was operated only during flowering. Stone et al. (1978) found that corn receiving limited irrigation at the silking stage produced less grain than corn irrigated throughout the season.

In plots irrigated in 1980, the soil water status in the Muir silt loam soil was not greatly different in 1980 than in 1979 (Fig. 4). However, the 1980 corn grain yields where fully irrigated were less than half of the 1979 yields. Grain yield of corn grown on Muir silt loam in 1980 was probably reduced because of higher temperatures from mid-June to September in 1980 than in 1979 (Fig. 5). Pierre et al. (1966) reported that a period of one or two weeks with above 32°C during summer wilts the plants during the day, and Aldrich et al. (1975) found that the plants burned when air temperatures were in the range of 38°C - 40°C .

The extremely high air temperatures during pollination caused pollination failure and poor grain numbers. Pollination failure has been discussed by several authors (Robins and Domingo, 1953; Paulsen, 1980).

A multiple regression analysis for irrigation, nitrogen rate, and plant

population was performed on 1980 grain yield. The stepwise-forward procedure applied to tested levels of irrigation, nitrogen rate, and plant population (independent variables), generated the final equation which indicated that grain yield was a function of irrigation, irrigation square, and the interaction between irrigation and nitrogen rate at $p = 0.0001$ level (Fig. 6).

Almost no grain yield was obtained from nonirrigated corn on the Eudora silt loam soil in 1980 (Table 13). Mean grain yield of the limited irrigation plots (Table 14) was 54% of the mean grain yield from full irrigated plots (Table 15). The Duncan's Multiple Range Test showed no significant differences in grain yields among the plant populations in the fully irrigated plots on the Eudora silt loam (Table 15), but significant differences in grain yield were obtained from plant populations in the limited irrigation plots (Table 14).

The interaction between irrigation, nitrogen fertilizer rate, and plant population had no significant influence on grain yield in the 1980 Muir study. Also, the interaction between nitrogen fertilizer rate and plant population had no significant influence on grain yield in 1979.

The Duncan's Multiple Range Test showed significant differences in yield per plant due to plant population in 1979 (Table 11). But nitrogen fertilizer rate and treatment interaction had no significant influence on yield per plant.

Significant influences on yield per plant were obtained with irrigation level, nitrogen fertilizer rate, and plant population in 1980 (Table 12). Yield per plant increased with an increase in irrigation level and nitrogen fertilizer rate; but decreased with an increase in plant population. William et al. (1968) and Poneleit (1979) also found that yield per plant decreased

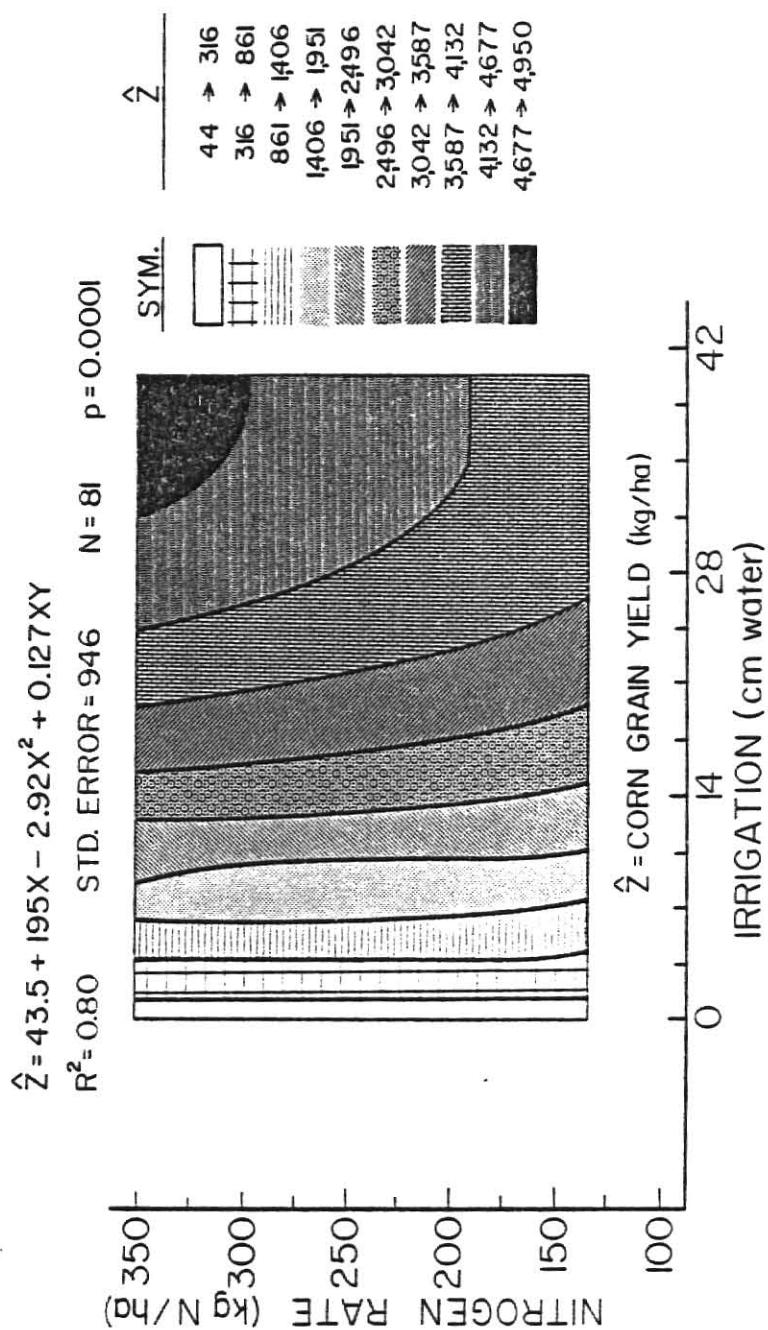


Fig. 6. Corn grain yield as influenced by irrigation level and nitrogen fertilizer rate in 1980 on the Muir silt loam.

Table 13. Mean corn grain yield, yield per plant, 100 kernel weight, number ears per hectare, number ears per plant, lodging, water use, and water use efficiency as influenced by plant population under nonirrigated conditions on Eudora silt loam in 1980. All grain weights are reported at a water content of 15.5% on a wet weight basis.

Treatment	Grain yield (kg/ha)	Yield per plant (g)	100 kernel weight (g/100)	Ear number (ears/ha)	Ear number (ears/plant)	Lodging (plants/ha)	Water use (mm)	Water use efficiency (kg/ha/cm)
Population (plants/ha)								
44,911	27	0	28.0	1,750	0.03	2,333b*	338a	1.3
52,493	0	0	---	0	0	4,083ab	326a	0
53,952 [†]	0	0	---	0	0	4,374a	293a	0
	0.444		0.444	0.444	0.444	0.060	0.208	0.174
				Significance level				

*Means within a column followed by the same letter are not different at the 0.05 significance level according to Duncan's Multiple Range Test.

[†] Higher frequency of dead and decomposed plants at harvest.

Table 14. Mean corn grain yield, yield per plant, kernel weight, number ears per hectare, number ears per plant, water use, water use efficiency, grain nitrogen content, and lodging as influenced by plant population under limited irrigation conditions on Eudora silt loam in 1980. All grain weights are reported at a water content of 15.5% on a wet weight basis.

Treatment	Grain yield (kg/ha)	Yield per plant (g)	100 kernel weight (g/100)	Ear number (ears/ha)	Ear number (ears/plant)	Water use (mm)	Water use efficiency (kg/ha/cm ³)	Grain nitrogen (%N)	Lodging (plants/ha)
<u>Population</u>									
<u>(plants/ha)</u>									
48,702	3,706a*	77a	28.5a	38,495a	0.79a	446a	81a	1.85a	874a
60,367	2,235b	37b	27.9a	36,745a	0.61ab	453a	50b	1.89a	0a
87,489	2,227b	25b	25.3b	42,286a	0.48b	503a	40b	1.96a	874a
<u>Significance level</u>									
	0.013	0.017	0.019	0.817	0.078	0.534	0.005	0.342	0.160

*Means within a column followed by the same letter are not different at the 0.05 significance level according to Duncan's Multiple Range Test.

Table 15. Mean corn grain yield, yield per plant, kernel weight, number ears per hectare, number ears per plant, lodging, water use, water use efficiency, and grain nitrogen content as influenced by plant population under full irrigation conditions on Eudora silt loam in 1980. All grain weights are reported at a water content of 15.5% on a wet weight basis.

Treatment	Grain yield (kg/ha)	Yield per plant (g)	100 kernel weight (g/100)	Ear number (ears/ha)	Ear number (ears/plant)	Lodging plants/ha	Water use (mm)	Water use efficiency (kg/ha/cm)	Grain nitrogen (%N)
Population (plants/ha)									
44,328	4,732a*	107a	29.9a	40,828a	0.92a	292a	494a	96a	1.76a
56,285	5,650a	101a	33.3a	50,452ab	0.90ab	275a	519a	111a	1.66a
81,073	4,764a	60a	31.4a	57,743b	0.72b	292a	527a	90a	1.66a
Significance level									
	0.608	0.129	0.509	0.022	0.074	0.428	0.539	0.627	0.535

*Means within a column followed by the same letter are not different at the 0.05 significance level according to Duncan's Multiple Range Test.

as plant population increased.

The weight of 100 kernels was not influenced by nitrogen fertilizer rate in either year (Tables 11 and 12). But the weight of 100 kernels decreased as plant population increased (Tables 11 and 14). Yamagushi (1974) and Muleba (1980) reported similar findings. The weight of 100 kernels increased as irrigation level increased (Table 12).

Where a significant and definite trend in ear number per hectare was established (Tables 11, 12, and 15), the ear number per hectare increased with an increase in plant population.

Tables 11, 12, 14, and 15 show that ear number per plant decreased as plant population increased. That result is in agreement with the finding of Yamagushi (1974).

Irrigation level (Table 12) significantly influenced ear number per hectare and ear number per plant, each increasing as irrigation level increased. The same trend was obtained on the Eudora soil (Tables 13, 14, and 15). Nitrogen fertilizer rate had no significant influence on ear number per hectare or ear number per plant (Tables 11 and 12).

Plant population significantly influenced the number of lodged plants per hectare (Tables 11, 12, and 13). Lodging increased with an increase in plant population. Yamagushi (1974) and Muleba (1980) also reported the same trend. Considerable lodging in the nonirrigated corn was related to plant death in late July-early August which was not disassociated from lodging counts (Tables 12 and 13). Nitrogen fertilizer rate significantly influenced lodging in 1979 (Table 11). Lodging was greater at the two higher N rates than at the lowest N rate. But nitrogen fertilizer rate had no significant influence on lodging in 1980 (Table 12).

The highest percentage of grain nitrogen content was obtained in the

nonirrigated plots (Table 12). Grain nitrogen content decreased as irrigation level increased (Tables 12, 14, and 15). On the Muir soil, grain nitrogen content decreased as plant population increased to the medium rate; but the medium and the highest plant populations statistically produced the same grain nitrogen content (Tables 11 and 12). Plant population on the Eudora soil did not significantly influence grain nitrogen content (Tables 14 and 15). An increase in nitrogen fertilizer rate significantly increased grain nitrogen content (Tables 11 and 12). Johnson et al. (1973) found significant grain protein responses to nitrogen fertilizer treatments at every test site over a 3-year period of experimentation. Jung et al. (1972) reported an increase in grain nitrogen content with increases in nitrogen fertilizer rate.

These data also are in agreement with the negative correlation found by Terman et al. (1969) between seed protein content and grain yield. Grain nitrogen was high in grains from low yielding plots and low in grains from high yielding plots when corn was grown under irrigation on the Muir soil in 1980.

Tables 11 through 15 contain the mean water use and water use efficiency data.

According to Duncan's Multiple Range Test, nitrogen fertilizer rate on the Muir soil (Tables 11 and 12) had no significant influence on corn water use but plant population did. The greatest water use was obtained with the medium plant population, but the medium and the highest plant populations were statistically the same. Plant population on the Eudora soil had no significant influence on water use (Tables 13, 14, and 15).

The nonirrigated corn used less water than the irrigated corn (Tables 12 through 15), but much of the nonirrigated corn had died soon after silking.

Corn under full irrigation used more water than corn under limited irrigation.

According to Duncan's Multiple Range Test, water use efficiency was not influenced by nitrogen fertilizer rate in 1979 but nitrogen fertilizer rate significantly influenced water use efficiency in 1980 (Tables 11 and 12). In 1980 (Table 12), water use efficiency increased as N fertilizer rate increased, and it increased with an increase in irrigation level (Tables 12 through 15). No significant difference in water use efficiency was obtained between limited and full irrigations on the Muir soil (Table 12). Plant population on the Muir soil significantly influenced water use efficiency in 1979 (Table 11) but not in 1980 (Table 12). In 1979 the medium plant population had the highest water use efficiency.

Tables 16, 17, and 18 list the mean daily evapotranspiration rates. Early in the season, corn used low amounts of water per day. The water use rate increased to maximum rates in mid-season and then gradually decreased as the grain matured. Doss et al. (1962) reported a similar daily evapotranspiration trend.

Table 16. Mean corn evapotranspiration rates as influenced by nitrogen fertilizer rate and plant population on Muir silt loam (1979).

Treatment	cm water/day									
	21 May [†] to 9 June	9 June to 11 June	11 June to 20 June	20 June to 3 July	3 July to 12 July	12 July to 1 Aug.	1 Aug. to 7 Aug.	7 Aug. to 21 Aug.	21 Aug. to 1 Sept.	1 Sept. to 11 Sept.
<u>Nitrogen rate</u> (kg N/ha)										
100	0.17	0.19	0.25a*	0.55a	0.64a	0.58a	0.66a	0.46a	0.36a	0.19a
225	0.17	0.19	0.27a	0.55a	0.64a	0.58a	0.75a	0.46a	0.32a	0.18a
350	0.17	0.19	0.21a	0.55a	0.65a	0.56a	0.69a	0.49a	0.37a	0.18a
<u>Significance level</u>										
	0.418		0.993	0.812	0.412	0.011	0.476	0.137		0.893
<u>Population</u> (plants/ha)										
44,943	0.17	0.19	0.22a	0.56a	0.60b	0.56b	0.63b	0.45a	0.40a	0.19ab
57,808	0.17	0.19	0.23a	0.55a	0.66a	0.57ab	0.74a	0.47a	0.36a	0.20a
78,384	0.17	0.19	0.28a	0.53a	0.68a	0.59a	0.74a	0.49a	0.30b	0.15b
<u>Significance level</u>										
	0.083		0.392	0.001	0.030	0.002	0.223	0.001		0.068

*Means within a column for N rate and for population followed by the same letter are not different at the 0.05 significance level according to Duncan's Multiple Range Test.

[†]Gravimetric sampling on 21 May and 9 June. Neutron sampling on 11 June and throughout remainder of season.

Table 17. Mean corn evapotranspiration rates as influenced by irrigation level, nitrogen fertilizer rate, and plant population on Muir silt loam (1980).

Treatment	cm water/day											
	29 May [†] to 10 June	10 June 18 June	18 June 25 June	25 June 8 July	8 July 14 July	14 July 24 July	24 July 29 July	29 July 5 Aug.	5 Aug. 12 Aug.	12 Aug. 21 Aug.	21 Aug. 4 Sept.	
<u>Irrigation</u>												
None	0.40b	0.28a	0.46a	0.65b [*]	0.50b	0.37b	0.24b	0.23c	0.34c	0.28b	0.16b	
Limited	0.37b	0.30a	0.48a	0.60b	1.28a	0.76a	0.61a	0.60b	0.54b	0.32b	0.22b	
Full	0.43a	0.24a	0.40a	1.05a	1.31a	0.94a	0.75a	1.02a	0.89a	0.53a	0.34a	
	<u>Significance level</u>											
	0.013	0.287	0.681	0.002	0.002	0.009	0.011	0.001	0.001	0.064	0.017	
<u>Nitrogen rate</u> (kg N/ha)												
140	0.42a	0.24b	0.44a	0.81a	1.11a	0.61a	0.51a	0.63a	0.57a	0.31a	0.24a	
225	0.39a	0.30a	0.47a	0.74a	1.03ab	0.73a	0.53a	0.62a	0.59a	0.42a	0.22a	
350	0.39a	0.28ab	0.43a	0.75a	0.94b	0.73a	0.56a	0.60a	0.62a	0.41a	0.26a	
	<u>Significance level</u>											
	0.392	0.077	0.517	0.105	0.059	0.196	0.784	0.810	0.452	0.150	0.171	
<u>Population</u> (plants/ha)												
42,578	0.39a	0.24b	0.46a	0.72b	0.97a	0.68a	0.55a	0.60a	0.59a	0.37a	0.23a	
55,410	0.41a	0.30a	0.44a	0.78ab	1.06a	0.70a	0.51a	0.63a	0.60a	0.38a	0.25a	
73,588	0.40a	0.29a	0.44a	0.80a	1.06a	0.68a	0.55a	0.63a	0.58a	0.38a	0.23a	
	<u>Significance level</u>											
	0.441	0.009	0.843	0.056	0.245	0.700	0.655	0.545	0.809	0.968	0.514	

*Means within a column for irrigation level, for N rate, and for population followed by the same letter are not different at the 0.05 significance level according to Duncan's Multiple Range Test.

[†] Neutron sampling throughout season.

Table 18. Mean corn evapotranspiration rates as influenced by plant population under three irrigation levels on Eudora silt loam (1980).

Irrigation	Treatment Population (plants/ha)	cm water/day											
		28 May [†] to 12 June	12 June to 19 June	19 June to 25 June	25 June to 7 July	7 July to 14 July	14 July to 25 July	25 July to 30 July	30 July to 5 Aug.	5 Aug. to 12 Aug.	12 Aug. to 22 Aug.	22 Aug. to 6 Sept.	
None	44,911	0.35a	0.34a	0.41b	0.66a	0.55a	0.27a	0.34a	0.11a	0.27a	0.28b	0.08a	
	52,493	0.29a	0.21a	0.64a	0.59a	0.53a	0.30a	0.23a	0.09a	0.24a	0.26b	0.14a	
	53,952	0.31a	0.40a	0.33b	0.54a	0.36a	0.18a	0.26a	0.13a	0.16a	0.41a	0.07a	
Limited						<u>Significance level</u>							
		0.848	0.145	0.039	0.322	0.439	0.359	0.514	0.752	0.694	0.040	0.271	
	48,702	0.33ab	0.23a	0.45a	0.70a	0.27b	0.82a	0.26a	0.52a	0.64a	0.35a	0.20a	
Full	60,367	0.31b	0.30a	0.44a	0.80a	0.56a	0.53a	0.75a	0.39a	0.65a	0.29a	0.15a	
	87,489	0.37a	0.30a	0.29a	0.78a	0.53ab	0.82a	0.53a	0.78a	0.60a	0.41a	0.14a	
						<u>Significance level</u>							
		0.078	0.759	0.453	0.638	0.071	0.372	0.248	0.269	0.960	0.689	0.442	
Full	44,328	0.39ab	0.24a	0.59a	0.54b	0.86a	0.74a	0.48a	0.47a	0.52a	0.45a	0.26a	
	56,285	0.35b	0.20a	0.63a	0.72a	0.84a	0.75a	0.66a	0.29a	0.45a	0.54a	0.30a	
	81,073	0.40a	0.33a	0.76a	0.60ab	0.81a	0.69a	0.43a	0.32a	0.61a	0.56a	0.32a	
					<u>Significance level</u>								
	0.079	0.391	0.437	0.051	0.876	0.875	0.210	0.759	0.396	0.355	0.547	0.547	

*Means within a column for each irrigation level followed by the same letter are not different at the 0.05 significance level according to Duncan's Multiple Range Test.

[†]Neutron sampling throughout season.

SUMMARY AND CONCLUSIONS

Intense irrigation of crops is depleting groundwater at a rate that will cause water shortages in the near future and will increase the energy required to pump water from the deeper depths. Careful management of water supplied by irrigation is necessary to maintain water supplies, keep energy costs at a minimum, and keep irrigation farming at a profitable level.

This study was conducted to investigate the influence that irrigation level, nitrogen fertilizer rate, and plant population would have on corn dry matter yield, grain yield, water use, and water use efficiency.

Corn experiments were conducted near Manhattan, Kansas, in 1979 and 1980 on Muir silt loam and in 1980 on Eudora silt loam. No irrigation water was applied in 1979 because of the sufficient rainfall of that season. Corn received three levels of irrigation in 1980--no irrigation, limited irrigation (at tasseling and blister stages), and full irrigation (applied weekly from one week before tasseling to dent stage). Three nitrogen fertilizer rates [100 (140 in 1980), 225, and 350 kg N/ha] were applied to the Muir soil. The Eudora had a uniform application of 215 kg N/ha in 1980. Corn was thinned to three plant populations of approximately 43,000; 57,000; and 86,000 plants/ha each year.

The results of this study show that dry matter yield obtained from the Muir soil and the Eudora soil in 1980 was significantly influenced by irrigation treatment. The greatest dry matter yield occurred under full irrigation conditions. Nitrogen fertilizer rate had no influence on dry matter yield in 1979, but significantly influenced dry matter yield at dent stage in 1980. Dry matter yield increased as nitrogen fertilization rate

increased. Plant population significantly influenced dry matter yield on the Muir soil in both years, 1979 and 1980. Dry matter yield increased as plant population increased. Plant population did not have a significant influence on corn dry matter yield on the Eudora silt loam soil.

Irrigation treatment had a significant influence on corn grain yield in 1980. On the Muir silt loam, corn receiving limited and no irrigation yielded 69 and 1%, respectively, as much grain as corn receiving full irrigation. On the Eudora silt loam, corn receiving limited irrigation yielded 54% as much grain as corn receiving full irrigation. Nitrogen fertilizer rate did not influence grain yield in 1979 but significantly influenced grain yield in 1980. Corn fertilized at the rate of 350 kg N/ha produced more grain than corn fertilized at the 140 and 225 kg N/ha rates but not significantly more than corn fertilized at the 225 kg N/ha rate. On the Muir silt loam soil in 1979, a plant population of approximately 69,000 plants per hectare produced the most grain. In 1980 on the Muir and Eudora soils there was no consistent and significant trend of plant population influencing grain yield.

Nitrogen application rate had no influence on corn water use during the two study years. Corn water use was significantly influenced by plant population on the Muir soil both years. Water use by the highest and medium plant populations was not significantly different but both plant populations used significantly more water than the lowest plant population.

Corn grown with full and limited irrigation on the Muir silt loam soil had nearly equal water use efficiency, the water use efficiency being greater than that with nonirrigated conditions. Corn receiving full irrigation on the Eudora soil had a greater water use efficiency than corn receiving limited irrigation. Nitrogen fertilization rate of corn had no

influence on water use efficiency in 1979, but N rates significantly influenced water use efficiency in 1980. Water use efficiency increased in 1980 as N application rate increased. No significant trend was established (or noted) between water use efficiency and plant population.

The interaction between nitrogen fertilizer rate and plant population in 1979, and between irrigation level, nitrogen fertilizer rate, and plant population in 1980 had no significant influence on dry matter yield, grain yield, water use, or water use efficiency.

The results and conclusions given in this thesis are true for the corn variety used.

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Appendix Tables

Table 1A. Significance of F values for corn dependent variables of Muir experiment in 1979.

Source of variation	df	Dependent variables										
		Grain yield	Yield per plant	100 kernel weight	Lodging	Grain nitrogen	Ears/ha	Ears/plant	Water use efficiency	Dry matter 1	Dry matter 2	Dry matter 3
		Level of significance										
Rep	8	0.0001	0.0006	0.0002	0.01	0.40	0.64	0.25	0.003	0.007	0.41	0.79
Nitrogen	2	0.97	0.74	0.89	0.04	0.0001	0.79	0.95	0.93	0.87	0.31	0.32
MS Error(a) ^{1/}	16	516,874	113	5.41	22,698,772	0.0048	23,783,630	0.002	6.81	235	43,874	1,947,961
Pop	2	0.0001	0.0001	0.0001	0.0001	0.0004	0.0001	0.0001	0.01	0.01	0.0001	0.004
Nitrogen*Pop	4	0.59	0.80	0.94	0.12	0.26	0.56	0.53	0.44	0.63	0.71	0.65
MS Error(b) ^{1/}	48	378,775	176	2.81	19,796,722	0.0066	23,104,818	0.002	3.39	257	46,084	1,307,761
												4,315,181

^{1/} Mean square value for each variable.

Table 2A. Significance of F values for corn dependent variables of Muir experiment in 1980

Source of variation	df	Grain yield	Yield per plant	100 kernel weight	Dependent variables								Grain nitrogen
					Lodging	Ears/ha	Ears/plant	Water use	Water use efficiency	Dry matter 1	Dry matter 2		
Level of significance													
Block	2	0.10	0.03	0.12	0.0001	0.26	0.27	0.10	0.08	0.11	0.24	0.65	
IRR	2	0.0001	0.0001	0.005	0.03	0.0001	0.0001	0.0001	0.0001	0.03	0.0004	0.002	
MS Error(a) ^{1/}	4	505,792	0.00024	1.35	5,258,812	16,735,592	0.0095	3.59	166	4,916,986	2,718,121	0.006	
Nitrogen	2	0.01	0.10	0.57	0.84	0.52	0.50	0.94	0.01	0.19	0.01	0.04	
IRR*Nitrogen	4	0.38	0.74	0.16	0.46	0.27	0.09	0.74	0.42	0.21	0.82	0.94	
MS Error(b) ^{1/}	12	409,856	0.00027	1.89	2,083,680	23,492,197	0.007	8.52	126	611,784	650,473	0.006	
Pop	2	0.31	0.0001	0.005	0.0001	0.04	0.0001	0.0002	0.22	0.01	0.30	0.001	
IRR*Pop	4	0.61	0.007	1.00	0.44	0.0008	0.02	0.0001	0.54	0.66	0.45	1.00	
Nitrogen*Pop	4	0.39	0.20	0.53	0.24	0.39	0.28	0.40	0.44	0.08	0.41	0.30	
IRR*Nitrogen*Pop	8	0.25	0.06	0.46	0.18	0.43	0.04	0.10	0.38	0.25	0.47	0.23	
MS Error(c) ^{1/}	36	1,009,028	0.00027	2.01 [†]	2,891,638	46,086,664	0.009	3.11	313	879,804	2,090,347	0.009 [†]	

^{1/} Mean square value for each variable.[†] df = 24

Table 3A. Significance of F values for corn dependent variables of Eudora experiment in 1980.

Source of variation	df	Grain yield	Yield per plant	100 kernel weight	Dependent variables							
					Lodging	Ears/plant	Ears/ha	Water Use	Water use efficiency	Dry matter 1	Dry matter 2	Grain nitrogen
<u>No Irrigation</u>												
Block	2	0.44	0.44	-- [†]	0.87	0.44	0.44	0.16	0.30	0.83	0.79	-- [†]
Pop	2	0.44	0.44	-- [†]	0.06	0.44	0.44	0.20	0.17	0.94	0.99	-- [†]
MS Error ^{1/}	4	727	34.10 ⁻⁸		595,337	0.0014	3,061,735	7	0.47	2,140,302	1,857,272	
<u>Limited Irrigation</u>												
Block	2	0.001	0.02	0.23	0.11	0.05	0.09	0.35	0.001	0.18	0.41	0.16
Pop	2	0.01	0.01	0.01	0.16	0.07	0.81	0.53	0.005	0.08	0.45	0.34
MS Error ^{1/}	4	144,548	0.0002	0.72	255,145	0.014	113,369,225	40	58	992,756	3,252,880	0.007
<u>Full Irrigation</u>												
Block	2	0.38	0.49	0.39	0.28	0.95	0.40	0.29	0.33	0.70	0.50	0.60
Pop	2	0.60	0.12	0.50	0.44	0.07	0.02	0.53	0.62	0.72	0.79	0.53
MS Error ^{1/}	4	1,442,050	0.0005	11	340,193	0.0072	19,220,889	12	685	4,794,051	6,884,775	0.013

[†] No grain yield was obtained.^{1/} Mean square value for each variable.

Table 4A. Data of corn, obtained in 1979 on Muir silt loam soil. Grain weights at 15.5% water content.

Plot no.	Treatment N (kgN/ha)	Population plants/ha	Grain yield (kg/ha)	Yield per plant (g)	100 kernel weight (g/100)	Lodging (plants/ha)	Ears/ha	Ears/plant	Water use (mm)	Water use efficiency (kg/ha/cm)	Grain nitrogen (ZN)
1	100	44,619	7,195	161	33.30	0	42,870	0.96	440	163	1.55
2	100	50,618	8,508	145	31.25	7,874	59,491	1.01	471	180	1.15
3	100	86,614	8,930	103	28.69	5,249	78,740	0.91	488	183	1.21
4	225	44,619	8,733	196	31.21	6,124	47,244	1.06	461	190	1.45
5	225	63,867	8,869	139	30.93	13,123	60,367	0.95	494	180	1.50
6	225	83,900	8,312	99	27.18	21,622	76,115	0.91	463	180	1.67
7	350	54,243	7,936	146	32.92	6,124	48,119	0.89	466	170	1.53
8	350	44,619	8,639	194	35.19	3,500	43,745	0.98	443	195	1.51
9	350	77,865	9,134	117	30.24	13,123	69,991	0.89	436	209	1.60
10	350	82,240	8,940	109	27.30	17,498	78,740	0.96	469	191	1.47
11	350	53,368	9,198	172	32.27	4,374	54,243	1.02	464	198	1.54
12	350	46,369	8,815	190	34.10	875	44,619	0.96	426	207	1.52
13	225	61,242	10,391	170	34.95	6,124	60,367	0.99	463	224	1.35
14	225	87,489	8,395	96	26.66	16,623	76,115	0.87	481	174	1.45
15	225	46,369	8,123	175	35.39	874	47,244	1.02	454	179	1.52
16	100	57,743	9,544	165	34.35	3,500	55,993	0.97	466	205	1.45
17	100	79,615	9,977	125	31.67	2,625	76,990	0.97	435	230	1.22
18	100	47,244	8,359	177	33.36	0	48,119	1.02	400	209	1.40
19	225	38,495	7,911	205	34.66	0	38,495	1.00	426	186	1.54
20	225	56,868	8,682	153	32.95	3,500	53,368	0.94	446	195	1.44
21	225	92,738	9,265	100	29.96	14,873	82,240	0.89	444	209	1.40
22	350	61,242	9,959	163	33.84	6,999	62,117	1.01	442	225	1.44
23	350	74,366	8,539	115	32.76	7,874	67,367	0.91	473	181	1.42
24	350	45,494	8,222	181	36.28	3,500	46,369	1.02	450	183	1.56
25	100	78,740	9,924	126	30.54	2,625	78,740	1.00	451	220	1.40
26	100	46,369	8,671	187	30.14	2,625	47,244	1.02	445	193	1.35
27	100	59,493	9,998	168	35.65	1,750	57,743	0.97	453	221	1.40
28	100	58,618	7,875	134	28.34	5,249	55,993	0.96	474	166	1.53
29	100	73,491	9,163	125	27.17	6,999	71,741	0.98	500	184	1.32
30	100	44,619	9,998	197	34.21	1,750	45,494	1.02	462	190	1.45
31	350	54,243	7,875	172	31.88	4,374	57,743	1.07	459	206	1.46
32	350	81,365	9,163	93	25.24	39,370	75,241	0.93	451	167	1.62
33	350	41,995	8,791	173	31.76	4,374	45,494	1.08	453	160	1.60
34	225	76,115	9,329	113	32.25	18,373	70,866	0.93	485	177	1.46
35	225	60,367	7,532	156	34.55	13,123	61,242	1.01	467	202	1.45
36	225	46,369	7,251	209	35.22	3,500	47,244	1.02	456	213	1.56

Table 4A. Data of corn, obtained in 1979 on Muir silt loam soil con't.

37	100	46,369	8,595	196	36.33	1,750	44,619	0.96	464	196	1.43
38	100	51,619	9,430	167	34.31	2,625	49,869	0.97	480	180	1.34
39	100	83,115	9,695	109	28.21	2,625	77,865	0.94	433	210	1.30
40	225	55,993	10,301	184	35.40	8,749	55,993	1.00	484	213	1.42
41	225	79,615	8,924	112	29.65	6,124	72,616	0.91	468	191	1.54
42	225	43,745	8,622	197	35.67	2,625	44,619	1.02	471	183	1.48
43	350	61,242	10,866	166	34.35	5,249	62,117	1.01	486	209	1.45
44	350	45,494	9,829	216	36.64	3,500	48,119	1.06	488	201	1.50
45	350	88,364	10,866	123	30.42	15,748	87,489	0.99	481	226	1.44
46	225	76,990	9,167	122	29.19	6,999	69,991	0.91	470	199	1.17
47	225	57,743	9,818	170	31.96	5,249	61,242	1.06	482	204	1.36
48	225	47,244	8,412	178	35.40	875	44,619	0.94	471	179	1.62
49	100	80,490	8,624	107	29.98	6,999	75,241	0.94	459	188	1.35
50	100	41,120	8,359	203	35.30	3,500	41,995	1.02	473	177	1.41
51	100	52,493	9,381	179	31.66	2,625	50,744	0.97	406	231	1.27
52	350	75,241	8,537	113	26.89	4,374	69,116	0.92	445	192	1.54
53	350	41,995	8,234	196	34.56	3,500	42,870	1.02	457	180	1.50
54	350	53,368	9,350	175	35.50	3,500	48,119	0.90	505	185	1.46
55	225	42,870	8,576	200	33.80	1,750	43,745	1.02	474	181	1.52
56	225	76,115	9,941	131	33.27	12,248	69,991	0.92	483	206	1.48
57	225	55,118	9,521	173	33.04	4,374	53,368	0.97	439	217	1.42
58	350	44,619	9,335	209	34.38	875	48,994	1.10	424	220	1.50
59	350	62,992	9,846	156	31.57	6,999	63,867	1.01	482	204	1.52
60	350	73,491	8,735	119	32.23	13,123	69,991	0.95	471	186	1.52
61	100	69,116	8,457	122	31.31	6,999	68,241	0.99	511	165	1.44
62	100	46,369	8,234	204	36.44	2,625	48,119	1.04	497	190	1.54
63	100	55,118	9,350	189	35.49	7,874	54,243	0.98	493	211	1.50
64	225	83,115	8,576	116	29.65	10,499	83,990	1.01	465	207	1.49
65	225	46,369	9,941	198	34.75	0	47,244	1.02	450	204	1.50
66	225	55,118	9,804	178	32.88	2,625	54,243	0.98	434	226	1.45
67	350	51,619	9,210	178	38.02	875	43,745	0.85	463	199	1.63
68	350	75,241	10,086	134	32.89	4,374	71,741	0.95	468	216	1.45
69	350	58,618	10,565	180	33.92	3,500	55,993	0.96	497	213	1.63
70	100	61,242	10,402	170	34.76	2,625	59,493	0.97	490	212	1.30
71	100	42,870	8,972	209	38.01	0	41,995	0.98	458	196	1.57
72	100	72,616	11,139	153	33.70	3,500	72,616	1.00	457	244	1.45
73	100	75,241	9,855	131	31.70	13,998	69,116	0.92	483	204	1.26
74	100	57,743	9,961	172	34.09	2,625	55,993	0.97	477	209	1.33
75	100	45,494	9,554	210	36.81	875	46,369	1.02	462	207	1.54
76	225	73,491	10,201	139	30.42	3,500	74,366	1.02	523	195	1.49

Table 4A. Data of corn, obtained in 1979 on Muir silt loam soil con't.

77	225	56,868	10,066	177	35.64	3,500	55,118	0.97	481	209	1.47
78	225	44,619	8,582	192	37.19	1,750	45,494	1.02	468	183	1.48
79	350	65,617	11,113	169	34.67	1,750	68,241	1.04	499	223	1.49
80	350	59,493	9,844	165	35.09	0	56,868	0.96	488	202	1.40
81	350	45,494	9,213	203	36.86	1,750	45,494	1.00	479	192	1.71

Table 5A. Data of corn, obtained in 1980 on Mndr silt loam soil. Grain weights at 15.5% water content.

Plot no.	IRR (mm)	N (kgN/ha)	Population (plants/ha)	Grain yield (kg/ha)	Yield per plant (g)	100 kernel weight (g/100)	Lodging (plants/ha)	Ears/ha	Ears/plant	Water use (mm)	Water use efficiency (kg/ha/cm)	Grain nitrogen (Zn)
1	0	140	49,869	0	0	--	4,374	0	0	339	0	--
2	0	140	56,868	0	0	--	5,249	0	0	342	0	--
3	0	140	79,615	0	0	--	1,750	0	0	330	0	--
4	0	225	43,745	0	0	--	0	0	0	345	0	--
5	0	225	55,118	0	0	--	1,750	0	0	350	0	--
6	0	225	56,868	0	0	--	4,374	0	0	346	0	--
7	0	350	62,992	0	0	--	3,500	0	0	379	0	--
8	0	350	39,370	173	0	27.6	0	15,748	0.5	370	5	2.10
9	0	350	71,761	0	0	--	4,374	0	0	351	0	--
10	394	350	89,239	1,956	0.02	26.4	0	41,119	0.5	698	28	1.85
11	394	350	59,493	6,568	0.11	29.3	875	57,743	0.9	684	97	1.70
12	394	350	41,995	4,999	0.12	28.3	875	40,245	0.9	662	76	1.82
13	394	225	59,493	4,925	0.08	31.0	875	28,871	0.5	673	74	1.70
14	394	225	91,864	5,430	0.06	28.8	3,500	64,742	0.7	709	76	1.60
15	394	225	39,370	2,399	0.06	27.7	0	39,370	1.0	701	34	1.90
16	394	140	52,493	2,033	0.04	28.4	0	45,494	0.9	722	28	1.92
17	394	140	69,991	4,111	0.06	29.0	1,750	48,119	0.7	706	60	1.55
18	394	140	41,995	2,769	0.06	28.4	0	41,120	0.9	646	43	1.60
19	173	225	42,870	1,708	0.04	26.2	0	36,745	0.9	465	36	2.00
20	173	225	55,993	3,435	0.06	28.0	875	51,619	0.9	509	64	1.75
21	173	225	69,116	1,354	0.02	26.8	875	36,745	0.5	505	26	1.90
22	173	350	55,993	2,779	0.05	29.6	875	45,494	0.8	549	49	1.81
23	173	350	77,865	3,072	0.04	28.4	2,625	52,493	0.7	534	56	1.72
24	173	350	40,245	3,117	0.07	29.9	0	34,996	0.9	522	58	1.80
25	173	140	69,991	1,676	0.02	27.3	2,625	41,995	0.6	501	34	1.75
26	173	140	38,495	2,639	0.07	27.0	0	35,871	0.9	493	54	1.70
27	173	140	56,868	3,840	0.07	28.6	875	48,994	0.9	534	72	1.68
28	173	140	48,119	1,434	0.03	26.8	875	41,120	0.9	546	27	1.88
29	173	140	94,488	3,392	0.04	27.5	2,625	62,992	0.7	543	63	1.70
30	173	140	41,120	1,940	0.05	28.9	0	36,745	0.9	536	37	1.90
31	173	350	59,493	4,513	0.08	28.4	875	49,869	0.8	524	87	1.72
32	173	350	65,617	3,396	0.05	27.6	1,750	45,494	0.7	534	64	1.68
33	173	350	42,870	2,614	0.06	28.0	0	38,495	0.9	524	50	1.90
34	173	225	69,991	1,848	0.03	27.9	4,374	47,244	0.7	541	34	1.82
35	173	225	59,493	3,457	0.06	26.4	0	51,618	0.9	528	65	1.75

Table 5A. Data of corn, obtained in 1980 on Muir silt loam soil con't.

36	173	225	44,619	4,920	0.11	28.9	0	40,245	0.9	503	98	1.74
37	0	140	33,246	0	0	--	0	5,249	0.2	363	0	--
38	0	140	35,871	0	0	--	1,750	0	0	341	0	--
39	0	140	66,492	0	0	--	5,249	0	0	330	0	--
40	0	225	48,119	0	0	--	0	0	0	391	0	--
41	0	225	79,615	0	0	--	5,249	0	0	360	0	--
42	0	225	42,870	0	0	--	2,625	0	0	368	0	--
43	0	350	62,117	0	0	--	1,750	0	0	353	0	--
44	0	350	43,745	329	0	24.8	875	15,748	0.4	401	8	2.02
45	0	350	55,993	0	0	--	8,749	0	0	351	0	--
46	394	225	68,242	3,170	0.05	27.4	3,500	54,243	0.8	711	45	1.74
47	394	225	57,743	5,127	0.09	30.0	875	55,993	0.9	750	73	1.68
48	394	225	43,745	4,108	0.09	29.4	0	38,495	0.9	671	61	1.80
49	394	140	81,365	5,510	0.08	28.7	875	63,867	0.8	695	79	1.46
50	394	140	44,619	3,209	0.07	30.2	875	41,995	0.9	644	50	1.80
51	394	140	63,867	3,177	0.05	30.1	2,625	54,243	0.8	714	45	1.70
52	394	350	69,116	4,029	0.06	26.9	5,249	48,994	0.7	699	58	1.77
53	394	350	45,494	5,593	0.12	34.2	875	43,745	0.9	667	85	1.70
54	394	350	55,993	5,729	0.10	30.3	1,750	52,493	0.9	720	80	1.72
55	173	225	41,120	2,321	0.06	24.1	4,375	34,996	0.9	479	48	2.00
56	173	225	80,490	3,940	0.05	26.6	5,249	62,992	0.8	552	73	1.70
57	173	225	58,618	4,378	0.07	28.0	1,750	47,244	0.8	501	88	1.76
58	173	350	44,619	5,077	0.11	26.7	0	45,494	1.0	460	110	1.76
59	173	350	57,743	3,126	0.05	29.9	1,750	47,244	0.8	508	61	1.90
60	173	350	75,241	2,998	0.04	25.3	6,124	43,744	0.6	490	61	1.82
61	173	140	90,114	960	0.01	26.8	10,499	26,247	0.3	556	17	1.88
62	173	140	45,494	3,043	0.07	27.8	2,625	43,745	0.9	506	61	1.88
63	173	140	52,493	4,785	0.09	29.2	875	39,370	0.8	532	90	1.79
64	394	225	81,365	3,847	0.05	25.8	8,749	61,242	0.8	720	53	1.75
65	394	225	48,994	5,018	0.10	29.4	2,625	48,119	1.0	654	76	1.70
66	394	225	52,493	5,745	0.11	29.1	875	47,244	0.9	665	86	1.68
67	394	350	46,369	5,103	0.11	27.7	2,625	37,620	0.8	620	81	1.68
68	394	350	77,865	5,453	0.07	27.9	6,124	53,368	0.7	679	79	1.60
69	394	350	53,368	4,084	0.08	30.7	875	48,994	0.9	683	59	1.85
70	394	140	56,868	3,730	0.07	30.6	3,500	47,244	0.8	721	51	1.72
71	394	140	38,495	5,380	0.14	39.0	875	44,619	1.1	657	78	1.58
72	394	140	56,868	5,311	0.09	30.3	1,750	55,118	0.9	666	78	1.52

Table 5A. Data of corn, obtained in 1980 on Muir silt loam soil con't.

73	0	140	74,366	0	0	--	9,624	0	0	0	345	0	--
74	0	140	45,494	0	0	--	8,749	0	0	0	369	0	--
75	0	140	42,870	92	0	23.1	4,375	5,249	0.1	0	368	2	1.95
76	0	225	59,493	0	0	--	10,499	0	0	0	330	0	--
77	0	225	62,117	0	0	--	6,999	0	0	0	381	0	--
78	0	225	36,745	319	0	27.5	6,124	7,874	0.2	0	383	8	2.00
79	0	350	50,744	0	0	--	5,249	0	0	0	322	0	--
80	0	350	63,867	0	0	--	10,499	0	0	0	365	0	--
81	0	350	44,619	263	0	24.5	1,750	11,374	0.3	0	351	8	2.10

Table 6A. Data of corn, obtained in 1980 on Eudora silt loam soil. Grain weights at 15.5% water content.

Plot no.	Population (plants/ha)	Grain yield (kg/ha)	Yield per plant (g)	100 kernel weight (g/100)	No. irrigation			Water use (mm)	Water use efficiency (kg/ha/cm)	Grain nitrogen (% N)
					Lodging (plants/ha)	Ears/ha	Ears/plant			
1	55,993	0	0	---	4,374	0	0	203	0	2.08
2	45,494	0	0	---	1,750	0	0	326	0	1.90
3	54,243	0	0	---	4,374	0	0	312	0	2.00
4	55,993	0	0	---	5,249	0	0	271	0	1.90
5	57,743	0	0	---	3,500	0	0	272	0	1.99
6	42,870	0	0	---	2,625	0	0	312	0	1.75
7	49,869	0	0	---	3,500	0	0	305	0	1.79
8	46,369	81	0.0017	28.04	2,625	5,249	0.11	267	3	1.82
9	45,494	0	0	---	4,374	0	0	116	0	1.88
Limited irrigation (88 mm)										
1	86,614	198	0	23.59	1,749	13,998	0.16	376	5	---
2	61,242	884	0.01	27.91	0	24,497	0.40	455	19	---
3	47,244	1,793	0.03	27.91	1,749	34,121	0.72	438	42	---
4	58,617	2,752	0.04	27.76	0	43,745	0.74	480	64	---
5	91,863	3,071	0.03	26.21	0	59,493	0.65	450	58	---
6	54,243	4,127	0.08	28.18	0	41,120	0.76	469	90	---
7	44,619	5,197	0.12	29.56	874	40,245	0.90	443	113	---
8	83,989	3,411	0.04	26.09	874	53,368	0.64	443	57	2.10
9	61,242	3,069	0.05	28.03	0	41,995	0.69	472	67	---
Full irrigation (201 mm)										
1	88,364	3,253	0.03	29.97	88,364	54,243	0.61	588	64	1.82
2	42,869	5,637	0.13	23.66	42,870	39,370	0.92	542	120	1.74
3	52,493	6,434	0.12	33.94	52,493	50,744	0.97	534	134	1.62
4	81,365	6,129	0.08	31.33	81,365	66,492	0.82	504	120	1.60
5	60,368	6,283	0.10	34.66	60,368	50,744	0.84	548	126	1.58
6	45,494	4,926	0.11	33.67	45,494	41,119	0.90	526	93	1.72
7	55,993	4,232	0.08	31.20	55,993	49,869	0.89	524	74	1.78
8	73,491	4,909	0.07	33.03	73,491	52,493	0.71	592	86	1.55
9	44,619	3,635	0.08	32.21	44,619	41,995	0.94	579	76	1.81

CORN (Zea mays L.) YIELD AND WATER USE AS
INFLUENCED BY IRRIGATION LEVEL, NITROGEN
FERTILIZATION, AND PLANT POPULATION

by

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B.S., National University of ZAIRE, 1973

AN ABSTRACT OF A MASTER'S THESIS

Submitted in partial fulfillment of the
requirements for the degree

MASTER OF SCIENCE

Department of Agronomy

Kansas State University
Manhattan, Kansas

1981

Intense irrigation is depleting groundwater at a rate that will cause water shortages in the near future and will increase the energy required to pump water from the deeper depths. Careful management of irrigation is necessary to maintain water supplies, keep energy costs at a minimum, and keep irrigation farming at a profitable level.

Corn experiments were conducted at the Ashland Research Farm near Manhattan, Kansas, on a Muir silt loam soil and on a Eudora silt loam soil to investigate the influence of irrigation level (no irrigation, limited irrigation at tasseling and blister and full irrigation), three nitrogen fertilization rates [100 (140 in 1980), 225, and 350 kg N/ha], and three plant populations (43,000; 57,000; and 86,000 plants/ha) on corn dry matter yield, grain yield, water use, and water use efficiency.

The results of this study show a reduction of corn dry matter yield in nonirrigated and limited irrigation conditions compared to full irrigation conditions on both soils. On the Muir silt loam, corn receiving limited and no irrigation yielded 69 and 1%, respectively, as much grain as corn receiving full irrigation. On the Eudora silt loam, corn receiving limited irrigation yielded 54% as much grain as corn receiving full irrigation. Corn fertilized at the rate of 350 kg N/ha produced the most dry matter, the most grain yield, and had the highest water use efficiency in 1980. But statistically those responses were not different from the responses to 225 kg N/ha. Nitrogen fertilization rate had no significant influence on corn dry matter yield, grain yield, or water use efficiency in 1979; and no influence on corn water use during the two-year study. Plant population of approximately 76,000 plants per hectare produced the most dry matter in 1979

and 1980. Also plant population of 78,384 plants per hectare produced lower grain yield and lower water use efficiency in the 1979 Muir study compared to the medium plant population of 57,808 plants per hectare.

All treatment interactions had no significant influence on corn dry matter yield, grain yield, water use, or water use efficiency. Irrigation level, nitrogen fertilization rate, and plant population also affected yield components (yield per plant, 100 kernel weight, ears per hectare, ears per plant, lodging and grain nitrogen content).

The results and conclusions of this study are true for the corn variety used.