THE ROLE OF PLANT DENSITIES AND GROWING DEGREE DAYS IN THE EVALUATION OF HIGH YIELDING CORN (*Zea mays* L.) GENOTYPES

by

CLEMENCE SEBASTIAN MUSHI

B. S., Kansas State University, 1980

A MASTERS THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Agronomy

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1986

Approved by:

Clyde E. Wassom
Major Professor

TABLE OF CONTENTS

LIST OF TABLES AND FIGURES

ABSTRACT

Six white and four yellow corn hybrids planted at four densities: 36,206, 45,289, 60,385, and 90,576 plants ha^{-1} were studied in 1985 and 1986 summers at two locations, in order to identify specific traits for breeding for high plant density tolerance.

Corn hybrids generally were significantly affected by plant densities in vegetative and reproductive stages, plant and ear heights, grain filling duration, dry matter accumulation rates, yield and yield components, leaf area per plant, leaf area index, yield efficiency and leaf canopy temperature at silking stage. However, differences were not observed at all locations and/or saesons.

The white corn hybrids generally yielded less grain, had shorter reproductve stage, smaller sink size and lower yield efficiency than yellow corn hybrids.

The study suggests that improvement of grain yield at higher plant densities could be achieved by breeding for high plant density tolerant genotypes with longer grain filling duration, larger sink size and higher yield efficiency. This may be especially important for white corn hybrids which generally have not received as much attention in breeding programs as yellow hybrids.

INTRODUCTION

Grain yield per plant for corn (*Zea mays* L.) may be described as a function of the rate and duration of dry matter accumulation by the individual kernels multiplied by the number of kernels per plant.

Increasing yield must be based on knowledge of factors which determine the capacities for storage and supply. Because these processes are dynamic and may be inter-dependent, information is required on changes which occur throughout the growth of the crop, the responses of the processes to the environment, and their relation to final yield. It is useful to consider the crop as a system which supplies assimilates from the leaves to a series of sinks where the assimilates are used first for growth and later for storage as grain.

Corn growth and development can be divided into five stages viz: (1)planting to emergence (2)emergence to flower,(3)flowering (4)flower to maturity and (5)dry down. The period from emergence to tasseling is referred to as the vegetative period. It is during this period that roots, leaves and stalks (source) are produced and reproductive organs are developed. The period of silking to maturity is referred to as the reproductive period in which the photosynthate produced is not needed for vegetative growth but is accumulated in the ear (sink) to produce the grain yield (Hanway and Russell, 1969).

Many factors influence plant size, leaf size and number, time between different developmental stages, and the final crop yield of corn plants. Plant density is an important factor affecting corn plant growth and development. It affects four of the five physiological determinants of growth listed by Charles-Edwards (1982) namely: (a) the amount of light energy intercepted by the crop, (b) the proportion of the daily increment in new dry matter partitioned to the harvestable component, (c) daily rate of dry matter loss, and (d) the duration of the period of dry matter production.

Plant density also affects growth of corn during vegetative period through its effect on leaf area index (LAI), leaf angle , and plant and ear heights. Several workers (Nunez and Kamprath, 1969; Evans, 1975; Alessi and Power, 1974; Prior and Russell, 1976) reported that LAI increased linearly with increasing densities. Pendleton et al. (1967) reported LAI's of 4.0 at 61,700 plants ha^{-1} for non-prolific and 4.1 at 51,000 plants ha^{-1} for a prolific hybrid. However, Larson and Hanway (1977) reported that under high management levels, 50,000 plants ha^{-1} produced an LAI of about 3.5 and yield remained constant up to an LAI of 4.5. Yield of maize has been found to be linearly related to LAI at silking, but the relationship didn't continue beyond an LAI of 3.0 (Eik and Hanway, 1965). Goldsworthy and Colegrove, (1974) reported LAI to reach maximum at flowering time.

Other workers have studied the relationship between assimilate sources such as (LAI) and sink in search of factors that limit grain yield of maize plants. Buren et al., (1974) found yield efficiency (YE), grain yield per unit leaf area, which was associated with smaller tassel size and shorter anthesis to silking interval, was also highly associated with high grain yield at high plant density. A similar finding was reported by Tanaka and Yamaguchi (1972). Tiamu et al., (1983), and Elsahookie and Wassom (1984) reported that increasing plant density decreased yield efficiency, yield per plant, and leaf area per plant. Increased plant density has been reported by several workers to delay silking (Enzie, 1942; Lang et al., 1956).

Densely populated stands of corn usually grow taller than widely spaced plantings. Rutger and Crowder (1967) stated that ear height but not plant height was increased at high plant density. El-Lakany and Russell (1971) and Duncan et al. (1973), however, found that higher densities increased plant and ear heights. Genter and Camper (1973) found that plant and ear heights changed very little with increasing plant densities. These studies suggest that plant and ear heights differ with genotype and environment.

Significant differences among population densities were reported for third internode diameter and number of ears per plant by Sotomayor-Rios et al. (1980).

Silking to maturity is the period when corn grain dry matter is produced (Shaw and Thom, 1951; Ritchie and Hanway, 1984). Increases in grain yield due to increased plant density were reported by several workers (Giesbrecht, 1969; CIMMYT, 1975; Nagy et al., 1976; Poneleit and Egli, 1979; and Muleba et al., 1983). However, Sotomayor-Rios et al. (1980) reported no yield advantage when densities were increased to 90,000 plants ha^{-1}. Nagy et al. (1976) and a CIMMYT report (1975) showed decrease in yield as populations were increased above 50,000 and 60,000 plants ha^{-1}, respectively. Gerakis and Papkosta-Tasopoulou (1980) found that increasing density from 5 plants to 12.5

plants m^{-2} was as detrimental to grain yield per plant as decreasing illumination 50% by shading. Poneleit and Egli (1979) pointed out that: (a) yield per plant was 2% less at 45,302 plants ha^{-1} than at 11,325 plants ha^{-1} but the yield per unit land area was increased by 122%, (b) all genotypes had significantly fewer kernels on the first ear at the high plant density than at low plant density, (c) kernel weight was 6% greater for low density than for high density, (d)kernel growth rate was not affected by plant density nor the genotype by density interaction and (e) higher plant density reduced the effective grain filling period by 2.5 days. However, earlier Daynard et al. (1971) , showed that effective grain filling period was unaffected by plant density. Estimates of yield increases in response to indirect selection at high crop densities showed that grain weight per unit leaf area (yield efficiency) was the most effective selection criterion (Cosmin et al., 1984). A CIMMYT report (1975) indicated that non-ear bearing stalks contributed to a loss in crop efficiency but the ratio of ears to number of stalks (main stem plus tillers) per plant was 0.55 and 0.44 at low and medium densities, respectively. Lang et al. (1956) found that barrenness was affected more by population level than by hybrid or fertility level. Alessi and Power (1974) also reported that number of barren stalks increased and grain weight per plant decreased as population increased.

The above studies indicate that plant density is an important factor that can be varied for more favorable yield results, but more knowledge of the effect of plant density on physiological and morphological traits is needed. This study examines the effect of plant density on the performance of ten corn hybrids grown in the midwest. The specific objectives are: (1) to study the effect of plant densities on duration of vegetative and reproductive phases and, grain filling rate and duration, (2) to determine the effect of various plant densities on yield and yield components, plant and ear heights, leaf area per plant, leaf area index, yield efficiency, and canopy leaf temperature, and (3) to compare the responses of some white and yellow corn hybrids at various plant densities.

MATERIALS AND METHODS

Experiments were conducted during 1985 and 1986 at the Kansas River Valley Experiment field, Rossville, Kansas (39^{o} 7' 30 " N, elevation 320m) and at Ashland Agronomy Farm, Manhattan, Kansas (39^{o} 11' N, elevation 310m). Soil types consisted of Sarpy sandy loam (Typic Udipsamments, mixed, mesic) and Haynie fine sandy loam (Mollic Udifluvent, coarse-silty, mixed, mesic) for the two sites, respectively.

Two row plots (plot size $12.51m^2$) were used at both locations, with inter-row spacing of 76 cm. The plots were over planted and then adjusted to the following plant densities: (1) 36,206, (2) 45,289, (3) 60,385 and (4) 90,576 plants per hectare. At Rossville, N, P, and K fertilizers were applied at 208, 47 and 23.3 kg/ha respectively. At Manhattan N fertilizer was applied at 230 kg/ha.

A split-plot in randomized complete block design with three replications was used at each site. Main plot treatments were densities and the sub-plot treatments were corn hybrids.

Six white and four yellow corn hybrids were used based on the basis of high yielding ability at moderately high plant densities in previous studies. The white hybrids were Zimmerman Z15AW, Zimmerman Z54W, DK77W, MV68W, Whisnand 73W, and G4779W. The yellow hybrids were Hoegemeyer SX2700, Pioneer 3183, MFA 6708 and RA 1502. All the hybrids were of similar maturity.

Data Collection

Data recorded as single observations for each plot are described below:

Growing Degree Days (GDD):

The GDD for a given day are defined as the difference between the daily mean temperature, estimated as the average of the daily maximum and minimum temperatures, minus a growth threshold temperature which for corn is 10 C. Any maximum above 30 C is taken as 30 C and any minimum below 10 C is designated as 10 C (Gilmore and Rogers, 1958,and Barger, 1969). The GDD for each day are then accumulated from growing point differentiation to physiological maturity.

GDD to flower:

Number of GDD when silks had emerged from at least 50 percent of the plants in a plot. This period was considered as the vegetative phase of development.

Plant and ear heights:

Eight guarded plants of each plot were randomly selected after flowering and the following recorded:

(1) plant height (m)- distance from the ground to the flag leaf collar

(2) ear height (m) - distance from the ground to the base of uppermost ear.

Leaf Area (LA):

The leaf area of the eighth leaf from the top of each of 8 randomly selected guarded plants were measured after flowering using leaf area meter, Li-Cor Model 3100. The area of eighth leaf was multiplied by 9.39 (Pearce et al., 1975) to estimate leaf area per plant.

Leaf Area Index (LAI):

LAI was calculated as plant density per unit land area (m^2) x average leaf area per plant (m^2)

Kernel growth rate and duration of filling:

(1) Manhattan 1985 - 9 guarded plants in each plot were self-pollinated for evaluation.

(2) Manhattan 1986 - 9 guarded plants in each plot were tagged on the date when first silks were visible.

(3) Rossville 1985 and 1986 - 9 guarded plants in each plot were tagged on the date when the first silks were visible.

(4) Three ears of selfed or tagged plants were harvested from each plot at 15, 30 and 45 days after pollination after the procedure of Johnson and Tanner, 1972. The ears were oven dried for 2 days at 60 C to bring samples to 0% kernel moisture.

(5) About 200 kernels were removed from the middle of each ear and mixed for each plot. From the mixture of each plot 100 kernels were counted and weighed. Rate of grain growth, hereafter called Dry Matter Accumulation rate (DMA), was calculated using the following formula:

$$DMA_n = \frac{\text{Mean kernel weight for Harvest Y - mean kernel wt. for harvest X}}{\text{GDD between Harvest Y and Harvest X}}$$

where n=1 is the period from 15 to 30 days after flowering, n=2 is the period from 30 to 45 days after flowering.

Effective Filling Duration (EFD):

The linear grain growth period was calculated as:

$$EFD = \frac{\text{Final kernel weight}}{\text{DMA rate}}$$

Yield Components:

At maturity, six guarded plants were hand harvested and the following determined:

(1) Number of kernel rows per ear and number of kernels per row.

(2) Barrenness - recorded as number of stalks with no ears or few kernels.

(3) Ears for each plot were shelled and weighed.

(4) Samples of 100 seeds were taken from each plot weighed and adjusted to 15 percent moisture to obtain 100 kernel weight.

Yield:

In 1985 remaining plants with ears in each plot were counted, combine harvested, weighed and percent moisture content measured. In 1986, a sample of 10 guarded plants were harvested for moisture and shelled weight determination. Grain yields were adjusted to 15% moisture content.

Yield Efficiency (YE):

Calculated from the following formula:

$$YE = \frac{\text{Grain yield per plant}}{\text{LA/plant}}$$

Leaf Temperature:

Canopy leaf temperature readings were obtained using an infrared thermometer accurate to 0.5 C (Everest Infrared thermometer) to determine stress due to high plant density. The readings were taken in accordance with the procedure outlined by Wiegand and Namken (1966), between 1330 and 1530 hrs on clear sunny days at 12th leaf stage, silking, blister, and dough stages of corn development. Four measurements per plot were taken and averaged as a datum.

Statistical Analyses

Analyses of variances were done for all traits at both locations to measure effects of densities and hybrids. Covariance analyses were used to determine the effects of individual independent variables. A regression analysis using backward elimination procedure was performed on grouped traits to determine their relationships with yield. Also, a correlation coefficient matrix for some traits was calculated to observe the mutual relationship of different traits. The white hybrids were contrasted against yellow corn hybrids using General Linear Model procedure of SAS.

RESULTS AND DISCUSSION

Growth stages

Data obtained on vegetative and reproductive stages are presented in tables 1.1 through 1.3. Analyses of variance for the growth stages are presented in appendix tables 1 through 4.

Significant differences in growth stages were observed among hybrids for both locations and years, but were significant among densities only at Manhattan in 1986.

The mean of growing degree days for ten hybrids at four densities, tend to vary with location and season, table 1.1. The hybrids x density interactions were not significant. The GDD for reproductive stage at Rossville were lower in 1985 than in 1986, due to the lower temperatures which occured during this period. However, the 1986 data indicate that, GDD for vegetative stage increased with increased plant density, while the GDD for reproductive stage decreased with increased plant density.

Hybrids differed in GDD for both growth stages. At Manhattan in 1985 DK77W had the highest GDD (1700) for vegetative stage while in 1986 G4779W had the highest GDD (1141). The GDD for reproductive stage were also not consistent in both years and locations, (tables 1.2 and 1.3).

The results reported above tend to agree with earlier findings by Muleba et al., (1983). They reported that, there was a delay in flowering with increased plant density. The delay in flowering or prolonged vegetative stage suggests that at high plant density, plants are under some environmental stress.

Table 1.1 Mean responses for growth stages of ten corn hybrids at four plant densities and two locations in 1985 and 1986.

	density (plant ha^{-1})				LSD	
Year/Trait/Location	36,206	45,289	60,385	90,576	.05	SL
<u>Manhattan</u>						
1985						
Veg. stage(GDD)	1336	1347	1342	1332	NS	.40
Rep. stage(GDD)	1602	1605	1629	1649	NS	.35
1986						
Veg. stage(GDD)	1030	1037	1057	1092	28.72	.01
Rep. stage(GDD)	1193	1188	1180	1171	14.86	.04
<u>Rossville</u>						
1985						
Veg. stage(GDD)	1818	1799	1796	1817	NS	.10
Rep. stage(GDD)	722	732	727	729	NS	.91
1986						
Veg. stage(GDD)	1245	1263	1264	1298	NS	.22
Rep. stage(GDD)	1102	1109	1107	1093	NS	.43

SL =significant level

Table 1.2 Means of growth stages for four densities at Manhattan and Rossville in 1985.

	Manhattan		Rossville	
Hybrid	Veg.stage (GDD)	Rep. stage (GDD)	Veg. stage (GDD)	Rep.stage (GDD)
Hoegemeyer SX2700	1543e	1368ab	1810abc	717c
Pioneer 3183	1624cd	1352abc	1800bc	720bc
MFA 6702	1529e	1376a	1802bc	721bc
RA 1502	1567e	1367ab	1800bc	720bc
Zimmerman 15AW	1580de	1380a	1810abc	717c
DK 77W	1700a	1286cd	1828a	743ab
MV68W	1676abc	1322abcd	1795c	740abc
Whisnand 73W	1632bcd	1354ab	1805bc	717c
G 4779W	1680ab	1308bcd	1807bc	755a
Zimmerman Z54W	1679ab	1282d	1818ab	730abc
LSD (.05)	52.60	65.96	18.8	25.31

Means followed by the same letter do not differ significantly at the .05 probability level.

Table 1.3 Means of growth stages for four densities at Manhattan and Rossville in 1986.

Hybrid	Manhattan Veg. stage (GDD)	Manhattan Rep. stage (GDD)	Rossville Veg. stage (GDD)	Rossville Rep.stage (GDD)
Hoegemeyer SX2700	1015c	1199b	1220d	1108a
Pioneer 3183	1002cd	1216ab	1213d	1112f
MFA 6702	995cd	1215ab	1200d	1111a
RA 1502	980d	1235a	1207d	1110a
Zimmerman 15AW	1094b	1158c	1293bc	1107a
DK 77W	1116ab	1149cd	1312b	1103a
MV 68W	1025c	1201b	1273c	1106a
Whisnand 73W	1086b	1164c	1289bc	1106a
G 4779W	1141a	1134d	1347a	1072b
Zimmerman Z54W	1092b	1162c	1319ab	1096a
LSD (.05)	31.13	23.49	30.69	17.78

Means followed by the same letter do not differ significantly at the .05 probability level.

Plant and Ear heights

Plant heights differed significantly among hybrids for both sites and years but among densities only at Manhattan in both seasons. Ear heights were significantly different between densities and hybrids for both locations and years, (tables 1.4 through 1.6)

Plant and ear heights increased with increased plant density, (table 1.4) and hybrids differed in both plant and ear heights. Zimmerman Z15AW was the tallest with plant height ranging from 2.27 to 2.58m while DK 77W attained the highest ear height of 1.41m, (tables 1.5 and 1.6).

Table 1.4 Mean plant and ear heights of ten corn hybrids at four plant densities and two locations in 1985 and 1986.

	density (plants ha^{-1})				LSD	
Year/Trait/Location	36,206	45,289	60,385	90,576	.05	SL
Manhattan						
1985						
Ear height (m)	1.08	1.12	1.17	1.22	.04	<.01
Plant height(m)	2.13	2.17	2.21	2.22	.07	.04
1986						
Ear height (m)	1.14	1.23	1.23	1.41	.04	<.01
Plant height(m)	2.31	2.34	2.40	2.41	.08	.05
Rossville						
1985						
Ear height (m)	1.15	1.17	1.28	1.29	.05	<.01
Plant height(m)	2.34	2.42	2.42	2.50	NS	.11
1986						
Ear height (m)	1.06	1.15	1.16	1.20	.07	.02
Plant height(m)	2.13	2.22	2.23	2.24	NS	.13

SL = significant level

Table 1.5 Mean plant and ear heights for four densities at Manhattan and Rossville in 1985.

Hybrid	Manhattan		Rossville	
	Plant-H (m)	Ear-H (m)	Plant-H (m)	Ear-H (m)
Hoegemeyer SX2700	2.25ab	1.17bc	2.44c	1.31b
Pioneer 3183	2.12c	1.08d	2.28d	1.10ef
MFA 6708	2.12c	1.10d	2.32d	1.16de
RA 1502	2.12c	1.01e	2.31d	1.07f
Zimmerman 15AW	2.27ab	1.17bc	2.58a	1.28b
DK 77W	2.25ab	1.31a	2.57a	1.41a
MV 68W	2.13c	1.15bc	2.42c	1.27b
Whisnand 73W	2.08cc	1.12cd	2.31d	1.20cd
G 4779W	2.28a	1.20b	2.50b	1.25bc
Zimmerman Z54W	2.22b	1.13cd	2.47bc	1.21cd
LSD (.50)	0.06	0.06	0.20	0.20

Means followed by the same letter do not differ significantly at the .05 probability level.

Table 1.6 Mean plant and ear heights for four densities at Manhattan and Rossville in 1986.

Hybrid	Manhattan		Rossville	
	Plant-H (m)	Ear-H (m)	Plant-H (m)	Ear-H (m)
Hoegemeyer SX2700	2.41bc	1.32a	2.23bc	1.16cd
Pioneer 3183	2.23e	1.09d	2.03f	0.97f
MFA 6702	2.26e	1.13d	2.20cd	1.11d
RA 1502	2.34d	1.13d	2.15de	1.04e
Zimmerman 15AW	2.53a	1.26bc	2.32a	1.16cd
DK 77W	2.37cd	1.33ab	2.28ab	1.25a
MV 68W	2.35d	1.26bc	2.20cd	1.23ab
Whisnand 73W	2.28e	1.21c	2.13e	1.18bc
G 4779W	2.44b	1.24c	2.31a	1.17cd
Zimmerman Z54W	2.43b	1.25c	2.21bc	1.14cd
LSD (.05)	0.06	0.06	0.07	0.06

Means followed by the same letter do not differ significantly at the .05 probability level.

Yield and yield components

Analyses of variance for yield, number of rows per ear, number of kernels per row and 100 seed weight are presented in appendix tables 1 through 4 . At Manhattan, in1985 significant differences among densities were obtained for yield, number of rows per ear, seed weight, and number of kernels per row but only the first three traits differed significantly among hybrids. At Rossville, yield differed significantly among densities and hybrids in both years. Seed weight was significantly different among hybrids in 1986. The hybrid x density interactions were not significant.

Yield per unit land area increased with increased plant density, while rows per ear, kernels per row and seed weight decreased with increased plant density, (tables 1.7). This reflects that at high plant densities, the increase in yield is due to increased number of harvested ears per unit land area. Hybrids differed significantly in both locations and years, (tables 1.8 through 1.11). RA 1502 attained the highest grain yield of 12.92 Mg ha^{-1} followed by Hoegemeyer SX2700 with the yield of 12.67 Mg h^{-1}, (appendix tables 13 and 14). 1985 data shows a negative correlation coefficient between yield and number of kernels per row, (tables 1.23 and 1.24), while the 1986 data indicate positive correlation coefficients between yield and its components, (tables 1.25 and 1.26). 1986 data indicate that seed weight and number of rows per ear are more correlated to yield than other yield components at Manhattan and Rossville respectively. A regression analysis using backward elimination procedure revealed that the model to predict yield would contain number of rows (b=.23) and seed weight (b=.12) at the .05 significant level.

Giesbrecht (1969) and, Elsahookie and Wassom (1983), reported no further increase in yield at densities higher than 75,000 plants ha^{-1}. In my study most hybrids continued to yield higher even up to 90,576 plants ha^{-1}. This indicates that the hybrids used in this study might have been selected for high plant density tolerance, which is one of the objectives of most breeding programs.

Table 1.7 Mean yield and yield components of ten corn hybrids at four plant densities and two locations in 1985 and 1986.

	density (plants ha^{-1})				LSD	
Year/Trait/Location	36,206	45,289	60,385	90,576	.05	SL
<u>Manhattan</u>						
1985						
Yield (Mg/ha)	2.84	3.57	3.99	4.83	0.85	.01
Rows per ear	15.43	14.70	14.07	14.40	NS	.04
Kernels per row	40.40	41.00	37.33	33.30	3.19	<.01
100 seed wt.(g)	48.38	47.18	44.00	41.45	NS	.03
1986						
Yield (Mg/ha)	6.45	7.40	8.22	9.77	2.23	.05
Rows per ear	15.83	15.80	15.40	14.80	NS	.37
Kernels per row	42.70	41.83	39.53	35.27	4.98	.04
100 seed wt. (g)	29.24	28.41	26.48	26.85	NS	.30
<u>Rossville</u>						
1985						
Yield (Mg/ha)	3.04	4.10	4.19	5.23	0.57	<.01
Rows per ear	14.03	14.01	13.40	12.77	NS	.07
Kernels per row	36.27	35.85	32.90	30.27	NS	.28
100 seed wt. (g)	37.03	36.04	33.73	33.57	NS	.41
1986						
Yield (Mg/ha)	4.09	4.90	5.39	6.72	1.62	.03
Rows per ear	15.10	14.50	14.37	14.17	NS	.66
Kernels per row	43.74	41.90	38.73	36.40	NS	.09
100 seed wt. (g)	21.16	21.10	21.00	19.82	NS	.20

SL = significant level

Table 1.8 Means of yield and yield components for four densities at Manhattan 1985.

Hybrid	Yield ($Mg\ ha^{-1}$)	100 seed (gm)	Rows per ear	Kernels per row
Hoegemeyer SX2700	5.03a	44.42bcd	14.67bc	41.98
Pioneer 3183	4.48ab	46.30ab	17.25a	35.42
MFA 6702	4.48ab	41.79cd	16.50a	39.33
RA 1502	3.92bc	41.02d	14.83bc	38.25
Zimmerman 15Aw	3.08def	49.08a	13.25de	37.58
DK 77W	3.75bcde	44.41bcd	15.33b	36.25
MV 68	3.57cdef	46.77ab	15.42b	36.42
Whisnand 73W	2.94f	46.16abc	14.25cd	37.33
G 4779W	2.97ef	46.38ab	12.42e	37.92
Zimmerman Z54W	3.84bcd	46.23ab	12.58e	40.08
LSD (.05)	0.79	4.38	1.07	4.27

Means followed by the same letter do not differ significantly at the .05 probability level.

Table 1.9 Means of yield and yield components for four densities at Rossville in 1985.

Hybrid	Yield ($Mg\ ha^{-1}$)	100 seed (gm)	Rows per ear	Kernels per row
Hoegemeyer SX2700	4.51abc	34.37	13.67	36.50
Pioneer 3183	5.01ab	34.12	13.58	31.92
MFA 6702	4.14bc	33.09	14.08	31.92
RA 1502	4.54abc	35.10	13.83	33.08
Zimmerman 15AW	3.48c	40.22	12.75	34.08
DK 77W	5.81a	36.01	14.17	30.92
MV 68W	3.32c	32.23	13.25	34.83
Whisnand 73W	3.72bc	32.94	13.00	35.67
G 4779W	3.45c	36.52	14.00	37.08
Zimmerman Z54W	3.43c	36.19	13.42	32.25
LSD (.05)	0.70	3.36	1.35	4.88

Means followed by the same letter do not differ significantly at the .05 probability level.

Table 1.10 Means of yield and yield components for four densities at Manhattan in 1986.

Hybrid	Yield (Mg/ha)	100 seed wt.(gm)	Rows per ear	Kernels per row
Hoegemeyer SX2700	9.62a	27.96	15.25cd	42.00
Pioneer 3183	8.43ab	28.16	17.25a	37.50
MFA 6702	9.18a	28.38	16.33abc	37.67
RA 1502	9.33a	27.22	16.67ab	40.33
Zimmerman 15AW	7.10bc	30.85	13.92de	41.58
DK 77W	7.97abc	25.74	16.50abc	41.25
MV 68W	7.05bc	26.43	16.92ab	38.58
Whisnand 73W	7.30bc	25.39	15.58bc	37.33
G 4779W	6.99bc	30.01	13.33e	42.08
Zimmerman Z54W	6.65c	27.33	12.83e	40.00
LSD (.05)	1.77	3.89	1.40	4.50

Means followed by the same letter do not differ significantly at the .05 probability level.

Table 1.11 Means of yield and yield components for four densities at Rossville in 1986.

Hybrid	Yield (Mg/ha)	100 seed (gm)	Rows per ear	Kernels per row
Hoegemeyer SX2700	6.23ab	19.92cde	15.42	45.17
Pioneer 3183	7.11a	21.75abcd	15.00	39.00
MFA 6702	5.23bc	18.21e	14.83	41.25
RA 1502	5.07bc	18.86de	14.08	42.17
Zimmerman 15AW	4.47c	21.86abc	13.67	37.42
DK 77W	5.36bc	23.01ab	14.92	37.75
MV 68W	4.40c	19.79cde	15.25	36.17
Whisnand 73W	4.97bc	20.70bcde	14.58	40.17
G 4779W	4.90bc	23.88a	13.17	42.92
Zimmerman Z54W	4.83c	20.37bcde	14.42	39.92
LSD (.05)	4.35	2.92	2.12	5.89

Means followed by the same letter do not differ significantly at the .05 probability level.

Dry matter accumulation rate (DMA) and effective filling duration (EFD)

DMA-1 in 1985 and 1986, and DMA-2 in 1986 were significantly different among hybrids at Manhattan and Rossville respectively. EFD differed significantly among hybrids at Manhattan in 1986, (appendix tables 5 through 8).

Both DMA rates decreased with increased plant density and DMA-1 was always greater than DMA-2 at all densities, (tables 1.12). This was also true for all hybrids except at Manhattan in 1986 where DMA-2 was higher than DMA-1, (tables 1.13 through 1.16). This could be attributed to the favourable climatic conditions experienced at the later stages of grain filling period. Results suggest that DMA rate differs with genotype, climatic conditions and locations.

EFD showed a general decreasing trend with increased plant density execept for Manhattan in 1985 and Rossville in 1986, where EFD increased to 1062 and 1118 GDD at the third and second densities respectively, and then decreased slightly, (tables 1.12). Hybrids responded differently in EFD at different locations and years, (tables 1.13 through 1.16).

Carter and Poneleit (1973) observed that rate of kernel dry matter accumulation during the filling period was significantly different among inbreds. Results of my study confirm that finding, but fail to agree with later observations by Poneleit and Egli (1979), in which they reported that EFD and not DMA is influenced to a limited extent by plant density.

Table 1.12 Mean grain filling rates and effective filling duration (EFD) of ten corn hybrids at four plant densities and two locations in 1985 and 1986.

	density (plants ha^{-1})				LSD	
Year/Trait/Location	36,206	45,289	60,385	90,576	.05	SL
<u>Manhattan</u>						
1985						
DMA1 (mg/kernel/GDD)	0.39	0.33	0.37	0.35	NS	.15
DMA2	0.27	0.24	0.22	0.21	NS	.18
EFD (GDD)	1059	1041	1062	1034	NS	.14
1986						
DMA1 (mg/kernel/GDD)	0.15	0.15	0.14	0.13	NS	.14
DMA2	0.20	0.19	0.19	0.19	NS	.73
EFD (GDD)	1559	1558	1555	1497	NS	.11
<u>Rossville</u>						
1985						
DMA1 (mg/kernel/GDD)	0.35	0.36	0.36	0.32	NS	.35
DMA2	0.27	0.27	0.21	0.19	NS	.08
EFD (GDD)	501	365	491	314	NS	.64
1986						
DMA1 (mg/kernel/GDD)	0.39	0.32	0.30	0.30	NS	.19
DMA2	0.22	0.18	0.21	0.17	.02	<.01
EFD (GDD)	1078	1118	1107	1107	NS	.09

SL = significant level

Table 1.13 Means of grain filling rates and effective filling duration (EFD) for four densities at Manhattan in 1985.

Hybrid	DMA-1	DMA-2	EFD
	mg/kernel/GDD		(GDD)
Hoegemeyer SX2700	0.42a	0.25	1094
Pioneer 3183	0.32c	0.22	1038
MFA 6702	0.35bc	0.25	1054
RA 1502	0.40a	0.22	1077
Zimmerman 15W	0.38ab	0.29	1075
DK 77W	0.37abc	0.20	1041
MV 68W	0.32c	0.25	1050
Whisnand 73W	0.33c	0.26	1044
G 4779W	0.41a	0.20	1044
Zimmerman Z54W	0.32c	0.24	977
LSD (.05)	0.05	0.08	72

Means followed by the same letter do not differ significantly at the .05 probability level.

Table 1.14 Means of grain filling rates and effective filling duration (EFD) for four densities at Rossville in 1985.

Hybrid	DMA-1	DMA-2	EFD (GDD)
	mg/kernel/GDD		
Hoegemeyer SX2700	0.37	0.17	338
Pioneer 3183	0.32	0.26	403
MFA 6702	0.28	0.19	369
RA 1502	0.32	0.23	397
Zimmerman 15AW	0.35	0.23	363
DK 77W	0.34	0.21	448
MV 68W	0.34	0.26	525
Whisnand 73W	0.23	0.23	408
G 4779W	0.39	0.23	505
Zimmerman Z54W	0.38	0.24	424
LSD (.05)	0.07	0.09	120

Means followed by the same letter do not differ significantly at the .05 probability level.

Table 1.15 Means of grain filling rates and effective filling duration (EFD) for four densities atManhattan in 1986.

Hybrid	DMA-1	DMA-2	EFD (GDD)
	mg/kernel/GDD		
Hoegemeyer SX2700	0.14bc	0.21	1542abc
Pioneer 3183	0.14bc	0.21	1573ab
MFA 6702	0.12c	0.15	1567a
RA 1502	0.13bc	0.17	1613a
Zimmerman 15W	0.17a	0.19	1553abc
DK 77W	0.14bc	0.22	1480c
MV 68W	0.13bc	0.19	1557abc
Whisnand 73W	0.15ab	0.16	1550abc
G 4779W	0.17a	0.22	1471c
Zimmerman Z54W	0.14bc	0.21	1495bc
LSD (.05)	0.02	0.08	91

Means followed by the same letter do not differ significantly at the .05 probability level.

Table 1.16 Means of grain filling rates and effective filling duration (EFD) for four densities at Rossville in 1986.

Hybrid	DMA-1	DMA-2	EFD
	____mg/kernel/GDD____		(GDD)
Hoegemeyer SX2700	0.30	0.15bc	1121
Pioneer 3183	0.30	0.16bc	1117
MFA 6702	0.30	0.10c	1140
RA 1502	0.30	0.20ab	1110
Zimmerman 15AW	0.36	0.21ab	1106
DK 77W	0.33	0.22ab	1104
MV 68W	0.29	0.22ab	1105
Whisnand 73W	0.28	0.23ab	1098
G 4779W	0.46	0.27a	1025
Zimmerman Z54W	0.34	0.23ab	1100
LSD (.05)	0.14	0.09	62

Means followed by the same letter do not differ significantly at the .05 level of probability.

Leaf area (LA), Leaf area index (LAI) and Yield efficiency (YE)

Differences in LA and LAI were significant among hybrids and densities in both years and locations except in 1986 at Manhattan LA was not significant. In 1986, YE was significantly different among hybrids at both sites but significant among densities at Manhattan only, (appendix tables 9 through 12).

LA per plant and YE decreased while LAI increased with increased plant density, (table 1.17). Hybrids differed in LA, LAI and YE, (table 1.18 through 1.19). DK77W had the highest LA and LAI but one of the lowest YE. Hybrids with low LA and LAI didn't necessarily have the highest YE as might be expected. However LA and LAI were negatively correlated with YE, (tables 1.23 through 1.26). The correlation coefficient for LAI and YE were higher and significant at both locations and years. Yield was shown to be positively correlated with LAI and YE, and negatively correlated with LA. This was exemplified by DK77W which had the highest LA but not the highest yield. A regression analysis of yield on LA, LAI and YE, employing the backward elimination procedure revealed that all the three variables remained in the model with b values of .35, -.0004 and 1.94 for YE, LA and LAI respectively at .05 significant level.This model had a coefficient of determination (R^2) of .92.

Elsahookie and Wassom (1983), reported that YE and LA decreased as plant density increased, and that genotypes with high YE resulted in high yields per hectare. The present study confirmed the above findings. Nunez and Kamprath, (1969) reported that maize grain yields increased with increased plant densities and reached a maximum yield at an LAI value of 4 before LAI reached its maximum values. Results of my study tend to disagree with those findings in that, yield per unit land area continued to increase even at an LAI of 5.58 obtained at Rossville in 1986. This again confirmed the superiority of the hybrids used at high plant densities. It also indicated that for those hybrids which continued to increase in yield, light interception was not a limiting factor.

Table1.17 Mean responses of morphological and physiological leaf traits of ten corn hybrids at four plant densities and two locations in 1985 and 1986.

	density (plants ha^{-1})				LSD	
Year/Trait/Location	36,206	45,289	60,385	90,576	.05	SL
Manhattan						
1985						
LA (cm^2/plant)	5295	5280	5132	5019	512	.53
LAI	2.24	2.45	3.28	4.05	NS	.22
YE (mg/cm^2 LA)	20.64	18.55	18.36	14.25	NS	.06
1986						
LA (cm^2/plant)	7016	6806	6612	5991	NS	.09
LAI	2.46	3.18	4.00	5.43	.62	<.01
YE (mg/cm^2LA)	30.70	28.77	23.94	20.89	6.26	.79
Rossville						
1985						
LA (cm^2/plant)	5623	5504	5481	4589	520	.04
LAI	2.04	2.48	3.32	4.40	.40	<.01
YE (mg/cm^2 LA)	16.86	15.70	13.73	14.74	NS	.79
1986						
LA (cm^2/plant)	7141	6998	6916	6151	649	.04
LAI	2.58	3.16	4.18	5.58	.54	<.01
YE (mg/cm^2LA)	15.95	15.48	12.93	12.33	NS	.17

SL = significant level

Table 1.18 Means of some morphological and physiological leaf traits for four densities at Manhattan and Rossville in 1985.

	Manhattan			Rossville		
Hybrid	LA/plant (cm^2)	LAI	YE (mg/cm^2)	LA/plant (cm^2)	LAI	YE (mg/cm^2)
Hoegem.	5198bcd	3.0bc	21.2ab	5230cde	3.0cd	16.9
Pioneer	5600a	3.3a	23.4a	5175de	2.9de	15.4
MFA 6702	4843e	2.8d	18.3abc	4973e	2.9de	17.0
RA 1502	4755e	2.7d	15.6bc	4916e	2.8e	15.3
Z 15AW	5441ab	3.1ab	16.3bc	5557b	3.2b	16.3
DK 77W	5367abc	3.1b	16.5bc	6231a	3.6a	14.0
MV 68W	4988de	2.9cd	19.3abc	5440bcd	3.1bc	14.3
Whisn.	5131cd	3.0bc	15.7bc	5232cde	3.0bcd	15.6
G4779W	5382abc	3.1ab	14.8c	5387bcd	3.0bcd	13.0
Z54W	5379abc	3.1ab	18.5abc	5526bc	3.2b	14.9
LSD (.05)	258	0.2	5.9	320	0.2	5.2

Means followed by the same letter do not differ significantly at the .05 probability level.

Table 1.19 Means of some morphological and physiological leaf traits for four densities at Manhattan and Rossville in 1986.

	Manhattan			Rossville		
Hybrid	LA/plant (cm^2)	LAI	YE (mg/cm^2	LA/plant (cm^2)	LAI	YE (mg/cm^2)
Hoegem.	6518bc	3.73bc	30.46a	6554ef	3.78de	17.12ab
Pioneer	6795ab	3.88ab	26.75abc	6731ef	3.8d	19.03a
MFA 6702	6239bc	3.59bc	28.8ab	6587def	3.8d	14.05bc
RA 1502	6245bc	3.70bc	28.65ab	6317f	3.6e	14.83bc
Z15AW	6834ab	3.89ab	22.3bc	7211b	4.1ab	11.32c
DK 77W	7226a	4.14a	25.68abc	7537a	4.3a	13.05c
MV 68W	6392bc	3.68bc	24.26bc	6881cd	3.9cd	11.58c
Whisna.	6128c	3.48ab	28.44ab	6309f	3.6e	14.62bc
G4779W	6710abc	3.84ab	22.63c	7117bc	4.1bc	13.15c
Z54W	6674abc	3.76bc	22.73c	6775de	3.9d	12.74c
LSD (.05)	619	0.32	5.19	300	0.2	3.60

Means followed by the same letter do not differ significantly at the .05 probability level.

Canopy leaf temperature

Due to cloudy and rainy days during much of the growing season in 1986, only one and two usable canopy leaf temperature readings were obtained at Rossville and Ashlamd respectively.

Analyses of variance for canopy leaf temperatures are presented in tables 9 through 12 appendix. AT Manhattan leaf temperature at silking stage were significantly different among densities in both years and among hybrids in 1986. Leaf temperatures from the different hybrids are presented in tables 1.21 through 1.22.

Plant temperature and water use are related because, if plants are well watered, the stomata are open, transpirational cooling occurs,and canopy temperatures are lower. Conversely, as a plant becomes water stressed stomata close, transpiration is reduced, and canopy temperature increases. Therefore, leaf temperatures may also be used to measure water stress imposed by high plant densities. However, not much stress was experienced at either of the two locations for both years and data collected do not indicate consistent trend, table 1.20. It would be interesting to repeat the experiment in more stressed environment.

Table 1.20 Mean canopy leaf temperatures for four stages of ten corn hybrids at four plant densities and two locations in 1985 and 1986.

Year/Stages/Location	density (plants ha^{-1}) 36,206	45,289	60,385	90,576	LSD .05	SL
Manhattan	C					
1985						
12 Leaf	30.03	29.92	29.80	30.25	NS	.79
Silk	31.24	31.89	31.60	32.74	.86	.03
Blister	28.93	28.30	28.70	28.21	NS	.33
Dough	31.27	31.24	31.58	31.32	NS	.32
1986						
12 Leaf	34.93	34.22	34.18	33.65	NS	.16
Silk	29.91	29.33	29.01	28.98	.47	.01
Rossville						
1985						
12 Leaf	29.23	28.66	28.92	28.89	NS	.47
Silk	26.86	27.31	27.36	27.06	NS	.26
Blister	27.47	27.77	27.55	27.91	NS	.73
Dough	31.33	31.40	31.35	31.33	NS	.99
1986						
Silk	35.51	35.12	35.40	36.01	NS	.49

SL = significant level

Table 1.21 Mean canopy leaf temperatures for four stages and four densities at Manhattan and Rossville in 1985.

Hybrid	Manhattan 12Leaf	Silk	Blist.	Dough	Rossville 12 Leaf	Silk	Blist.	Dough
	C							
Hoegem.	29.9	32.0	28.9	31.3	29.3	27.6	27.8	31.5
Pioneer	29.3	32.0	28.7	31.5	28.9	27.2	27.6	31.7
MFA 6702	29.9	31.5	28.4	31.4	29.3	27.3	28.0	31.3
RA 1502	30.2	31.9	28.4	31.4	28.6	27.2	27.4	31.3
Z15AW	29.7	32.6	28.6	31.4	28.9	27.1	27.2	31.1
DK 77W	29.9	32.0	28.5	31.5	28.7	27.2	27.4	31.0
MV 68W	30.4	31.8	28.7	31.2	28.9	27.0	28.3	31.3
Whisna.	29.7	31.2	28.5	31.3	28.7	26.9	27.3	31.1
G4779W	30.4	32.2	28.6	31.2	28.9	26.9	28.0	31.6
Z54W	30.0	31.6	28.3	31.3	29.0	27.1	27.7	31.7
LSD (.05)	0.6	1.0	0.3	0.6	0.5	0.4	0.9	0.6

Means followed by the same letter do not differ significantly at the .05 probability level.

Table 1.22 Mean canopy leaf temperatures for four stages and four densities at Manhattan and Rossville in 1986.

Hybrid	Manhattan 12 Leaf	Manhattan Silking	Rossville Silking
		C	
Hoegem.	34.2	29.6a	35.2
Pioneer	34.2	29.5ab	35.3
MFA 6702	34.3	29.7a	35.3
RA 1502	34.3	29.4ab	35.3
Z15AW	34.2	29.5ab	35.3
DK 77W	34.3	29.3abc	35.4
MV 68W	34.1	29.3abc	35.4
Whisna.	34.4	28.8c	35.3
G4779W	34.3	29.1bc	35.3
Z54W	34.3	29.1bc	35.4
LSD (.05)	0.2	0.5	12.5

Means followed by the same letter do not differ significantly at the .05 probability level.

Table 1.23 Correlation coefficients of some morphological and physiological traits at Manhattan in 1985.

Traits	R/E	K/R	SWT	EFD	YE	LA	LAI
				r			
Grain yield, GY	.229*	-.074	.366*	.061	.099	.078	.339*
Rows/ear, R/E		.051	-.106	.129	.299*	-.068	.165*
Seed weight,SWT				.033	.070	.138	-.247*
EFD					-.007	.068	-.045
Yield efficiency,YE						.105	-.265*
Leaf area, LA							.026

* significant at the .05 probability level.

Table 1.24 Correlation coefficients of some morphological and physiological traits at Rossville in 1985.

Trait	R/E	K/R	YE	LA	LAI
			r		
Grain yield, GY	.018	-.227*	.082	-.113	.389*
Rows/ear, R/E		.267*	.054	.093	-.209*
Kernals/row, K/R			.264*	.046	-.366*
Yield efficiency,YE				-.120	-.191*
Leaf area, LA					-.057*

* significant at the .05 probability level.

Table 1.25 Correlation coefficients of some morphological and physiological traits at Manhattan in 1986.

Traits	R/E	K/R	SWT	YE	LA	LAI
	r					
Grain yield, GY	0.14	0.12	0.32*	0.36*	-0.31*	0.35
Rows/ear, R/E		-0.12	-0.17*	0.24*	0.06	-0.35*
Kernals/row,K/R			0.27*	0.44*	0.19*	-0.43*
Seed weght, SWT				0.05	-0.10	-0.17*
Yield efficiency,YE					-0.16*	-0.60*
Leaf area, LA						-0.05

* significant at the .05 probability level.

Table 1.26 Correlation coefficient of some physiological traits at Rossville in 1986.

Trait	R/E	K/R	SWT	YE	LA	LAI
	r					
Grain yield, GY	0.26*	0.15*	0.19*	0.18*	0.19*	0.44*
Rows/ear, R/E		0.20*	-0.10	0.29*	0.14	-0.02
Kernals/row,K/R			0.07	0.42*	0.07	-0.34*
Seed weight,SWT				0.33*	0.21*	-0.10
Yield efficiency, YE					0.02	-0.31*
Leaf area, LA						-0.27*

* signifficant at the .05 probability level.

Comparison of white vs yellow corn hybrids

White hybrids were contrasted with yellow hybrids on various agronomic traits. SAS General Linear Model procedure was employed with the model statement:-

$$Obs_1, Obs_2 ......Obs_{15} = Hbr.$$

The results of these analyses are presented in table 1.27.

The white and yellow hybrids differed significantly in vegetative and reproductive stages (GDD-V and GDD-R respectively), plant and ear heights and, grain yield at both locations and in both years. Yield efficiency was significantly different at both locations in 1986 while leaf area were different among the hybrids at Manhattan in 1985 and at Rossville in both years. Number of rows per ear and seed weight differed with location and season.

Figures 1a through 8b were drawn using combined data over locations. Figures 1a & b show that the white hybrids were less yielding than the yellow hybrids at all plant densities, except at the fourth density in 1985. This lag in yield could be partly due to longer vegetative stage and relatively shorter reproductive stage (figures 2a & b and 3a & b), the period when part of the assimilates which accumulated in vegetative plant parts are translocated to the grain. Also the effective filling duration, which is the linear grain growth duration is generally lower in white than in yellow hybrids. However, seed weight was higher in white than in yellow hybrids, (figures 5a & b). This could have been due to lower number of rows per ear observed in the white than in the yellow hybrids, (figures 6a & b).

Yield efficiency was lower in white than in yellow hybrids and decreased with increased plant density, (figures 7a & b). However, leaf area per plant was higher in white than in yellow hybrids and tended to decrease with increased plant density, (figures 8a & b). This suggests that at the high plant densities used in this study, white hybrids are experiencing some solar radiation stress, causing some leaves to have low photosynthetic rates.

Phenotypically the basic difference between white and yellow corn hybrids in this study were color of endosperm and cob, which are genetically controlled and are not necessarily related to the differences in agronomic traits observed. This suggests that less breeding work has been done on the white hybrids compared to the yellow hybrids in selecting for the following: (1) longer reproductive stage and specifically longer grain filling duration, (2) larger sink size (higher number of rows per ear) and (3) higher yield efficiency.

Table 1.27 Contrast of white vs yellow corn hybrids on some agronomic traits at two locations and years.

	Locations			
	Manhattan		Rossville	
	Years			
Trait	1985	1986	1985	1986
GDD-V	**	**	*	**
GDD-R	**	**	*	*
Plant height	**	**	**	**
Ear height	**	**	**	**
No. rows/ear	**	**	NS	NS
No. kernels/row	NS	NS	NS	NS
Seed weight	*	NS	NS	*
Yield	**	**	**	*
DMA-1	NS	NS	*	NS
DMA-2	NS	NS	NS	**
EFD	NS	NS	NS	NS
YE	NS	*	NS	**
LA	*	NS	**	**
LAI	NS	NS	NS	NS
Leaf temperature	NS	NS	*	NS

*, ** significantly different at .05 and .01 probability level respectively.

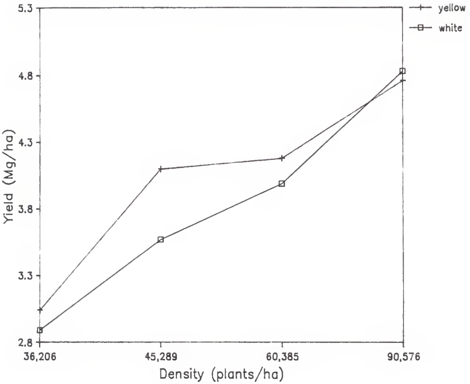

Figure 1a. Mean grain yield of yellow vs white corn hybrids at four plant densities in 1985.

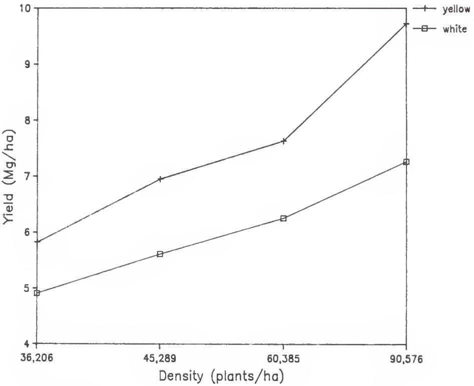

Figure 1b. Mean grain yield of yellow vs white corn hybrids at four plant densities in 1986

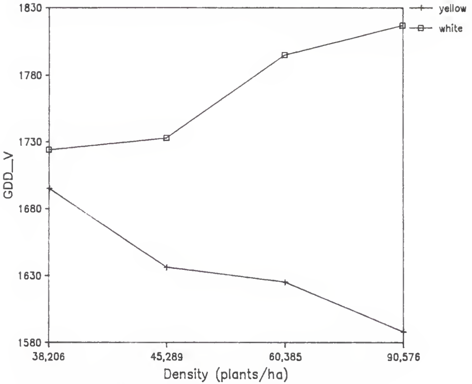

Figure 2a. Mean vegetative stage (GDD_V) of yellow vs white corn hybrids at four plant densities in 1985.

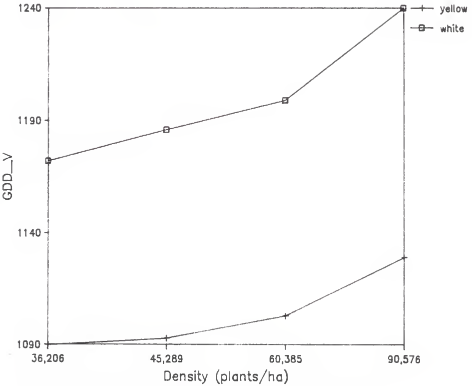

Figure 2b. Mean vegetative stage (GDD_V) of yellow vs white corn hybrids at four plant densities in 1986.

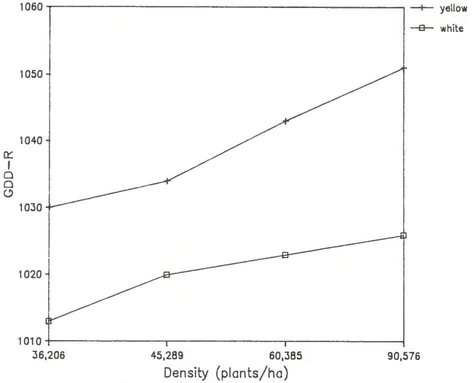

Figure 3a. Mean reproductive stage (GDD_R) of yellow vs white corn hybrids at four plant densities in 1985.

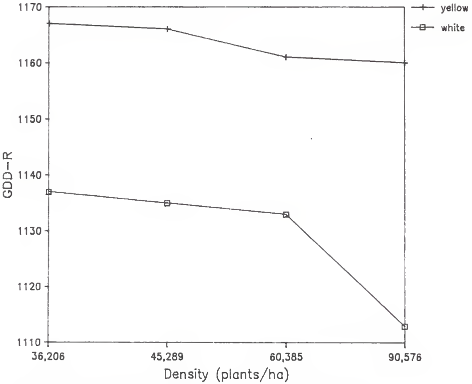

Figure 3b. Mean reproductive stage (GDD_R) of yellow vs white corn hybrids at four plant densities in 1986.

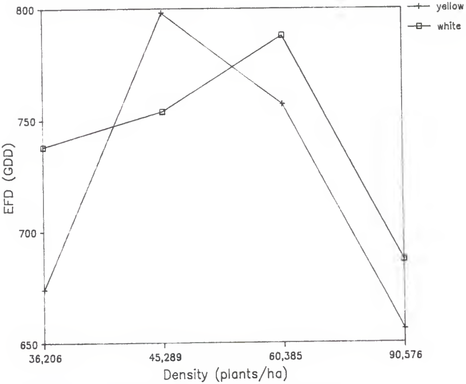

Figure 4a. Mean effective filling duration (EFD) of yellow vs white corn hybrids at four plant densities in 1985.

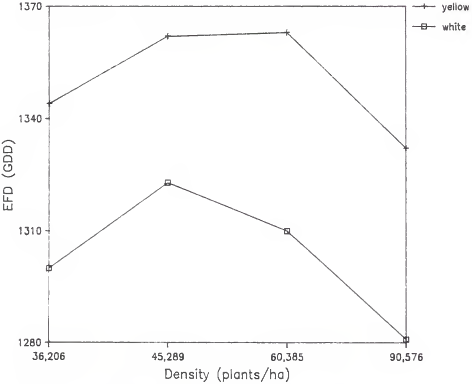

Figure 4b. Mean effective filling duration (EFD) of yellow vs white corn hybrids at four plant densities in 1986.

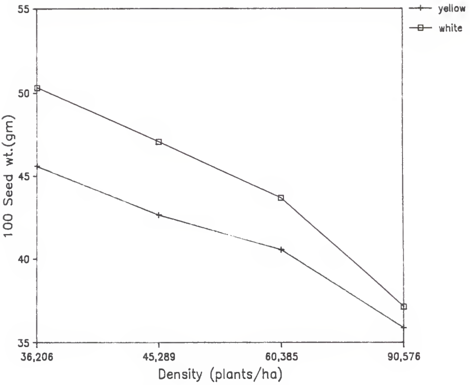

Figure 5a. Mean 100 seed weight of yellow vs white corn hybrids at four plant densities in 1985.

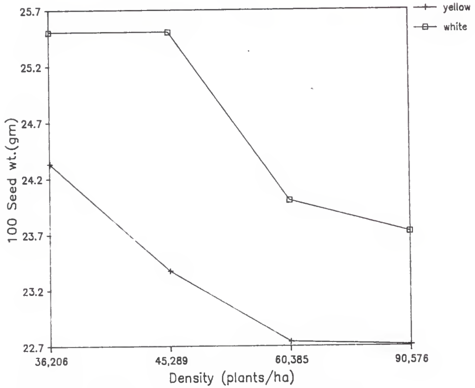

Figure 5b. Mean 100 seed weight of yellow vs white corn hybrids at four plant densities in 1986.

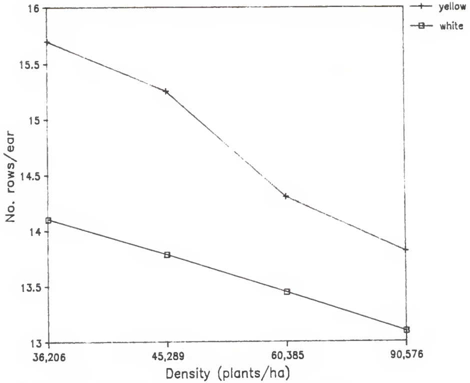

Figure 6a. Mean number of rows per ear of yellow vs white corn hybrids at four plant densities in 1985.

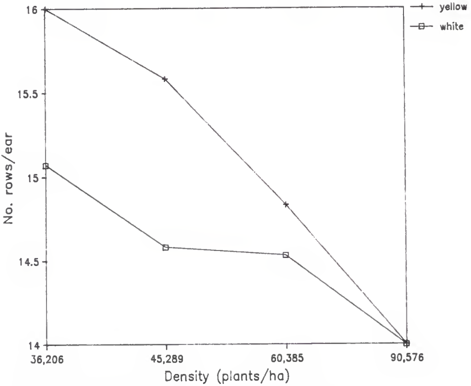

Figure 6b. Mean number of rows per ear of yellow vs white corn hybrids at four plant densities in 1986.

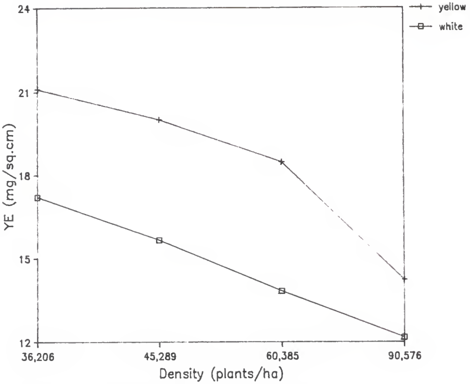

Figure 7a. Mean yield efficiency (YE) of yellow vs white corn hybrids at four plant densities in 1985.

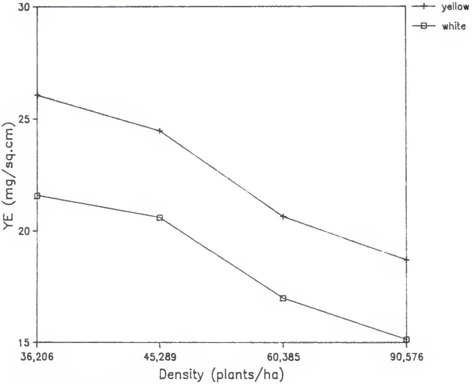

Figure 7b. Mean yield efficiency (YE) of yellow vs white corn hybrids at four plant densities in 1986.

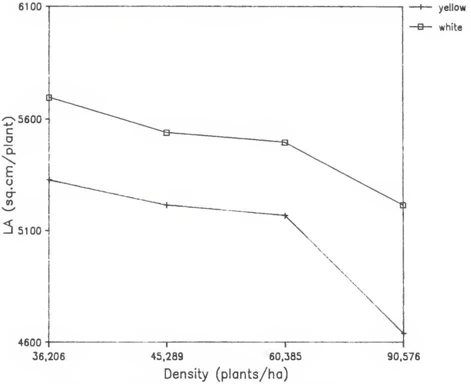

Figure 8a. Mean leaf area per plant (LA) of yellow vs white corn hybrids at four plant densities in 1986.

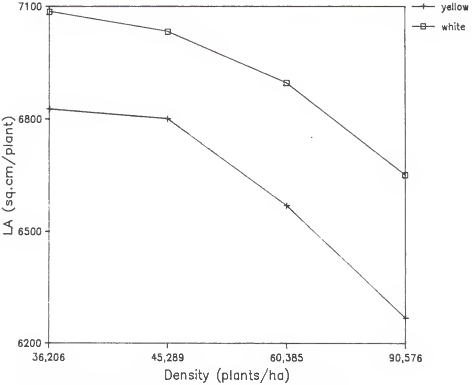

Figure 8b. Mean leaf area per plant (LA) of yellow vs white corn hybrids at four plant densities in 1986.

SUMMARY

The results obtained in this study indicate that:-

1. Vegetative stage, plant and ear heights, grain yield and leaf area index increased with increased plant density.
2. Reproductive stage, number of rows per ear, number of kernels per row, seed weight, effective filling duration, dry matter accumulation rates, leaf area per plant and yield efficiency decreased with increased plant density.
3. White hybrids yield less than yellow hybrids due to shorter reproductive stage, smaller sink size and lower yield efficiency.

The above suggest that grain yield at high plant densities could be improved through breeding for longer grain filling durations, larger sink sizes and higher yield efficiencies.

Finally, white hybrids could be improved by selecting for longer reproductive stages, larger sink sizes and higher yield efficient genotypes.

REFERENCES

1. Alessi, J. and J.F. Power. 1974. Effect of plant population, row spacing, and relative maturity dryland corn in the Northern Plains 1.Corn forage and grain yield. Agron. J. 66:316-319.

2. Buren, L.L., J.J. Mock, and I.C. Anderson. 1974. Morphological and physiological traits in maize associated with tolerance to high plant density. Crop Sci. 14:426-429.

3. Carter, M.W. and C.G. Poneleit. 1973. Black layer maturity and filling period variation among inbred lines of corn. Crop Sci. 13:436-439.

4. Charles-Edwards, D.A. 1982. Physiological determinants of crop growth. Academic Press:pp 13-17.

5. CIMMYT,1975. Report on maize improvement. CIMMYT Review 1976:p.28.

6. Cosmin, O.,N. Bica, T. Sarca, I.Ciocazam, T. Restea, T. Suba, S.Ilicevici, G.Munteamu, and E. Chirvasciu. 1984. Response of genotype to crop density and its implication in work on maize breeding. Probleme de Genetica Teoretica si Apliocata (Ro.) 16:267-296.

7. Daynard, T.B., J.W. Tanner, and W.G. Duncan. 1971. Duration of the grain filling period and its relation to grain yield in corn (Zea mays L.). Crop Sci. 11:45-48.

8. Duncan, W.G., D.N. Shaver and W.A. Williams. 1973. Isolation

and temperature effects on maize growth and yields. Crop Sci. 13:187-190.

9. El-Lakany, M.A., and W.A. Russell. 1971. Relationship of maize characters with yields in test crosses of inbreds at different plant densities. Crop Sci. 11:698-701.

10. Elsahookie, M.M., and C.E. Wassom. 1984. Moisture regime and plant density effects on yield, yield efficiency and other agronomic traits of several hybrids of corn (Zea mays L.). Iraqi Journal of Agric. Sci. Zonco 2(4):29-42.

11. Enzie, W.D. 1942. New York Agric. Expt. Sta. Bull. 700.In Corn Plant Population and Soil Productivity. Advances in Agronomy 10:436-471.

12. Eik, K., and J.J. Hanway. 1965. Some factors affecting development and longevity of leaves of corn. Agron. J. 57:7-12.

13. Evans. L.T. 1975. The physiological basis of crop yield. p.327-355. In L.T. Evans (ed.) Crop Physiology- Some Case Histories, Camb. Univ. Press, London.

14. Genter, C.F. and H.M. Camper,Jr. 1973. Components of plant part development in maize as affected by hybrids and population density. Agron. J. 65:669-671.

15. Gerakis, P.A., and D. Papkosta-Tasopoulou. 1980. Effects of dense planting and artificial shading on five maize hybrids. Agricultural Meteorology 21(2):129-137.

16. Giesbrecht, J. 1969. Effect of population and row spacing on the performance of four corn (*Zea mays* L.) hybrids. Agron. J. 61:439-441.

17. Gilmore, E.C. Jr., and J.S. Rogers. 1958. Heat units as a method of measuring maturity in corn. Agron. J. 50:611-694.

18. Goldsworthy, P.R., and M. Colegrove. 1974. Growth and yield of highland maize in Mexico. J. Agric. Sci., Camb. 83:213-221.

19. Hanway, J., and W. A. Russell. 1969. Dry matter accumulation in corn plant. Comparison among single cross hybrids. Agron. J. 61:947-951.

20. Johnson, D.R., and J.W. Tanner. 1972. Calculation of the rate and duration of the grain filling in corn (*Zea mays* L.). Crop Sci. 12:485-486.

21. Lang, A.L., J.W. Pendleton, and G.H. Dungan. 1956. Influence of Population and Nitrogen levels on yield and protein and oil contents of nine corn hybrids. Agron. J. 48: 284-289.

22. Larson, W.E., and J.J. Hanway. 1977. Corn production. *In* G.F. Sprague (ed.) Corn and Corn Improvement, p.625-663. ASA, Madison, Wisconsin.

23. Muleba, N., T.G. Hart, and G.M. Paulsen. 1983. Physiological factors affecting maize yields under tropical and temperate conditions. Trop. Agric. (Trinidad) 60(1):3-10.

24. Nagy, C., I. Lasu, I. Chiorescu, and A. Ciorlaus. 1976. Effect of plant density on yield of maize hybrids. Technice,

Fundulea (Ro.) 41:161-168.

25. Nunez, R., and E. Kamprath. 1969. Relationship between N response, plant population and row width on growth and yield of corn. Agron. J. 61:279-282.

26. Pearce, R.B., J.J. Mock, and T.B. Bailey. 1975. Rapid method for estimating leaf area per plant in maize. Crop Sci. 15:691-694.

27. Pendleton, J.W., D.B. Egli, and D.B. Peters. 1967. Response of corn (Zea mays L.) to a "light" rich environment. Agron. J. 59:395-397.

28. Poneleit, C.G., and D.B. Egli. 1979. Kernel growth rate and duration in maize as affected by plant density and genotype. Crop Sci. 19:385-388.

29. Prior, C.C., and W.A. Russell. 1976. Leaf area index and grain yield for nonprolific and prolific single crosses of maize. Crop Sci. 16:304-305.

30. Ritchie, S.W., and J.J. Hanway. 1984. How a corn plant develops. Special report no.48. Iowa State University of Science and Technology:1-21.

31. Rutger, J.H., and L.V. Crowder. 1967. Effect of high plant density on silage and grain yield of six corn hybrids. Crop Sci.7:182-188.

32. Shaw, R.H., and H.C.S. Thom. 1951. On the phenology of field corn, silking to maturity. Agron. J. 43:541-546.

33. Sotomayer-Rios, A., C. Torres, and M. Ellis. 1980. Effect of plant density on yield and plant characters of twelve corn hybrids and selections. J. of Agric. University of Puerto Rico, 64(4):407-413.

34. Tanaka, A., and J. Yamaguchi. 1972. Dry matter production, yield components and grain yield of the maize plant.J. Faculty of Agric. Hokkaido University, 57:72-132.

35. Tiamu, A., I. Picu, and M. Tiamu. 1983. Influence of sowing density on some physiological elements in maize yield formation under irrigation. Probleme de Agrofitotechnic Teoretica si Aplicata (Ro.), 5(3):219-230.

36. Wiegand, C.L., and L.N. Namken. 1966. Influences of plant moisture stress, solar radiation, air temperature and cotton leaf temperature. Agron. J. 58:582-586.

APPENDIX

Table 1: Analyses of variance for growth stages, yield and yield components at Manhattan during 1985

Source	df	mean squares					
		GDD-V	GDD-R	rows/ear	kern/row	seed wt.	yld
Replication	2	*	NS	NS	*	NS	NS
Density (Den)	3	NS	NS	*	**	*	**
Error (a)	6	13024	1023	1.86	25.43	47.70	1.82
Hybrid (Hy)	9	**	*	**	NS	*	**
Den x Hy	27	NS	NS	NS	NS	NS	NS
Error (b)	72	4177	6570	1.72	27.55	28.98	.95

* , ** significant at .05 and .01 probability level respectively.

Table2: Analyses of variance for growth stages, yield and yield components at Rossville during 1985

Source	df	mean squares					
		GDD-V	GDD-R	rows/ear	kern/row	seed wt.	yld
Replication	2	**	NS	NS	NS	NS	NS
Density (Den)	3	NS	NS	NS	NS	NS	**
Error (a)	6	1229	3076	2.90	144	3153	0.83
Hybrid (Hy)	9	*	*	NS	NS	NS	**
Den x Hy	27	NS	NS	NS	NS	NS	NS
Error (b)	72	534	967	2.75	35.92	10.98	.75

* , ** significant at .05 and .01 probability level respectively.

Table 3: Analyses of variance for growth stages, yield and yield components at Manhattan during 1986.

Source	df	mean squares					
		GDD-V	GDD-R	rows/ear	kern/row	seed wt.	yld.
Replications	2	NS	NS	NS	NS	NS	NS
Density (Den)	3	**	**	NS	*	NS	*
Error (a)	6	2067	553	5.45	45.56	33.38	12.4
Hybrid (Hy)	9	**	*	**	NS	NS	**
Den x Hy	27	NS	NS	NS	NS	NS	NS
Error (b)	72	1463	833	2.99	31.05	22.83	4.72

* , ** significant at .05 and .01 probability level respectively.

Table 4: Analyses of variance for growth stages, yield and yield components at Rossville during 1986.

Source	df	mean squares GDD-V	GDD-R	rows/ear	kern/row	seed wt.	yld.
Replications	2	NS	NS	NS	NS	**	NS
Density (Den)	3	NS	NS	NS	NS	NS	*
Error (a)	6	7493	1524	8.57	92.11	6.49	6.42
Hybrids (Hy)	9	**	**	NS	NS	**	**
Den x Hy	27	NS	NS	NS	NS	NS	NS
Error (b)	72	1408	473	6.77	52.05	12.87	2.77

* , ** significant at .05 and .01 probability level respectively

Table 5: Analyses of variance for grain filling stages at Manhattan in 1985.

Source	df	mean squares DMA-1	DMA-2	EFD
Replication	2	NS	NS	NS
Density (Den)	3	NS	NS	NS
Error (a)	6	0.01	0.01	2005
Hybrids (Hy)	9	**	NS	NS
Den x Hy	27	NS	NS	NS
Error (b)	72	.004	.009	7848

* , ** significant at .05 and .01 probability level respectively.

Table 6: Analyses of variance for grain filling stages at Rossville during 1985.

Source	df	mean squares DMA-1	DMA-2	EFD
Replication	2	NS	NS	NS
Density (Den)	3	NS	NS	NS
Error (a)	6	0.01	0.01	93967
Hybrids (Hy)	9	NS	NS	NS
Den x Hy	27	NS	NS	NS
Error (b)	72	.007	.011	21650

* , ** significant at .05 and .01 probability level respectively.

Table7: Analyses of variance for grain filling stages at Manhattan in 1986.

Source	df	mean squares DMA-1	DMA-2	EFD
Replication	2	NS	NS	NS
Density (Den)	3	NS	NS	NS
Error (a)	6	.001	.006	8604
Hybrid (Hy)	9	**	NS	*
Den x Hy	27	NS	NS	NS
Error (b)	72	.0006	.009	12590

* , ** significant at .05 and .01 probability level respectively.

Table 8: Analysis of variance for grain filling stages at Rossville during 1986.

Source	df	mean squares DMA-1	DMA-2	EFD
Replication	2	NS	**	NS
Density (Den)	3	NS	**	NS
Error (a)	6	.022	.001	2639
Hybrid (Hy)	9	NS	*	NS
Den x Hy	27	NS	NS	NS
Error (b)	72	.0031	.011	5773

* , ** significant at .05 and .01 probability level respectively.

Table 9: Analyses of variance for some physiological and morphological leaf traits at Manhattan in 1985.

Source	df	mean squares LA	LAI	YE	12 Leaf	Silk	Blist.	Dough
Replication	2	NS	NS	NS	NS	NS	NS	NS
Density (Den)	3	**	**	NS	NS	*	NS	NS
Error (a)	6	655939	10.43	4.81	3.19	1.89	2.46	0.54
Hybrid (Hy)	9	**	**	NS	NS	NS	NS	NS
Den x Hy	27	NS	NS	NS	NS	NS	NS	NS
Error (b)	72	100464	.05	53	.60	1.5	.86	.60

* , ** significant at .05 and .01 probability level respectively.

Table 10: Analyses of variance for some physiological and morphological leaf traits at Rossville during 1985.

Source	df	mean squares						
		LA	LAI	YE	12 Leaf	Silk	Blist.	Dough
Replication	2	NS	NS	NS	NS	NS	NS	NS
Density (Den)	3	**	**	NS	NS	NS	NS	NS
Error (a)	6	676398	0.41	151.6	1.67	0.91	2.76	1.16
Hybrid(Hy)	9	**	**	NS	NS	NS	NS	NS
Den x Hy	27	NS	*	NS	NS	NS	NS	NS
Error (b)	72	154942	.06	41	.41	.24	1.2	.51

* , ** significant at .05 and .01 probability level respectively.

Table 11: Analyses of variance for some physiological and morphological leaf traits at Manhattan in 1986.

Source	df	mean squares				
		LA	LAI	YE	12 Leaf	Silk
Replication	2	NS	NS	NS	**	**
Density (Den)	3	NS	**	*	NS	**
Error (a)	6	164321	0.95	98.3	3.32	0.55
Hybrid (Hy)	9	*	*	**	NS	*
Den x Hy	27	NS	NS	NS	NS	NS
Error (b)	72	579117	0.16	40.69	0.06	0.41

* , ** significant at .05 and .01 probability level respectively.

Table 12: Analyses of variance for some physiological and morphological leaf traits at Rossville during 1986.

Source	df	mean squares			
		LA	LAI	YE	Silk
Replication	2	NS	NS	*	**
Density (Den)	3	*	**	NS	NS
Error (a)	6	1.05m	0.74	42.54	261
Hybrid (Hy)	9	**	**	**	NS
Den x Hy	27	NS	NS	NS	NS
Error (b)	72	136093	0.06	19.55	233

* , ** significant at .05 and .01 probability level respectively.

Table 13: Average grain yield (Mg ha^{-1}) of ten corn hybrids during 1985.

Hybrid	Location	Density (plants ha^{-1}) 36,206	45,289	60,385	90,576	Mean
	Manhattan					
Hoegemeyer SX2700		3.36	5.33	4.99	6.45	5.03
Pioneer 3183		3.04	4.12	5.00	5.76	4.48
MFA 6702		2.97	3.85	4.38	6.76	4.48
RA 1502		2.57	3.54	4.38	5.19	3.92
Zimmerman 15AW		1.91	2.94	3.69	3.75	3.08
DK 77W		3.23	3.86	3.15	4.76	3.75
MV 68W		2.88	3.33	2.48	5.59	3.57
Whisnand 73W		2.46	2.95	3.74	2.63	2.94
G 4779W		2.86	2.40	3.46	3.16	2.97
Zimmerman Z54W		3.08	3.39	4.66	4.24	3.84
	Rossville					
Hoegemeyer SX2700		3.52	4.25	4.45	5.86	4.51
Pioneer 3183		3.76	5.22	5.35	5.69	5.01
MFA 6702		2.78	3.35	4.91	5.53	4.14
RA 1502		3.21	5.03	4.95	4.97	4.54
Zimmerman 15AW		3.36	3.42	3.40	3.74	3.48
DK 77		3.02	4.82	4.79	5.81	4.64
MV 68		1.84	3.69	3.52	4.23	3.32
Whisnand 73W		3.10	4.32	3.41	4.05	3.72
G 4779W		2.86	3.36	3.79	3.78	3.45
Zimmerman Z54W		2.99	3.49	3.30	3.93	3.43

Table 14: Average grain yield (Mg ha^{-1}) of ten corn hybrids during 1986.

Hybrid	Location	Density (plants ha^{-1}) 36,206	45,289	60,385	90,576	Mean
	Manhattan					
Hoegemeyer SX2700		7.76	9.85	8.23	12.67	9.63
Pioner 3183		7.07	9.29	7.84	9.52	8.43
MFA 6702		7.10	8.14	9.93	11.53	9.18
RA 1502		6.74	6.96	10.64	12.96	9.33
Zimmerman 15AW		5.10	8.15	7.77	7.36	7.10
DK 77W		6.02	6.71	8.63	10.52	7.97
MV 68W		6.85	6.12	7.78	7.50	7.05
Whisnand 73W		6.16	6.46	8.74	7.84	7.30
G 4779W		5.88	7.04	5.36	9.69	6.99
Zimmerman Z54W		5.85	5.26	7.33	8.16	6.65
	Rossville					
Hoegemeyer SX2700		4.84	5.96	5.72	8.41	6.23
Pioneer 3183		5.39	6.37	7.53	9.14	6.36
MFA 6702		3.47	4.17	5.75	7.66	5.26
RA 1502		4.19	4.82	5.41	5.86	5.07
Zimmerman 15AW		2.87	4.23	6.63	4.16	4.47
DK 77W		3.78	5.40	6.33	5.94	5.36
MV 68W		3.53	4.16	3.98	5.90	4.39
Whisnand 73W		3.85	4.41	5.26	7.03	5.14
G 4779W		5.30	4.48	3.96	5.86	4.90
Zimmerman Z54W		3.67	4.57	3.76	7.30	4.83

PART II

USE OF GROWING DEGREE DAYS FOR SELECTING HIGH YIELDING CORN GENOTYPES

ABSTRACT

Growing degree days (GDD) were calculated using temperatures recorded in the field, from silking to 45 days after silking, for ten corn hybrids. Effective grain filling duration (EFD) defined as final grain yield divided by the average rate of grain dry weight accumulation during the linear period of grain formation was calculated using GDD instead of calendar days.

Significant differences were found among hybrids in the EFD. Yield was highly correlated to EFD. Results suggest that significant potential exist in corn for higher grain yields through a genetic extension of the length of the grain filling period and, that using GDD instead of calendar days for EFD would serve as a better selection criterion.

INTRODUCTION

Plants respond to many environmental forces but temperature is perhaps one of the most significant single factor. Time-temperature indexing as a method of predicting plant growth dates back to the French scientist, Reamur. He first proposed such a system in 1735 (Newman and Dale, 1969).

The concept of considering a plant as a heat storage unit via physiological conversion of heat into carbohydrates and other plant components led to the definition of heat units or Growing Degree Days (GDD) (Van Den Brink et al.,1971). The GDD for a given day is defined as the difference between the daily mean temperature, usually estimated as the average of the daily maximum and minimum temperatures, minus a growth threshold temperature which for corn usually is taken as 10 C.

Gilmore and Rogers (1958) compared the precision of the GDD index method for corn with that of 14 other heat unit methods. They concluded that the best was an "effective degree" method in which any daily minimum temperature below 10 C was assumed to be 10 C, and any maximum temperature above 30 C was adjusted by substracting from the daily mean temperature the number of degrees by which the daily maximum temperature exceeded 30 C. Barger (1969) modified the "effective degree" method for corn by setting any daily maximum temperature greater than 30 C egual to 30 C before computing the daily mean temperature.

The concept of GDD is widely accepted as a method of relating plant growth and maturation to temperature. Several scientists (Mederski et al., 1973; Arnold, 1975; Russell et al., 1984 and Sammis et al., 1985) showed that GDD are a better measure for the length of a phenological stage than calendar days.

Several researchers have reported positive associations of the duration (calendar days) of grain dry matter accumulation with yield (Daynard et al., 1971; Eastin, 1972a; Duncan et al., 1978; Dunphy et al., 1979; McKee et al., 1979 and McGarrahan and Dale, 1984). Therefore by using the GDD for grain filling duration, rather than calendar days, corn hybrid yielding ability could be identified better.

The following study evaluates the use of growing degree days for effective filling duration for identifying high yielding corn genotypes.

MATERIALS AND METHODS

Materials used were the same as those planted in the summers of 1985 and 1986 at Ashland Agronomy Farm, Manhattan Kansas, and Kansas River Valley Experiment field, Rossville, Kansas and detailed in the foregoing section, Part I.

Data Collected

Growing Degree Days (GDD)

The GDD for a given day was defined as the difference between the daily mean temperature, estimated as the average of the daily maximum and minimum temperatures, minus a growth threshold temperature which for corn is 10 C. Any maximum above 30 C was taken as 30 C and any minimum below 10 C was designated as 10 C (Gilmore and Rogers, 1958 and Barger, 1969).

The daily minimum and maximum temperatures were taken in the field just above the crop canopy to account for some of the considerations of heat units posed by Wang, 1960. Standard minimum-maximum thermometers were placed in small well ventillated boxes (6 x 9 x 12 in.). The boxes containing the thermometers were raised during the season as the plants grew in height. Daily readings were taken each morning before the air temperature had started to rise.

The GDD for each day were then accumulated as reported in the previous study. For this study the GDD for effective filling duration were used. This was the period in which linear grain filling rate was assumed to occur (Johnson and Tanner, 1972 and Cross, 1975).

Grain yield

Obtained from density four reported in the foregoing section, Part 1.

Statistical Analyses

The experiment was analysed as a randomized complete block design using data from the fourth density, which was the highest yielding density in Part I. Analyses of variance and regression analyses are performed using yield as the dependent variable and GDD for EFD as the independent variable.

RESULTS AND DISCUSSION

The GDD for EFD at Rossville in 1985 were very low due to the low temperatures recorded from silking to 45 days after silking. Grain yields for 1986 were higher than 1985 due to high rainfalls and favorable temperatures experienced.

Data on grain yield and EFD (GDD) are presented in tables 2.1 to 2.2. Significant differences in yield and EFD were observed in both locations and years. Hoegemeyer SX2700 had the highest grain yield in 1985 and the longest EFD at Manhattan. In 1985, G4779W and Whisnand 73W had the lowest yields and one of the lowest EFD. In 1986, Zimmerman Z15AW and MV68W had the lowest yields at Manhattan and Rossville respectively, but not the least EFD. However, highly significant R^2 values were observed at both sites, (table 2.3). The percentage variation in yield accounted for by EFD was very high, .78 and .74 for Manhattan and Rossville respectively.

While the EFD for different hybrids were calculated from GDD obtained on the same number of calendar days (45 days), the study has pointed out that differences exist among hybrids in GDD for EFD. This supports merits of using GDD for explaining the length of a phenological stage reported by several scientists, (Mederski et al., 1973; Arnold, 1975; Russell et al., 1984 and Sammis et al.,1985). Also the results of this study agree with an earlier study by Daynard et al., 1971, that differences in EFD were highly correlated with yield.

Results suggest that significant potential exists in corn for grain yield improvement through a genetic extension of the length of grain filling period and that GDD for EFD was a better selection criterion than calendar days.

Table 2.1 Mean grain yield and effective filling duration of ten corn hybrids at two locations in 1985.

Hybrid	Manhattan		Rossville	
	Yield (Mg/ha)	EFD (GDD)	Yield(Mg/ha)	EFD (GDD)
Hoeg. SX2700	6.95a	1087a	5.83a	231c
Pioneer 3183	5.77ab	1009bc	5.69ab	259bc
MFA 6702	6.76a	1063ab	4.56cd	251bc
RA 1502	5.19bc	1066ab	4.97abc	302b
Zimmer. Z15AW	4.38bcd	1030abc	3.74de	280bc
DK 77W	4.76bcd	1007bc	4.84bc	292b
MV 68W	5.59abc	1082a	4.23cde	398a
Whisnand 73W	3.58d	1054ab	3.67e	256bc
G 4779W	3.41d	1026abc	4.39cde	271bc
Zimmer. Z54W	4.24cd	978c	4.49cde	252bc
LSD (.05)	1.4	71	0.88	53

Means followed by the same letter do not differ significantly at the .05 probability level.

Table 2.2 Mean grain yield and effective grain filling duration of ten hybrids at two locations in 1986.

Hybrid	Manhattan		Rossville	
	Yield (Mg/ha)	EFD (GDD)	Yield (Mg/ha)	EFD(ggd)
Hoeg. SX2700	12.65a	1487ab	8.41a	1113ab
Pioneer 3138	9.52ab	1577ab	9.14abc	1117ab
MFA 6702	11.53ab	1591a	7.66abcd	1128ab
RA 1502	12.96a	1554ab	5.86cde	1094b
Zimmer. Z15AW	7.36b	1464ab	5.16de	1092b
DK 77W	9.18ab	1411ab	5.94cde	1142a
MV 68W	9.24ab	1554ab	4.90e	1116ab
Whisnand 73W	9.67ab	1446ab	7.20abcde	1130ab
G 4779W	8.36ab	1372b	6.76bcde	1115ab
Zimmer. Z54W	8.16ab	1443ab	9.62a	1116ab
LSD (.05)	5.18	207	2.70	43

Means followed by the same letter do not differ significantly at the .05 probability level.

Table 2.3 Coefficient of determination (R^2) for grain yield on effective grain filling duration (EFD) duration for two locations during 1985 and 1986.

Location	Year	R^2
Manhattan	1985	0.78**
	1986	0.40
Rossville	1985	0.74**
	1986	0.74**

REFERENCES

1. Arnold, C.Y. 1975. Heat unit systems in corn production. Ill. Res. 17 (2):10-11.

2. Barger, G.L. 1969. Total growing degree days. Weekly Weather Crop Bull. 56:10.

3. Cross H.Z. 1975. Diallel of duration and rate of grain filling of seven inbred lines of corn. Crop Sci. 15:532-535.

4. Daynard, T.B., J.W. Tanner, and W.G. Duncan. 1971. Duration of the grain filling period and its relation to grain yield in corn, (Zea mays L.). Crop Sci. 11:45-48.

5. Duncan, W.G., D.E. McCloud, R.L. McGraw, and K.H. Boote. 1978. Physiological aspects of peanut yield improvement. Crop Sci. 18:1015-1020.

6. Dunphy, E.J., J.J. Hanway, and D.E. Green. 1979. Soybean yields in relation to days between specific developmental stages. Agron. J. 71:917-920.

7. Eastin, J.D. 1972a. Sorghum in seventies. IBH and Oxford New Delhi, pp. 224-246.

8. Gilmore, E.C. Jr. and J.S. Rogers. 1958. Heat units as a method of measuring maturity in corn. Agron. J. 50:611-615.

9. Johnson, D.R. and J.W. Tanner. 1972b. Calculation of the rate and duration of grain filling in corn. Crop Sci. 12:485-486.

10. McGarrahan, J.P. and R.F. Dale. 1984. A trend toward a longer

grain filling period for corn: A case study in Indiana. Agron. J. 76:518-522.

11. McKee, G.W., H.J. Lee, D.P. Knievel, and L.D. Hoffman. 1979. Rate of fill period for nine cultivars of spring oats. Agron. J. 71:1029-1034.

12. Mederski, H.J., M.E. Miller, and C.R. Weaver. 1973. Accumulated heat units for classifying corn hybrids maturity. Agron. J. 65(5):743-747.

13. Newman, J.E., and R.F. Dale. 1969. Growing degree days their-use in forecasting crop growth and maturity. Weekly Weather and Crop Bulletin. Purdue University:12-13.

14. Russell, M.P., W.W. Wilhem, R.A. Olson, and J.F. Power. 1984. Growth analysis based on degree days. Crop Sci. 24(1):28-32.

15. Sammis,T.W., C.L. Mapel, D.G. Lugg, R.R. Lansford, and J. T. McGuckin. 1985. Evapotranspiration crop coefficients predicted using growing degree days. Transactions of the ASAE 1985. 28(3):773-780.

16. Van Den Brink, C., N.D. Stromen, and A.L. Kenworthy. 1971. Growing degree days in Michigan. Research Report 131. Farm Science, Michigan State University Agricultural Experiment Station, East Lansing, Michigan.

17. Wang, Je Yu. 1960. A critique of the heat units approach to plant response studies. Ecology 41:785-790.

ACKNOWLEDGEMENTS

I wish to express my sincere appreciation and gratitude to Dr. Clyde E. Wassom for his invaluable guidance and encouragement in conducting this study. My sincere appreciation is also extended to Dr. G. A. Milliken for his assistance in the statistical analyses of the data and, to Dr. R. Vanderlip for assistance and editorial remarks.

I also owe a special debt of gratitude to Dr. David Acker, Director of Tanzania Farming Systems Research Project, for his continued financial and moral support throughout the entire course of the study. I am also very much grateful to Larry Klocke and James Thomas for assisting in data collection.

Finally, I would like to extend deep appreciation to my mother and my wife, my daughter Noela and my son Pendo for their patience and moral support.

THE ROLE OF PLANT DENSITIES AND GROWING DEGREE DAYS IN THE EVALUATION OF HIGH YIELDING CORN (*Zea mays* L.) GENOTYPES.

by

CLEMENCE SEBASTIAN MUSHI

B.S.,1980 Kansas State University

AN ABSTRACT OF A MASTER'S THESIS

submitted in partial fufillment of the

requirement for the degree

MASTER OF SCIENCE

Department of Agronomy

KANSAS STATE UNIVERSITY

Manhattan, Kansas

1986

ABSRACT

Many corn breeding programs in the world are breeding for high plant density tolerance. Our goal was to identify specific traits to use in selection for tolerance to high plant densities. In this study we planted four yellow and six white corn hybrids at four plant densities: 36,206, 45,289, 60,385, and 90,576 plants ha^{-1}. Growing degree days were calculated using minimum and maximum temperatures recorded just above the crop canopy, and were used to define different phenological stages.

Results indicated that corn hybrids generally were significantly affected by plant densities in vegetative and reproductive stages, plant and ear heights, grain filling duration, dry matter accumulation rate, yield and yield components, leaf area per plant, leaf area index, yield efficiency and canopy leaf temperature at silking stage. However, differences were not at all locations and/or seasons.

The white corn hybrids generally yielded less grain, had shorter reproductive stage, smaller sink size and lower yield efficiency than the yellow corn hybrids in this test.

The study suggests that improvement of grain yield at higher plant populations could be achieved by breeding for genotypes tolerant of increased plant densities, having longer grain filling duration, with larger sink size and higher yield efficiency. This may be especially important for white corn hybrids which generally have not recieved as much attention in breeding programs as yellow hybrids. Lastly, growing degree days were better measures of effective filling duration, and therefore appeared to be a better means of classifying grain filling

duration to identify high yielding genotypes.