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COMPARISON OF SUPERTHICK AND CONVENTIONAL GRAIN SORGHUM MANAGEMENT SYSTEMS AND RELATED COMPONENTS

by

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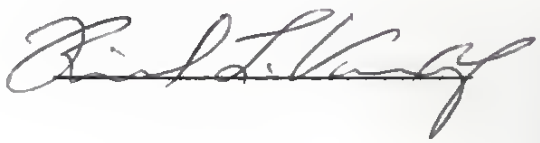

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Introduction

Grain sorghum is an important crop to Kansas agriculture. About 20 percent of all crop acreage in Kansas for 1983 and 1984 was planted to grain sorghum (22). Kansas produced 5.47 million metric tonnes of grain sorghum, on 1.72 million hectares, in 1984 and a record total of 7.5 million metric tonnes, on 1.68 million hectares, in 1985 (50,51). These state production totals ranked Kansas as the number one grain sorghum producer in the United States for both years.

Grain sorghum production practices in Kansas generally range from continuous cropping, in the eastern part of the state, to a sorghum - fallow - wheat rotational system in the western part. Conventionally grown grain sorghum is planted on dates ranging from 1 May to 20 June for all areas of the state. Recommended plant populations range from 49,500 to 74,000 plants per hectare in western Kansas and from 74,000 to 110,000 plants per hectare in the eastern half of the state. Conventional row spacings are 76 to 100 cm between rows (23,32,49).

A new concept in grain sorghum production was developed by Carlyle Thompson, in 1972, at the Fort Hays Branch Experiment Station located in west-central Kansas. Thompson's research has shown this new practice is a useful management option, over conventionally grown grain sorghum, in the Hays area. The "superthick" method, as referred to by Thompson, involves planting an early to medium-early maturity hybrid approximately three weeks later than conventional planting. The seeding rate is increased 2-3 times the conventional rate and row spacing is

narrowed from 76-100 cm to 25-30 cm (48).

Results from Hays show that the superthick system can be an effective method of grain sorghum production and some advantages of the system could promote its use over the conventional system, in the location of its development. Promising results from Hays and possible advantages have created an interest in the system in other grain sorghum producing areas.

The purpose of this study was to test the superthick system over a wide range of conditions, other than the area of its origin. This was accomplished by locating plots in as many different grain sorghum producing areas across the state as possible.

Literature Review

The superthick system has produced yields equal to or greater than grain sorghum produced by conventional methods at Hays. Thompson (48,49) developed the superthick management system in a region where the sorghum - fallow - wheat rotation was primarily being used. The rotational system has a fallow period between fall sorghum harvest and wheat planting the following fall season, and a second fallow period between summer wheat harvest and grain sorghum planting the next spring. The fallow periods leave large lengths of time when the soil can be eroded by wind and water if proper ground cover is not maintained. The superthick system could be a means to promote soil conservation by providing more complete ground cover both during the growing season (denser and more equidistant spacing of plants providing a more uniform canopy) and after harvest (greater amounts and more uniform distribution of the residue on the soil surface and roots below the soil surface).

The superthick system involves planting an earlier maturing hybrid, at a later planting date, in a narrower row spacing, and at a higher seeding rate than conventional methods. Thompson has described the following advantages and disadvantages for the superthick system (48,49).

Advantages

1. Can be planted with a conventional disc or hoe grain drill. The farmer could lower his investment in machinery by owning only one piece of planting

equipment.

2. Seeding rates can be high with little fear of "burning up" sorghum plants. A later planting and earlier maturity hybrid favors higher plant populations.
3. Better weed control due to a later tillage operation and a thick stand that promote strong competition for weeds.
4. Provides a denser canopy over the soil during the growing season and after harvest, which will help to:
    a. Shade the soil and reduce evaporation.
    b. Reduce wind and water erosion.
    c. Reduce water runoff and increase water intake.
    d. Increase grazing potential with more leaf area and more palatable stalks.
5. Matures more evenly by reducing later ripening tillers due to higher plant populations.
6. Superthick maintains or increases yields.

Disadvantages

1. Some hybrids under certain environmental conditions will lodge. Earlier maturity hybrids and high plant populations may contribute to this problem. There are few pickup attachments available for narrow rows.
2. Mechanical cultivation is not possible.
3. Higher seeding rates increase production costs.
4. Reduced or no till management systems may cause trash problems when planting with a conventional grain drill.

In unpublished data, Thompson has summarized the following conclusions concerning the management decisions one will have to

make to use the superthick system.

1. When planting early maturing hybrids:
   a. Plant as late as possible.
   b. Choose a hybrid that stands well.
   c. Use a high seeding rate.

2. When planting continuous sorghum:
   a. Plant early to medium-early maturing hybrids.
   b. Plant as late as possible.
   c. Choose a hybrid that stands well.
   d. Use a high seeding rate.

3. When using a high seeding rate following wheat:
   a. Plant mid- to late-June.
   b. Plant medium to medium-early maturing hybrids.
   c. Choose a hybrid that stands well.
   d. Seeding rate should be based on depth of moist soil and expected seasonal moisture from July 1 to September 30.

4. When using a high seeding rate in continuous sorghum:
   a. Plant early July up to mid-July.
   b. Plant a early or medium-early maturing hybrid.
   c. Choose a hybrid that stands well.
   d. Seeding rate should be based on depth of moist soil and expected seasonal moisture from July 1 to September 30.

5. When determining row spacing:
   a. Use drilled sorghum if:
      1) You can get through the residue.
      2) Lodging is normally not a problem.
      3) You want maximum grazing following harvest.
      4) You plant 3 to 6 weeks later than conventional.
      5) You have had several years experience.
   b. Use wide rowed sorghum if:
      1) Heavy residues is a problem.
      2) Your field has a history of severe lodging.
      3) You want to use pickup attachments on your combine.

The superthick system contains four principal components: a later planting date, earlier maturity hybrid, 2 to 3 times the normal seeding rate, and narrow row spacing.

Planting Date

The average number of days in the frost free period in Kansas ranges from 150 to 200 days (3). Planting dates could

range from early May to early July. Studies conducted primarily in Kansas (5,10,18,31,34,37,44) indicate the optimum date of planting would be May to early June for maximum yield.

Earlier planting dates seemed to lengthen the time from planting to transition of the growing point and from the vegetative to floral stage, lengthen the time from floral transition to half-bloom, reduce the time from half-bloom to physiological maturity of the grain, and expand generally the total number of days from planting to physiological maturity of the grain (31,42,44).

Irrespective to the aforementioned results, the superthick system recommends a late planting date, to allow more time for moisture to be stored in the soil profile and to reduce the vegetative growth period (49). The possibility of extra stored water would only be an advantage in arid conditions or droughty years since total water used at maturity does not seem to differ between planting dates under more favorable conditions (distribution of use may differ between dates) (5). Maximum leaf area index is reached earlier and could be higher in late plantings because of higher temperatures during vegetative growth (5). A later planting date reduces tillering (47,49), but can be compensated for by an increased number of seeds per head (5).

Hybrid Maturity

Hybrid maturity is determined by the number of leaves, duration of growth, and overall plant size (35). These factors are usually indexed by the number of days to half bloom, with earlier maturities having fewer days to half bloom.

Later maturities tend to yield better when environmental conditions are favorable for maximum growth (12), but an early planting date is necessary to take advantage of the entire growing season and allow maturation before frost.

Many times the hybrid maturity is chosen based on the length of the growing season and after a desirable planting date has been determined (42). It is possible for an early maturing hybrid, planted on a late date, to reach physiological maturity on the same date as a late maturing hybrid planted on an earlier date. Plants on either date would be under the same environmental conditions during the grain-fill period (37).

Earlier maturing hybrids have less depression in yields due to growing conditions as compared to later maturity hybrids (44). Part of the more stable yields of the earlier maturing hybrids may be due to a lower leaf area index on a equal number of plants per unit area basis. A lower LAI indicates less water use by the plant and probably lower production under favorable conditions (16). An early maturing hybrid may be an advantage only if a delay in planting date occurs or if frost is a problem (10). Blum (4) found that yield potential was directly related to duration of growth under non-competitive conditions and inversly related under extreme competition. Grain sorghum grown on stored soil moisture favored earlier maturing hybrids.

The superthick system suggests an earlier hybrid maturity (55 to 65 days to half bloom) (49). This seems to be a logical choice, considering the later planting date and the fact that most grain sorghum is grown on stored soil moisture (49).

Seeding Rate

The superthick management system suggests seeding rates of 2 to 3 times the normal rate based on the amount of stored soil moisture and the amount of anticipated rainfall for the growing season (49). Since the 1920's (39) many population studies have been conducted (2,7,13,15,17,19,20,30,34,43,47) and support yield advantages to high plant populations under favorable conditions. Others (4,7,9,47,52) have noted an advantage or disadvantage of higher populations depending on the amount of stored soil moisture. At Hays, Brown and Schrader (9) showed that as moist soil changed from 210 cm to 90 cm the optimum plant population decreased from 225,000 to 37,500 plants/ha.

Other studies support practices used in the superthick system. Bunck (10) and Jaiyesimi (18) found higher seeding rates gave better yields when planting date was delayed. Blum (4) reported higher yields of earlier maturing hybrids and conversely lower yields of later maturing hybrids when planted at higher seeding rates. He stated an earlier maturing hybrid is more adapted to a limited moisture regime (or denser plant population) due to its lower demand during most growth stages. Almost identical soil moisture depletion patterns resulted in later maturing hybrids at low densities as early ones at high density. Welch et al. (52) had more residue produced in high populations leading to a sound conservation practice for wind erosion. Their study also indicated greater yield per inch of soil water at higher plant populations.

Row Spacing

A row spacing of 25 to 30 cm is recommended when planting

the superthick system. Many row spacing studies have been conducted (7,8,9,21,27,28,36,45,46,47) that indicate narrow row spacings result in the same to higher yields over wide row spacings. Equal plant spacing is normally regarded as the explanation for a yield increase. Stickler and Wearden (45) and Stickler and Younis (46) found 7 to 11% higher yields in narrower row spacings from west to east in Kansas. A yield response is normally true if favorable moisture is present. Moisture stress may result in wider row spacings producing the highest yields. Myers and Foale (25) suggested that the optimum row spacing is likely to vary, in different regions, from narrow row spacing in high rainfall areas to wide row spacing in low rainfall areas.

Other researchers (20,25,29,38,41,47) have indicated that maximum production is best achieved if plant population is increased as row spacing is narrowed to provide more interplant competition.

In addition to possible yield advantages, more complete ground cover and earlier soil shading of narrow rows will help suppress weed growth (14,20,26) and help reduce wind and water erosion (1,11,24). Adams and Richardson (1) showed runoff was reduced by 45% and soil loss reduced by 39% when reducing row width from 1.0 m to 0.5 m. Less soil evaporation has been reported in narrow rows due to a more equidistant plant arrangement (6,40,43). Porter et al. (33) reported narrow rows tended to use more more water early in the season but, as also reported by others (6,7,15), no significant differences in total

water use between row spacings were found.

Materials and Methods

Experiments were conducted in 1984 and 1985 at five locations across Kansas (Table 1). These locations were chosen based on soil types (Fig. 1), geographical differences (Fig. 2), normal rainfall patterns (Fig. 3) and the average number of days in the freeze-free period (Fig. 4). The study was a modified split-plot design with dates as the main plots stripped across replicates. Subplot treatments, consisting of hybrid maturity, rate of planting, and row spacing, were randomized within blocks and replicated four times per planting date. Individual plot measurements were 3.05 m wide by 7.6 m long.

Fertilizer was applied by each experiment station, according to the normal practices for the location (Table 2). Each experiment was planted on two dates, approximately 3 to 4 weeks apart. Two row spacings, 25 cm and 76 cm, were planted with a double-disc opener drill. In combination with the two row spacings, two seeding rates and three hybrids, varying in maturity, were used (Table 1).

Granular Furadan 10-G (Carbofuran) was applied at planting (1.12 kg a.i./ha) for early insect control. The seed was safened with Screen (flurazole) to allow Lasso (Alachlor) to be used for grassy weed control. Lasso plus atrazine or Lasso plus propazine were applied post plant, depending on the location, for season-long grass and broad leaf weed control (Table 3). Hand hoeing provided any additional weed control necessary throughout the growing season.

All plots were planted at the high planting rate. Normal

(low) planting rates were obtained by thinning two to three weeks after planting. Plant counts were taken after thinning to determine exact plant population (plants/ha) for all treatments. Data for plant counts and yield were taken from the middle 4.5 m section of the center two rows of the four row plots planted at 76 cm row spacing. Data for the 25 cm row plots were collected from the third, fourth, fifth, eight, ninth, and tenth rows of twelve row plots. This allowed data to be collected from equal land areas for all plots. At Tribune, due to severe lodging, yield data (kg/ha) was collected from the fourth, fifth, sixth, seventh, eighth and ninth rows for the 25 cm plots. All plots were hand harvested (Table 4).

Additional information recorded included: half-bloom date (day of the year), heads harvested (heads/ha), lodging (% of heads harvested), yield (kg/ha), seeds/head, and seed weight (g/1000 seeds). Yield was calculated based on the threshed grain weight corrected to 13.5% moisture. Seeds/head were calculated based on yield, heads harvested, and seed weight.

Statistical analysis was conducted with SAS (statistical analysis system) on yield and the yield components using ANOVA (analysis of variance) and GLM (general liner model) procedures. Mean comparisons within a location were made using an LSD value calculated at the 5% level. No comparisons across locations were attempted due to the great variation in environmental conditions.

In 1985 a small study was designed to compare more detailed measurements on a limited number of treatments (Tables 5 and 6). These additional plots were planted at the same time as the main study, but to the right side of the first planting date and to

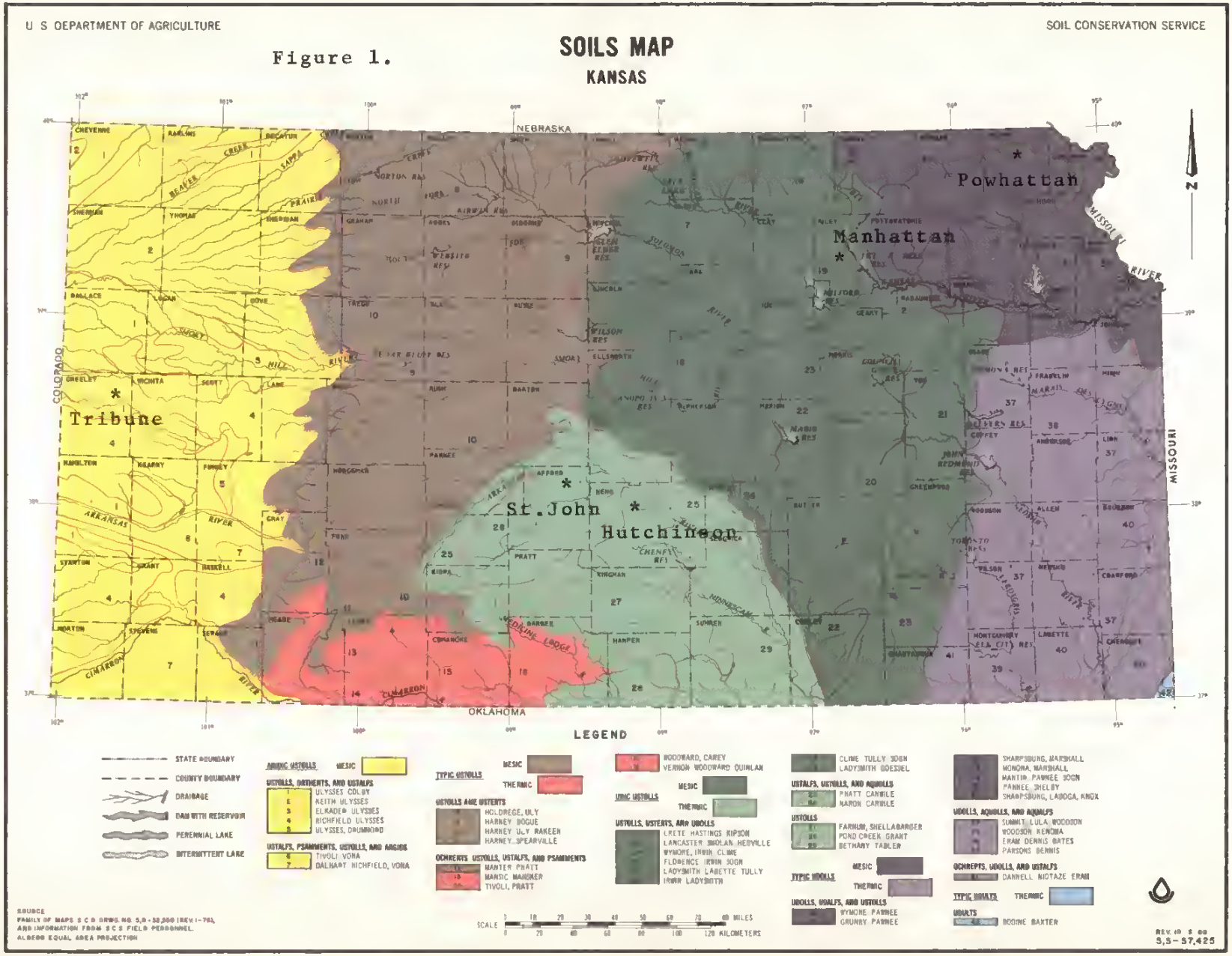
the left of the second to allow side-by-side comparisons between dates.

Neutron probe access tubes were placed in the third and eighth rows of the 76 cm and 25 cm row spacings, respectively. Soil moisture was monitored periodically throughout the growing season to the 110 cm depth at Powhattan, Manhattan, and St. John and to the 240 cm depth at Hutchinson and Tribune.

Data collected, in addition to yield and yield component data mentioned above, included: leaf area index (LAI), specific leaf area (cm^2/g), leaf dry weight (g/m^2), and stem dry weight (g/m^2).

Comparisons of total soil moisture depletion for the growing season and total soil moisture at each date of neutron probe readings were made between the means of each treatment. Statistical analyses were conducted with SAS on soil moisture, yield, yield components, and the additional data listed above using ANOVA. Mean comparisons were made using a LSD calculated at the 5% level.

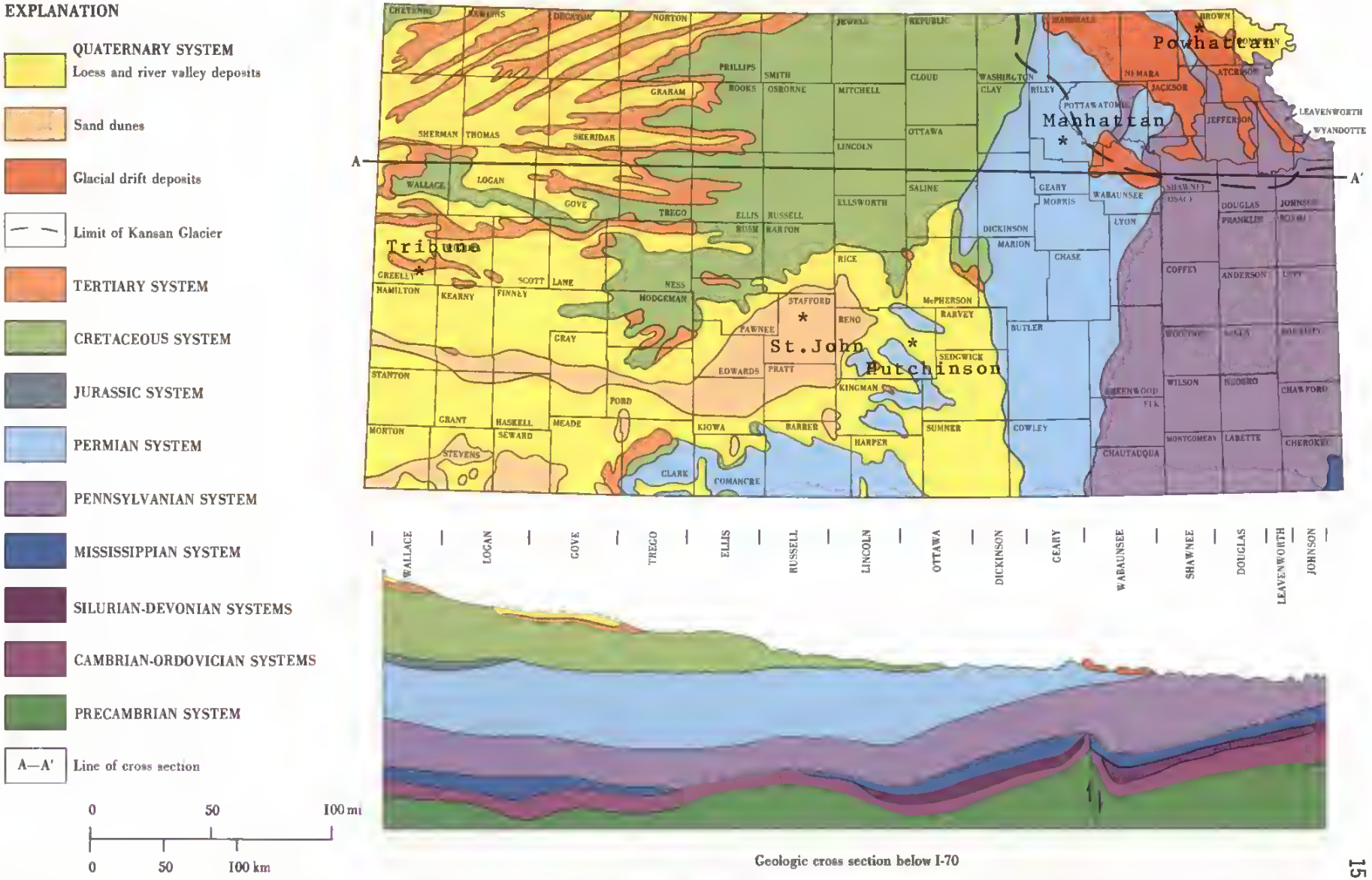
Figure 1.



USDA-SCS-FORT WORTH, TEXAS 1984

Figure 2.

Generalized Geologic Map of Kansas



Geologic cross section below I-70

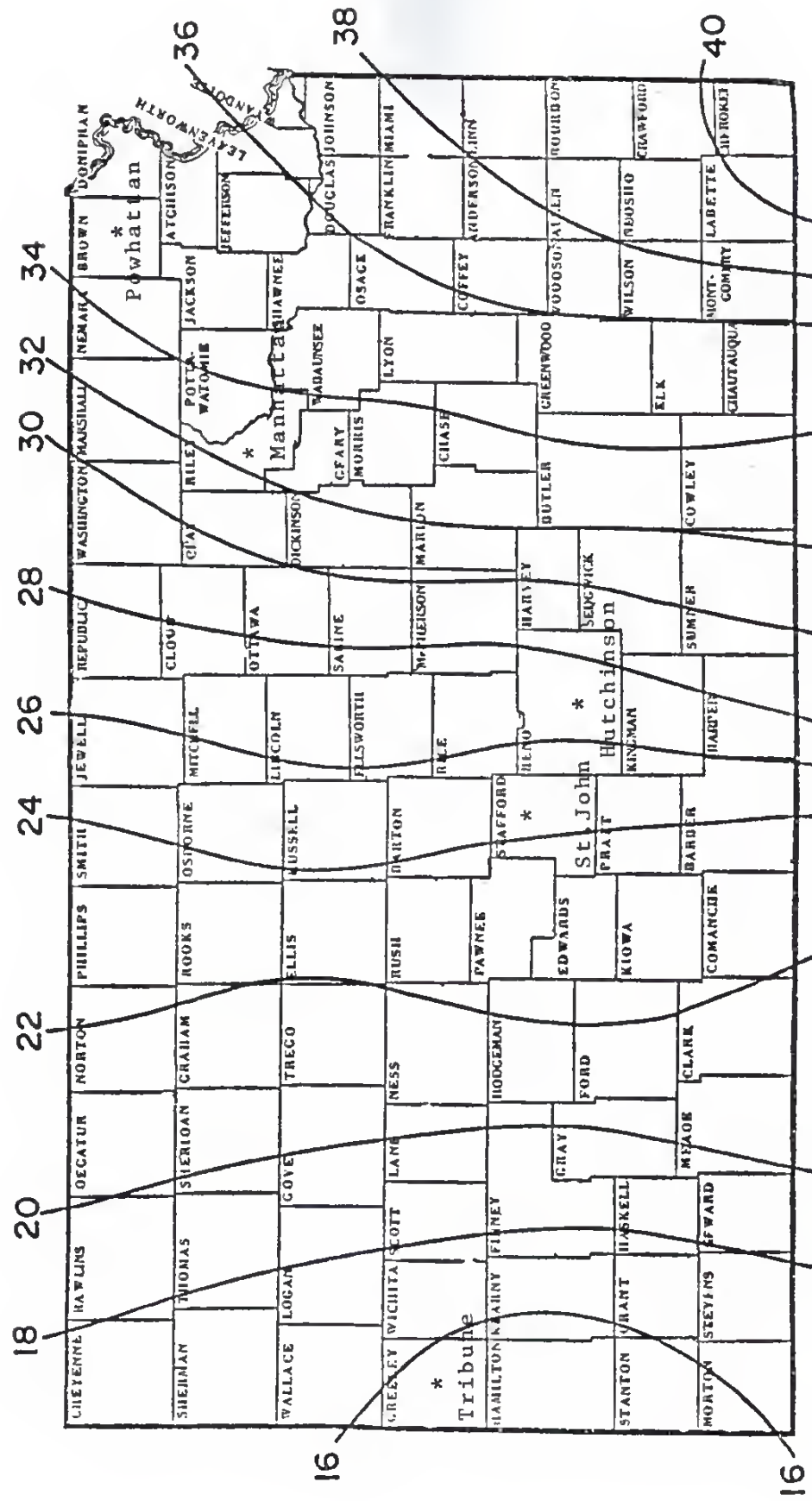


Figure 3. Normal annual precipitation 1951-1980. (L. D. Bark)

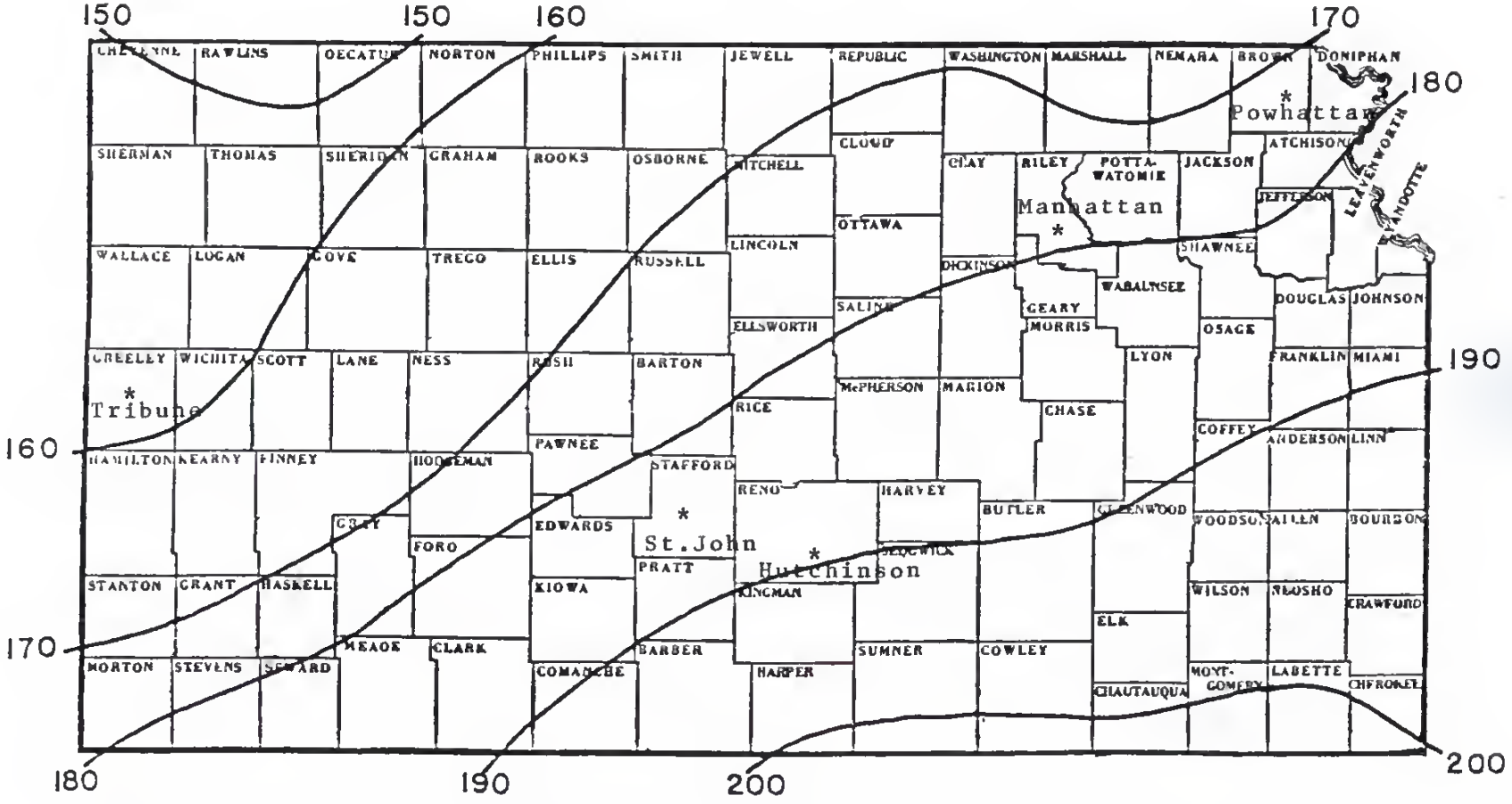


Figure 4. Average number of days in the freeze-free period (Based on 0^{o} freeze).

Table 1. Specific Location Data, 1984 and 1985.

Location	Hybrids	Maturity	Seeding Rates (sds/ha) Low	High	Date of Planting (1984/1985) First	Second	Soil Type
Powhattan	Asgrow Dorado E Golden Acres T-E Dinero DeKalb DK-59E	Early Medium Late	135,800	271,600	June 1/ June 11	July 9/ July 2	Grundy Silty Clay Loam, 4-7% Eroded. Aquic Argiudoll , Fine, Montmorillonitic, Mesic.
Manhattan	Asgrow Dorado E Golden Acres T-E Dinero DeKalb DK-59E	Early Medium Late	123,500	246,900	June 4/ June 14	June 28/ July 1	Reading Silt Loam, 0-1% Eroded, Typic Argiudoll, Fine-silty, Mixed, Mesic.[a]
Hutchinson	Asgrow Dorado E DeKalb DK-46 NC+ 271	Early Medium Late	86,400	246,900	June 6/ May 29	June 26/ June 4	Clark-Ost Complex. Typic Calciustoll, Fine loamy, Mixed, Thermic.
St. John	Asgrow Dorado E DeKalb DK-46 NC+ 271	Early Medium Late	86,400	246,900	June 6/ May 30	June 27/ June 24	Naron Loamy Fine Sand. Udic Argiustoll, Fine-loamy, Mixed, Thermic.
Tribune	Asgrow Dorado E DeKalb DK-46 NC+ 271	Early Medium Late	49,400	148,200	June 7/ May 31	June 27/ June 28	Ulysses Silt Loam, 0-1% Aridic Haplustoll, Fine-silty, Mixed Mesic.

[a]In 1985, Kahola Silt Loam, Cumulic Hapludoll, Fine-silty, Mixed, Mesic.

Table 2. Previous crop and fertility practices for five locations, 1984 and 1985.

Location	Previous crop[a]	Fertility practice 1984	Fertility practice 1985
Powhattan	Soybeans	112.5 kg N/ha as anhydrous ammonia on May 14. Followed by 112.5 kg/ha of 18-46-0 on May 15.	112.5 kg N/ha as anhydrous ammonia.
Manhattan	Soybeans	102 kg N/ha and 34 kg P/ha as a liquid on May 17.	68 kg N/ha as a liquid on April 16.
Hutchinson	Wheat	102 kg N/ha applied as ammonium nitrate on June 5.	36 kg N/ha as anhydrous ammonia on April 11 followed by 38 kg N/ha as ammonium nitrate on April 16.
St. John	Grain Sorghum	112.5 kg/ha of 18-46-0 on June 5. Side dressed 45 kg N/ha.	112.5 kg N/ha of 18-46-0 on May 29.
Tribune	1983 poorly established wheat	No fertilizer in addition to what was applied 1983 for wheat	No fertilizer.

[a]Tribune 1985 planted on 1984 fallow.

Table 3. Herbicides used, rate of application and time of application for five locations, 1984 and 1985.

Location	Herbicide[1]	Rate 1984	Rate 1985
Powhattan	Alachlor	2.25 kg/ha	2.81 kg/ha
	Atrazine	1.69 kg/ha	1.13 kg/ha
Manhattan	Alachlor	2.25 kg/ha	2.81 kg/ha
	Atrazine	1.69 kg/ha	1.13 kg/ha
Hutchinson	Alachlor	2.25 kg/ha	2.81 kg/ha
	Propazine	1.13 kg/ha	1.13 kg/ha
St. John	Alachlor	2.25 kg/ha	2.25 kg/ha
	Propazine	0.56 kg/ha	0.56 kg/ha
	Atrazine[2]	0.56 kg/ha	
Tribune	Alachlor	2.25 kg/ha	2.25 kg/ha
	Propazine	1.13 kg/ha	1.13 kg/ha

[1]All applied post plant except as noted. All rates a.i.
[2]Applied June 27 for additional puncture vine control to the first planting date in 1984.

Table 4. Date of grain harvest for five locations, 1984 and 1985.

Location	Date	Hybrids harvested
1984		
Powhattan	10/11	All hybrids, first planting and the early hybrid, second planting.
Manhattan	9/20	All hybrids, first planting.
	10/12	All hybrids, second planting.
Hutchinson	9/27	All hybrids, both plantings.
St. John	9/27	All hybrids, first planting.
	10/27	All hybrids, second planting.
Tribune	9/29	Early and medium hybrids, first planting.
	10/19	Late hybrid, first planting and early and medium hybrids, second planting.
1985		
Powhattan		Hail damage no harvest.
Manhattan	9/16	All hybrids, both plantings.
Hutchinson	9/19	All hybrids, first plantings.
	10/04	All hybrids, second planting.
St. John	10/03	All hybrids, first planting.
	10/04	All hybrids, second planting.
Tribune	9/27	Early and medium hybrids, first planting.
	10/25	Late hybrid, first planting and early and medium hybrids, second planting.

Table 5. Individual treatments for soil water depletion study. Manhattan 1985.

Date of Planting	Hybrid (maturity)	Desired Population (plants/ha)	Row Spacing (cm)	Description of Individual Treatments (maturity, pop, space)
6/14/85	Early	123,500	76	Early, Low, Wide
		246,900	25	Superthick, Date 1
		246,900	76	Early, High, Wide
	Late	123,500	25	Late, Low, Narrow
		123,500	76	"Conventional"
		246,900	25	Late, High, Narrow
7/1/85	Early	123,500	76	Early, Low, Wide
		246,900	25	"Superthick"
		246,900	76	Early, High, Wide
	Late	123,500	25	Late, Low, Narrow
		123,500	76	Conventional, Date 2
		246,900	25	Late, High, Narrow

Table 6. Individual treatments for soil water depletion study. Hutchinson, St. John and Tribune, 1985.

Date of Planting	Hybrid (maturity)	Desired Population (plants/ha)	Row Spacing (cm)	Description of Individual Treatments (maturity, pop, space)
Date 1[a]	Early	123,500	76	Early, Low, Wide
		246,900	25	Superthick, Date 1
		246,900	76	Early, High, Wide
	Medium	123,500	25	Medium, Low, Narrow
		123,500	76	"Conventional"
		246,900	25	Medium, High, Narrow
Date 2[b]	Early	123,500	76	Early, Low, Wide
		246,900	25	"Superthick"
		246,900	76	Early, High, Wide
	Medium	123,500	25	Medium, Low, Narrow
		123,500	76	Conventional, Date 2
		246,900	25	Medium, High, Narrow

[a]Hutchinson = 5/29/85, St. John = 5/30/85, Tribune = 5/31/85

[b]Hutchinson = 6/24/85, St. John = 6/24/85, Tribune = 6/28/85

Results 1984

A cool, wet spring delayed some plantings, but stands and early growth were excellent in many areas. Subsequent prolonged drouth delayed development and severely reduced yields in many plantings. Sharp killing frosts in late September stopped development prematurely over much of Kansas, especially on late-planted or replanted fields. Prolonged wet weather and poor drying conditions in October and November delayed harvest in many areas.

Powhattan 1984

Temperature for June was above average with July and August only slightly above average. Rainfall was: June 40.1 cm (26.2 cm above normal), July 4.2 cm (6.9 cm below normal) and August 4.9 cm (5.7 cm below normal), (Table A-1). One of the most influential weather phenomenon was a severe hail storm on 28 June which reduced the leaf area on the plants in the first planting date to near zero and caused compaction and crusting on the newly planted seed bed in the second date, resulting in poor stands. Replanting was necessary for date 2. The second phenomenon was an earlier than normal damaging frost on 26 September and a killing frost on 29 September. The early frost, plus replanting 9 July resulted in almost zero yield from the medium and late maturing hybrids for date 2. Therefore, no data were used for these hybrids from date 2.

Yields ranged from 3461 to 5768 kg/ha (Table A-2) and were affected by date of planting, hybrid maturity, and hybrid * spacing interactions (Table A-3).

The late maturity hybrid yielded more when planted in 76 cm rows than 25 cm rows (Figure 5 and Table 7). It produced more heads per hectare, slightly more seeds in each head, and had a slightly higher seed weight as compared to the 25 cm row spacing. The other hybrids did not respond to row spacing.

The early maturity hybrid produced lower yields than the medium or late maturity hybrids (Figure 5 and Table 7). It tended to produce fewer heads per hectare and lower seed weights. The early maturity hybrid yields represent the average of two planting dates while the medium and late maturity yields are based on the the first planting date. The late replant date and killing frost, mentioned earlier, resulted in significantly lower yields and seed weights (Table A-2) and was the major contribution to the lower yields of the early maturity hybrid planted at the late date. Lodging was a problem in the early and medium maturity hybrids, especially in the 76 cm row spacing.

The later date of planting resulted in lower yields (Table 8). The yield reduction is due to replanting later than the originally desired date which did not allow the seeds to fill properly resulting in lower seed weights. Lodging was more of a problem in date 1 than date 2, possibly due to invasion of pathogens after the hail damage.

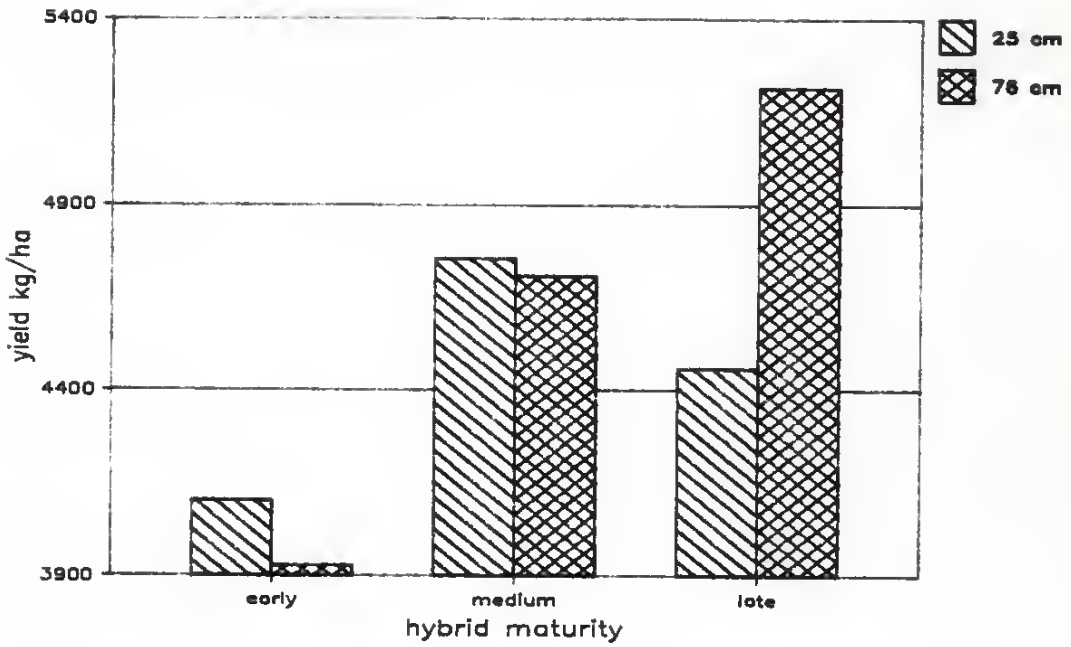


Figure 5. Hybrid * row spacing means for yield, Powhattan 1984. (LSD 0.05 = 388)

Table 7. Hybrid * row spacing means for yield, heads/ha, seeds/head, seed weight, and lodging percent, Powhattan 1984.

Hybrid (maturity)	Row Spacing (cm)	Yield (kg/ha)	Heads per ha	Seeds per head	Seed weight (g/1000)	Lodging (%)
Early	25	4104	195339	1396	16.3	8.30
	76	3928	196236	1204	17.5	13.00
Medium	25	4756	237134	1057	18.3	7.80
	76	4709	201618	1327	18.7	15.90
Late	25	4459	193904	1313	17.8	1.80
	76	5215	214712	1382	18.0	2.30
LSD 0.05		388	NS	NS	NS	9.00

Table 8. Date of planting and hybrid means for yield, heads/ha, seeds/head, seed weight, and lodging percent, Powhattan 1984.

Date of Planting	Yield (kg/ha)	Heads per ha	Seeds per head	Seed weight	Lodging (%)
Date 1	5035	191244	1368	19.7	11.7
Date 2	4022	221737	1191	15.8	0.0
LSD 0.05	289	NS	NS	1.4	6.1

Manhattan 1984

Temperatures for June, July, and August were near normal. Rainfall was: June 28.4 cm (15.2 cm above normal), July 3.4 cm (6.6 cm below normal), and August 2.3 cm (5.7 cm below normal), (Table A-1). Heavy rains on 7 and 9 June , 8.2 cm and 8.5 cm, respectively, caused severe damage to two replications of date 1 due to erosion and soil deposition. Since extensive damage occurred no data were taken from these two replications.

Yields ranged from 3196 to 6440 kg/ha (Table A-4) and were affected by date of planting, hybrid maturity, rate of planting, row spacing, and hybrid * rate * spacing interactions (Table A-5).

A comparison of hybrid differences within a plant population and row spacing, in the hybrid * rate * spacing interaction (Figure 6 and Table 9), showed the early maturity hybrid yielded significantly better than the medium and late maturities when grown at low population and in 25 cm rows. Fewer seeds in each head and lower seed weights of these hybrids gave the early maturity hybrid the yield advantage. The late maturity hybrid yielded significantly less than the early but not the medium maturity hybrid when planted at the high population and in 25 cm rows. The late maturity hybrid had fewer seeds per head and lower seed weights than its early maturity counterpart. At the high population and 76 cm row spacing, the early maturity hybrid yielded significantly more than the medium maturity hybrid due to more seeds produced in each head by the early maturity.

The later date of planting resulted in lower yields than

date 1 (Table 10). This could be attributed to almost no moisture stress through July allowing date 1 to have a better flowering and beginning grain filling period than date 2 which flowered later and was more influenced by the low August rainfall and the earlier than normal September killing frost. Seed weights of the second planting date were lower because of the early freeze.

The early maturity hybrid yielded significantly better than the other hybrids (Table 10). Most of the yield advantage was due to more seeds in each head. An early September frost influenced yields of the later maturities more than the early maturity hybrid.

The wide row spacing yielded significantly better than the narrow spacing (Table 10). The wide row spacing had slightly more heads per hectare and slightly higher seed weights.

The high population produced the highest yield (Table 10). The high population had slightly lower seed weights and considerably fewer seeds in each head, but number of heads per hectare more than compensated for these factors to significantly increase yields.

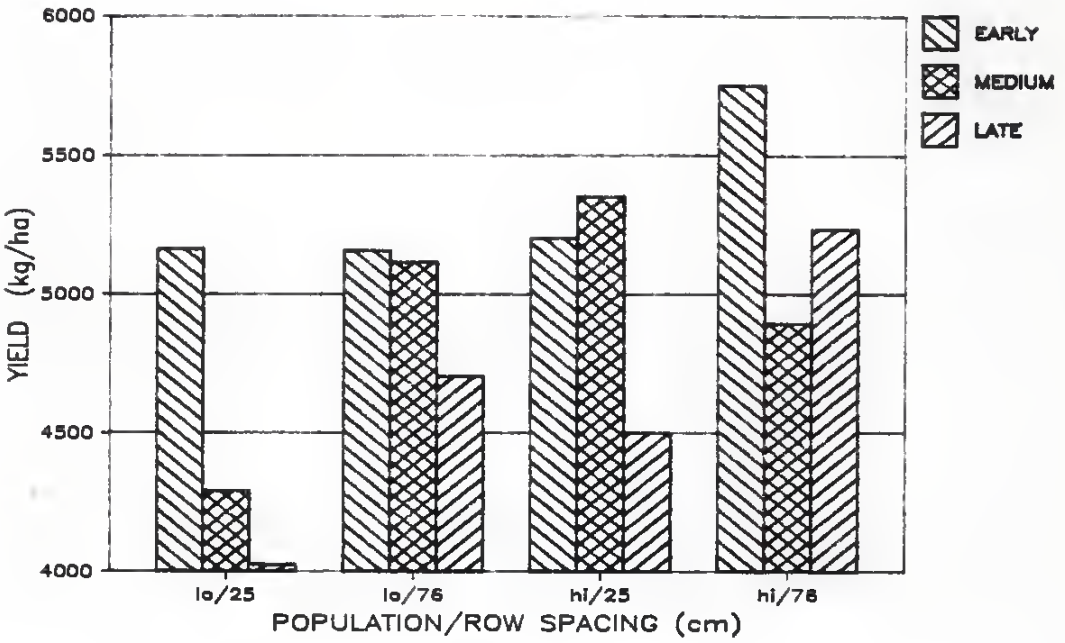


Figure 6. Hybrid * rate * spacing means for yield, Manhattan 1984. (LSD 0.05 = 802)

Table 9. Hybrid * rate * spacing means for yield, heads/ha, seeds/head, seed weight and lodging percent, Manhattan 1984.

Hybrid (maturity)	Population (plants/ha)	Row Spacing (cm)	Yield (kg/ha)	Heads per ha	Seeds per head	Seed weight (g)	Lodging (%)
Early	92821	25	5163	111524	2193	20.6	0.0
	125108	76	5157	132331	1806	21.2	0.0
	205468	25	5202	201211	1410	18.5	0.0
	242396	76	5750	232889	1268	19.2	0.0
Medium	118508	25	4289	115577	1773	20.4	0.0
	115244	76	5115	121031	1903	21.9	0.0
	255012	25	5353	240064	1114	19.9	0.0
	283054	76	4892	231334	1020	20.7	0.1
Late	105198	25	4024	110089	1933	18.6	0.6
	117754	76	4704	116367	2002	20.3	0.0
	283855	25	4499	257176	924	19.0	0.0
	339318	76	5234	305655	858	19.4	0.0
LSD 0.05	NS		802	NS	NS	NS	NS

Table 10. Date of planting, row spacing, plant population (rate), and hybrid means for yield, heads/ha, seeds/head, seed weight and lodging percent, Manhattan 1984.

Date of Planting	Yield (kg/ha)	Heads per ha	Seeds per head	Seed weight	Lodging (%)
Date 1	5424	172045	1515	23.1	0.1
Date 2	4473	190496	1519	16.9	0.0
LSD 0.05	303	12829	NS	0.5	0.1
Hybrid (maturity)					
Early	5318	195788	1668	19.9	0.0
Medium	4912	219376	1452	20.7	0.0
Late	4615	204308	1429	19.3	0.1
LSD 0.05	401	16357	109	0.8	0.1
Row spacing (cm)					
25	4755	172607	1558	19.5	0.1
76	5142	189934	1476	20.5	0.0
LSD 0.05	327	10905	NS	0.5	0.0
Population (plants/ha)					
112438	4742	117820	1935	20.5	0.1
268184	5155	244721	1099	19.3	0.0
LSD 0.05	327	10905	73	0.5	0.1

Hutchinson 1984

Temperatures for June, July, and August were near normal. Rainfall was: June 9.2 cm (0.4 cm below normal), July at 1.7 cm (6.2 cm below normal), and August a trace (6.9 cm below normal), (Table A-1). Low rainfall for the growing season caused drought stress which severely affected yields of all treatments. Adequate soil moisture was the most limiting factor on yields. Bird damage also caused yield reduction, with the most damage occurring in the first planting date.

Yields ranged from 469 to 2389 kg/ha (Table A-6) and were affected by date of planting, hybrid maturity, date * hybrid, rate of planting, rate * spacing, and date * spacing interactions (Table A-7).

The medium maturity hybrid yielded significantly lower than the early maturity, and the late maturity yielded less than both of the other hybrids in the first date of planting (Figure 7 and Table 11). The primary reason for the yield reduction was the medium hybrid produced 35% fewer heads and had a 10% lower seed weight than its early maturity counterpart. The late maturity hybrid produced 55% fewer heads per hectare and 26% fewer seeds in each head, but produced 16% heavier seeds as compared to the early maturity hybrid. In the second planting date the early maturity hybrid yielded significantly less than either of the later hybrids. This response was primarily due to a much lower number of seeds per head, which was not counteracted by the higher number of heads per hectare. The second date of planting yields were higher than the first date as a result of more seeds

in each head. Less bird damage was apparent in the second planting date when compared to the first. Lodging was greater with the early maturity hybrid at both planting dates than either of the other two hybrids.

The 25 cm row spacing yielded significantly less than the 76 cm row spacing in the first planting date (Figure 8 and Table 12). A 35% higher number of heads per hectare for the wide row spacing, as compared to the narrow spacing in the first planting, gave this spacing the yield advantage. The yield from both row spacings was much higher in the second planting date than in the first. As in the date * hybrid interaction, this yield advantage primarily was the result of a higher number of seeds in each head for the later planting date.

When planted in 25 cm row spacing, the low plant population yielded better than both row spacings planted at the high population (Figure 9 and Table 13). The high population produced more heads per hectare, but not enough to compensate for the much lower seed number per head and lower seed weights. The wide row spacing, low population yielded significantly higher than the high population, narrow row spacing but not its high population counterpart. Comparing the two populations, at the 76 cm spacing the higher number of heads produced per hectare, in the high population, was able to compensate for lower seed weights.

All plots suffered from season long moisture stress. This stress was the main reason for low yields. Bird damage was a problem, with the first planting date receiving the most yield loss.

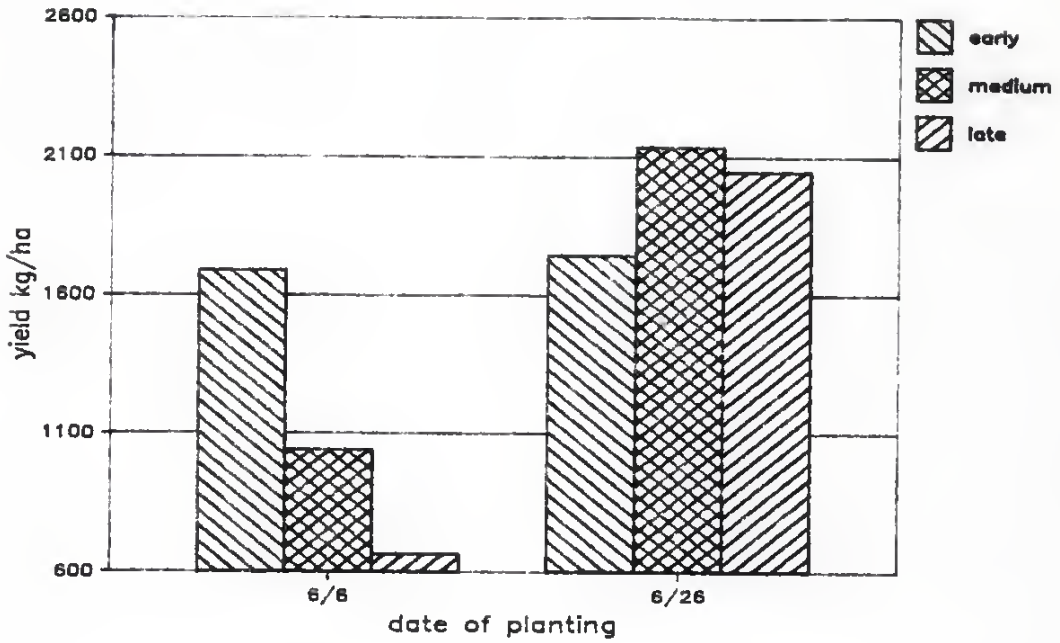


Figure 7. Date of planting * hybrid maturity means for yield, Hutchinson 1984. (LSD 0.05 within dates = 273 and between dates = 334)

Table11. Date of planting * hybrid means for yield, plants/ha, heads/ha, seeds/head, seed weight andlodging percent, Hutchinson 1984.

Date of Planting	Hybrid (maturity)	Yield (kg/ha)	Plants per ha	Heads per ha	Seeds per head	Seed weight	Lodging (%)
Date 1	Early	1689	142964	127536	822	16.1	4.9
	Medium	1040	136773	84755	822	14.6	0.2
	Late	663	152738	57131	604	18.7	0.0
Date 2	Early	1744	110633	109091	1180	14.3	27.9
	Medium	2135	87982	82312	1763	14.7	0.4
	Late	2046	82396	89641	1349	17.1	0.7
LSD 0.05 within dates		273	15813	13094	18	1.0	4.6
LSD 0.05 between dates		334	18491	16603	39	1.3	5.4

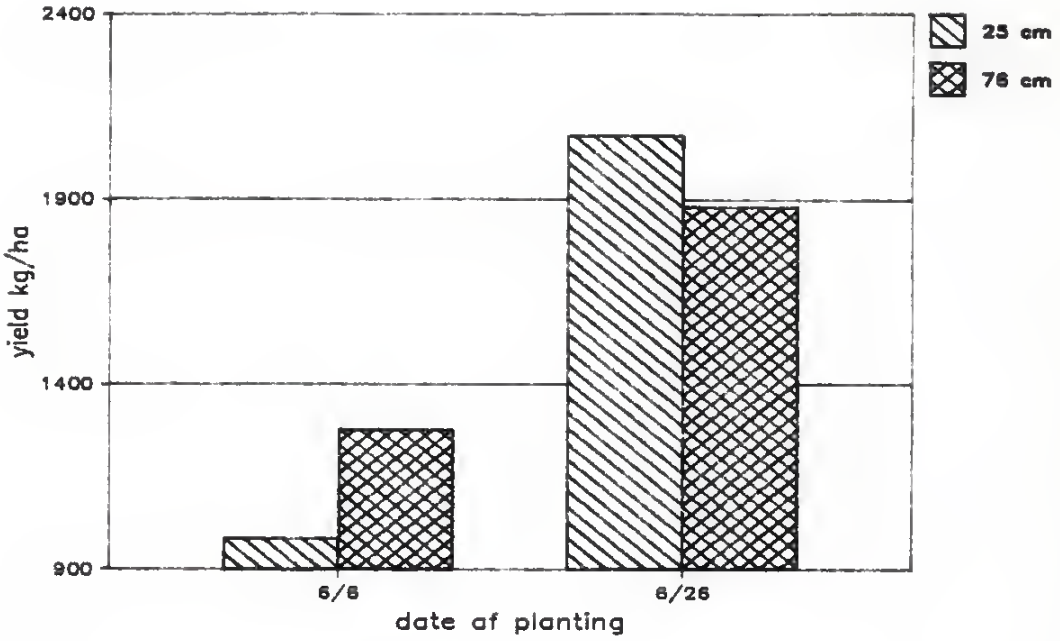


Figure 8. Date of planting * row spacing means for yield, Hutchinson 1984. (LSD 0.05 within dates = 223 and between dates = 273)

Table12. Date of planting by row spacing means for yield, plants/ha, heads/ha, seeds/head, seed weight and lodging percent, Hutchinson 1984.

Date of Planting	Row Spacing (cm)	Yield (kg/ha)	Plants per ha	Heads per ha	Seeds per head	Seed weight (g)	Lodging (%)
Date 1	25	984	131781	70554	776	16.8	1.80
	76	1278	156535	109060	723	16.1	1.60
Date 2	25	2072	84905	90883	1528	15.6	11.10
	76	1879	102435	96479	1333	15.2	8.30
LSD 0.05							
within dates		223	12911	10691	NS	NS	3.80
between dates		273	15098	13556	186	1.1	4.40

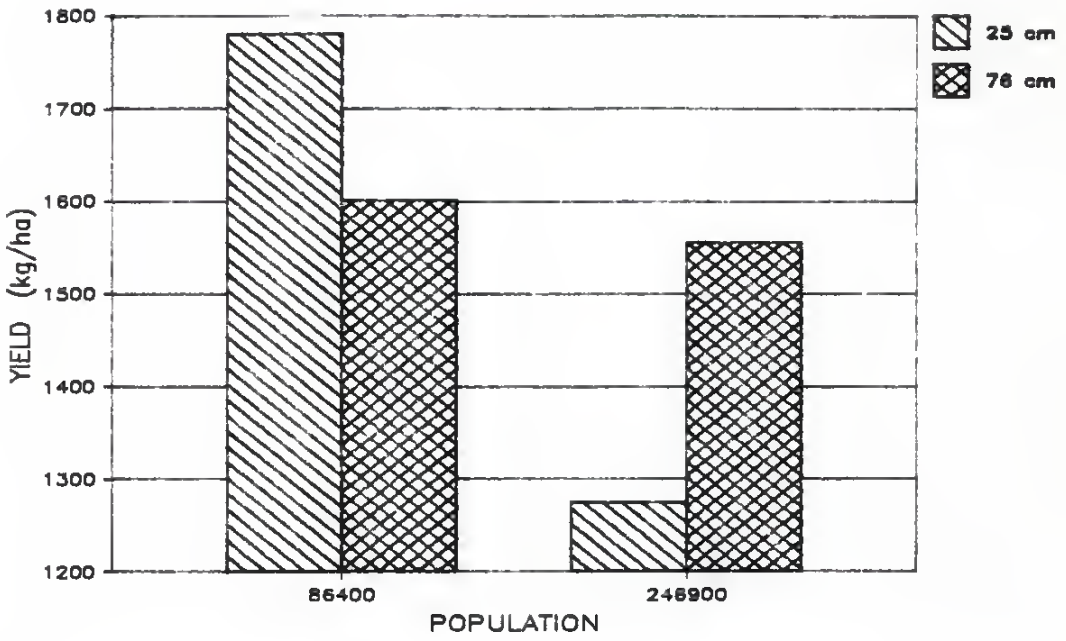


Figure 9. Plant population * row spacing means for yield, Hutchinson 1984. (LSD 0.05 = 223)

Table13. Plant population * row spacing means foryield, heads/ha, seeds/head, seed weight and lodging percent, Hutchinson 1984.

Population (Plants/ha)	Row Spacing (cm)	Yield (kg/ha)	Heads per ha	Seeds per head	Seed weight	Lodging (%)
76216	25	1780	75067	1359	16.9	7.70
88037	76	1601	79762	1227	16.1	6.50
140470	25	1275	86371	944	15.4	5.20
170932	76	1556	125777	829	15.2	3.30
LSD 0.05 12911		223	10697	NS	NS	3.80

St. John 1984

Temperatures for June, July, and August were near normal. Rainfall was: June 6.1 cm (2.9 cm below normal), July 0.6 cm (6.7 cm below normal), and August 2.5 cm (3.4 cm below normal), (Table A-1). Sandy soil and below normal rainfall for the entire growing season caused the plants to be under constant moisture stress. Yields were reduced over all treatments.

Yields ranged from 239 to 1948 kg/ha (Table A-8) and were affected by hybrid maturity, date * hybrid, date * spacing and date * spacing * rate interactions (Table A-9).

The first planting date, in the date * rate * spacing interaction, indicated the wide row spacing treatment yielded better planted at the low population and the narrow row spacing treatment yielded more planted at the high population (Figure 10 and Table 14). At the low population the 76 cm row spacing treatment produced 32 % more heads per hectare as a result of having a 16 % higher plant population. This gave the low population, 76 cm row spacing combination a 413 kg/ha (32 %) significant yield advantage compared to the 25 cm row spacing. The high population treatment yield difference, of 311 kg/ha, gave the 25 cm row spacing a 25 % advantage based on the 76 cm row spacing. The high population, 25 cm row spacing combination produced 21 % fewer heads per hectare but had a 36 % higher number of seeds per head and a 9 % higher seed weight. The second planting date, low population combination gave the opposite result compared to the first planting date. The 25 cm row spacing combination produced much higher yields because of a

higher number of seeds per head and higher seed weights. The high population grouping, in the second planting date, had the least yield difference between row spacings of any of the date * population combinations.

By combining populations within a date one can determine that the narrow row spacing yielded significantly better than the wide row spacing in the second planting date (Figure 10 and Table 14). The primary factor contributing to this yield advantage was that more seeds were produced in each head at the 25 cm row spacing. There was a slight yield increase for planting in wide rows at the early planting date.

In the first planting date no hybrids were significantly different. The major hybrid contribution came in the second planting date. The low yields of the late and medium hybrids (date 2) were due to fewer heads per hectare and low seed weights as a result of the early killing frost (Figure 11 and Table 15).

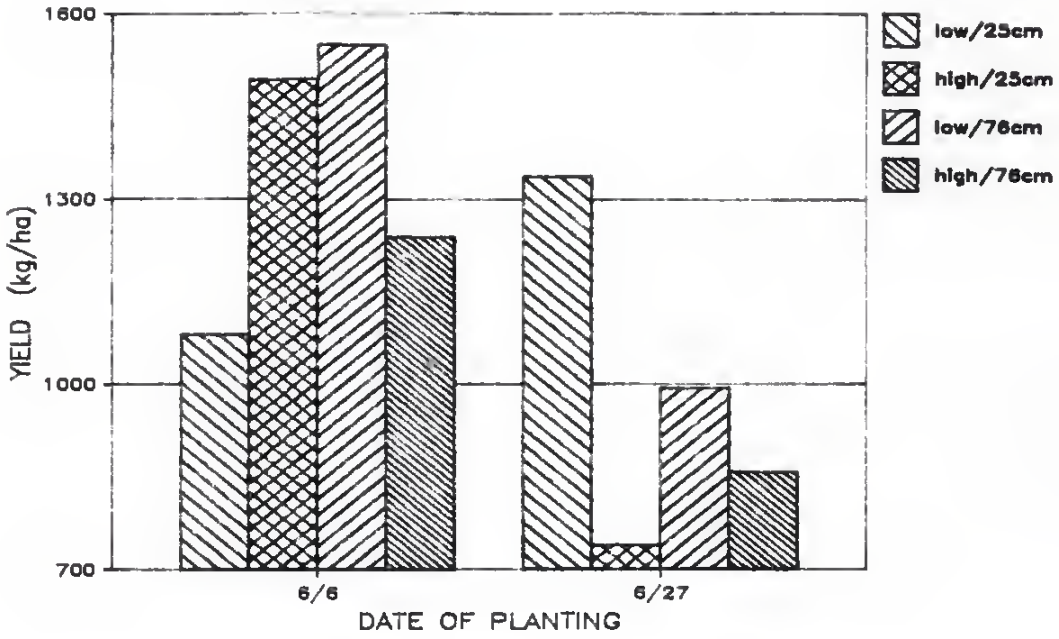


Figure 10. Date of planting * plant population (rate) * spacing means for yield, St. John 1984. (LSD 0.05 within dates = 338 between dates = 438)

Table14. Date of planting * plant population (rate) * spacing means for yield, heads/ha, seeds/head, seed weight and lodging percent, St. John 1984.

Date of Planting	Population (plants/ha)	Row Spacing (cm)	Yield (kg/ha)	Heads per ha	Seeds per head	Seed weight (g)	Lodging (%)
Date 1	90428	25	1081	53402	828	22.4	0.0
	107500	76	1494	78799	842	22.4	0.0
	161056	25	1549	94446	770	21.8	0.0
	224700	76	1238	119768	565	20.0	0.0
Date 2	76892	25	1337	56683	1274	17.1	2.5
	96863	76	739	57041	665	16.8	2.9
	209510	25	994	90285	740	16.1	1.3
	209630	76	857	89448	544	15.9	0.8
LSD 0.05 within dates	NS		338	NS	207	NS	2.3
between dates	42571		438	31304	255	2.6	2.4

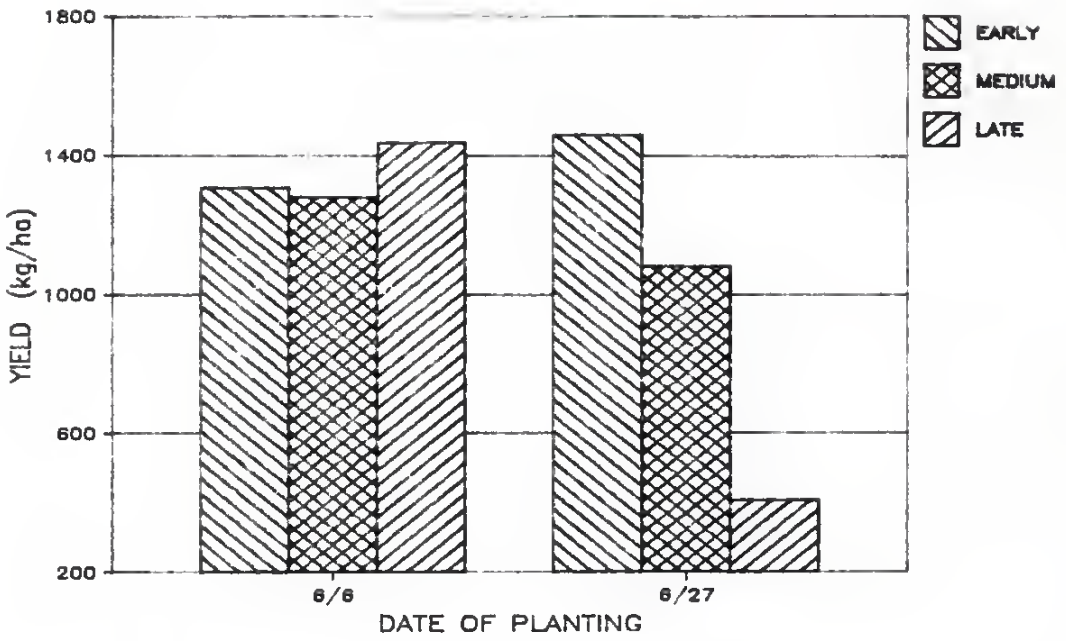


Figure 11. Date of planting * hybrid means for yield, St. John 1984. (LSD 0.05 within dates = 292 and between dates = 379)

Table15. Date of planting * hybrid means for yield, plants/ha, heads/ha, seeds/head, seed weight andlodging percent, St. John 1984.

Date of Planting	Hybrid (maturity)	Yield (kg/ha)	Plants per ha	Heads per ha	Seeds per head	Seed weight	Lodging (%)
Date 1	Early	1307	170952	116413	507	24.0	0.0
	Medium	1278	151497	82575	748	20.4	0.0
	Late	1438	115315	60823	999	20.6	0.0
Date 2	Early	1459	162065	117042	728	19.8	5.1
	Medium	1080	127177	69239	940	16.3	0.4
	Late	406	155428	33812	750	13.4	0.0
LSD 0.05 within dates		292	NS	NS	179	NS	1.8
LSD 0.05 between dates		379	36868	27110	221	2.2	2.1

Tribune 1984

Temperatures for June, July, and August were near normal. Rainfall was recorded for the months of June at 4.0 cm (2.5 cm below normal), July 8.3 cm (2.4 cm above normal), and August 1.4 cm (4.4 cm below normal), (Table A-1). Conditions for growth were good for the first half of the growing season. Moisture stress from flowering on seemed to induce lodging and lower yields, both of which were more severe in the later date of planting. A killing frost in September reduced the yield of the late maturing hybrid in date 2 to practically zero. For this reason no data were included for this hybrid and date.

Yields ranged from 802 to 3527 kg/ha (Table A-10) and were affected by date of planting and hybrid maturity (Table A-11).

More seeds set and higher seed weights provided the early date of planting with a yield advantage (Table 16). Yield of the early maturity hybrid was greater, primarily due to more heads per hectare (Table 16), but lodging was severe with this hybrid. Lodging was also severe with the medium maturity hybrid.

Table 16. Date of planting and hybrid maturity means for yield, heads/ha, seeds/head, seed weight and lodging percent, Tribune 1984.

Date of Planting	Yield (kg/ha)	Heads per ha	Seeds per head	Seed weight	Lodging (%)
Date 1	2364	131362	1340	13.1	18.6
Date 2	1031	133814	689	11.0	69.9
LSD 0.05	333	NS	120	0.7	9.7
Hybrid (maturity)					
Early	2113	156505	1023	12.3	74.4
Medium	1641	124038	1074	11.5	23.1
Late	1649	100629	1204	13.7	0.4
LSD 0.05	219	11871	144	0.8	6.0

Results 1985

Warm April weather encouraged early plantings, but many farmers waited until normal planting time and encountered delays because of muddy seedbeds. Moisture usually was adequate for optimum growth, but below-average temperatures in late summer and fall delayed maturity, thus intensifying the deleterious effects of the early killing freezes in late September. Prolonged wet weather and poor drying conditions delayed harvest, even where freezes had killed plants, and considerable lodging occurred in some areas. Despite those problems, record amounts of grain were harvested in Kansas.

Powhattan 1985

All plots suffered hail and wind damage on August 6. The damage resulted in total devastation of the grain sorghum plants. Therefore, no data were collected.

Manhattan 1985

Temperatures for June, July, and August were slightly below normal. Rainfall was: June, 10.1 cm (3.1 cm below normal); July, 3.2 cm (6.7 cm below normal); and August, 13.1 cm (5.2 cm above normal), (Table A-12). A killing frost in September reduced the yield of the plots in the second planting date.

Yields ranged from 3553 to 6932 kg/ha (Table A-13) and were affected by date of planting, hybrid maturity, rate of planting, and date * spacing interaction (Table A-14).

Treatments including the wide row spacing factor provided a yield advantage in the early date of planting and conversely treatments with the narrow row spacing proved better in the late

date (Figure 12 and Table 17). These slight yield advantages resulted from small changes in the yield components. The early date of planting treatments yielded better than the later date for both row spacings. The later planting date combination produced more heads per hectare, because it had more plants per hectare, but fewer seeds in each head and lower seed weights caused the major yield reductions.

The much higher seed weight of the early maturity hybrid was the main factor contributing to its significantly higher yield as compared to the medium and late maturities. The higher seed weight of the medium maturity hybrid gave it a yield advantage over the late maturity hybrid (Table 18). The early frost tended to lower the yields and seed weights of the later maturity hybrids, primarily in the second planting date (Table A-13).

The production of 40% more heads per hectare with only a 35% reduction in the number of seeds per head increased the higher plant population yields about 5% above the lower population (Table 18). Lodging was not a problem in any treatment.

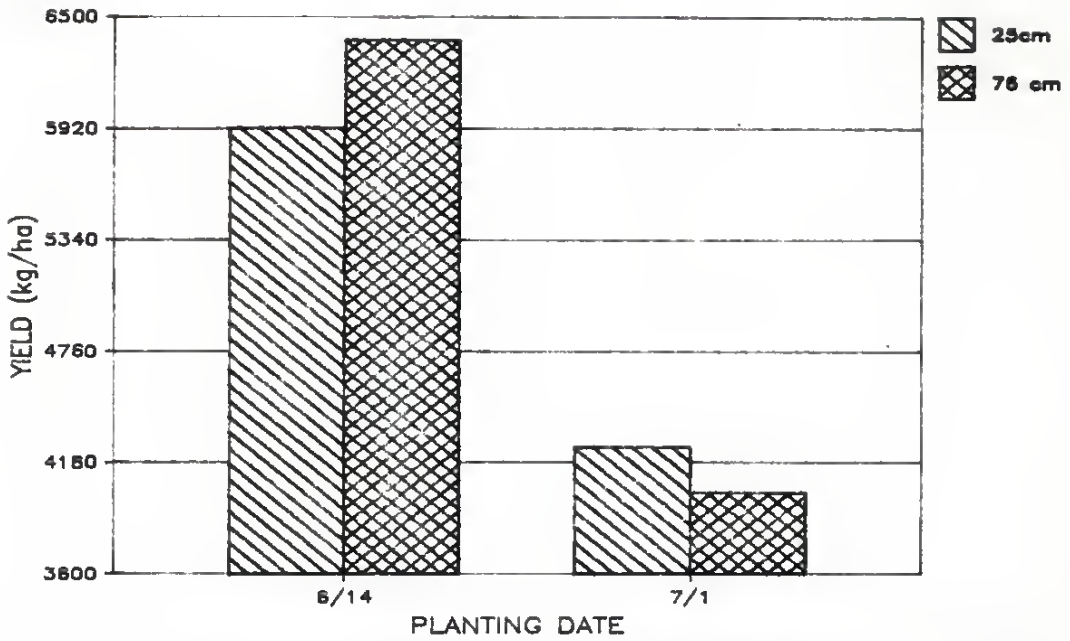


Figure 12. Date of planting * row spacing means for yield Manhattan 1985. (LSD 0.05 within dates = 226 and between dates = 266)

Table 17. Date of Planting * Row Spacing means for yield, heads/ha, seeds/head, seed weight and lodging percent, Manhattan 1985.

Date of Planting	Row Spacing (cm)	Yield (kg/ha)	Plants per ha	Heads per ha	Seeds per head	Seed weight (g)	Lodging (%)
Date 1	25	5924	189659	171124	1608	21.3	0.9
	76	6380	185294	178897	1647	21.8	0.3
Date 2	25	4261	210407	197910	1484	15.3	0.1
	76	4022	232530	206281	1423	15.5	0.0
LSD 0.05 within dates		226	14357	NS	NS	NS	NS
between dates		266	17245	15513	182	1.1	NS

Table 18. Hybrid maturity and rate of planting means for yield, heads/ha, seeds/head, seed weight andlodging percent, Manhattan 1985.

Hybrid maturity	Yield (kg/ha)	Heads per ha	Seeds per head	Seed weight	Lodging (%)
Early	5414	195025	1494	19.7	0.63
Medium	5113	174173	1598	18.6	0.26
Late	4913	196460	1528	17.1	0.03
LSD 0.05	196	11421	NS	0.8	NS
Population (plants/ha)					
124696	5013	141049	1883	18.3	0.51
284250	5280	236058	1197	18.5	0.10
LSD 0.05	159	9325	104	NS	NS

Hutchinson 1985

Temperatures for June, July, and August were slightly below normal. Rainfall was: June, 13.2 cm (1.7 cm above normal); July, 10.9 cm (2.5 cm above normal); and August, 9.0 (1.9 cm above normal), (Table A-12). Greater than normal rainfall for the growing season enhanced yields. Bird damage caused some yield reduction, with the most damage occurring in the first planting date to the early and medium maturity hybrids.

Yields ranged from 2018 to 5050 kg/ha (Table A-15) and were affected by date of planting, hybrid maturity, row spacing, rate of planting and date * hybrid interactions (Table A-16).

Extensive bird damage resulted in drastic seed loss in the first planting date. To compensate for this bird damage, the yields for the hybrids in date 1 were calculated based on the threshing percentage of the hybrids in date 2. Actual yields for the hybrids in date 1 were much lower than the calculated yields.

The early maturity hybrid yielded less than both of the later maturities and the medium maturity hybrid yielded less than the late maturity hybrid in the first planting date (Figure 13 and Table 19). The most influential yield component contributing to these yield reductions was the number of seeds in each head. The medium maturity hybrid produced 43 % fewer and the early maturity hybrid produced 175 % fewer seeds in each head as compared to the late maturity hybrid. In the second planting date the early maturity hybrid yielded significantly less than both of the other maturities. Fewer seeds in each head was the major factor contributing to the lower yield of the early

maturity hybrid. The early maturity hybrid yielded less at both planting dates. The late maturity hybrid yielded 814 kg/ha more in the first planting date and only 75 kg/ha less in the second planting date as compared to the medium maturity hybrid. The calculated yields of the hybrids in the first planting date were all lower than the yields in the second planting date.

The 25 cm row spacing yielded significantly higher than the 76 cm row spacing (Table 20). More heads produced per hectare compensated for the lower seed weight to give the 25 cm row spacing the yield advantage.

The high plant population increased yields 9 % as compared to the low plant population (Table 20). The high population produced 82 % more heads per hectare to compensate for the lower number of seeds in each head and lower seed weight as compared to the low population.

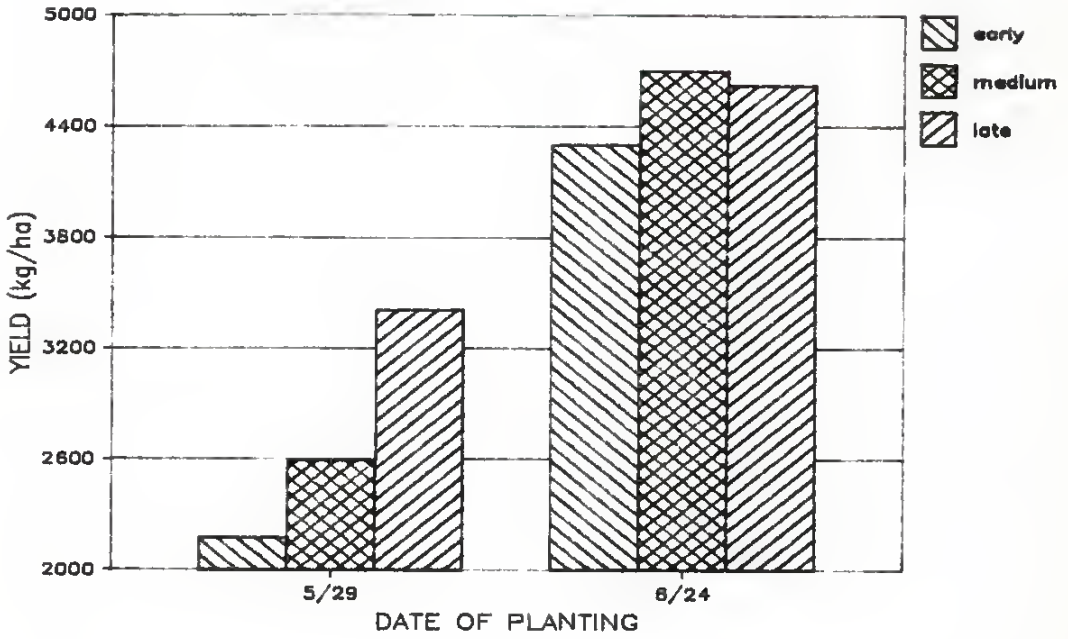


Figure 13. Date of planting * hybrid maturity means for yield, Hutchinson 1985. (LSD 0.05 within dates = 235 and between dates = 307)

Table 19. Date of Planting * Hybrid Maturity means for yield, heads/ha, seeds/head, seed weight and lodging percent, Hutchinson 1985.

Date of Planting	Hybrid (maturity)	Yield (kg/ha)	Plants per ha	Heads per ha	Seeds per head	Seed weight	Lodging (%)
Date 1	Early	2178	142962	270318	354	24.1	2.6
	Medium	2597	136773	177581	682	22.0	11.2
	Late	3411	152738	205026	974	18.5	0.5
Date 2	Early	4301	110633	174711	1325	18.8	4.7
	Medium	4698	87982	136056	1949	17.3	6.4
	late	4623	82396	182963	1732	15.7	0.1
LSD 0.05							
within dates		235	13437	16151	180	1.1	4.0
between dates		307	16600	18999	223	1.3	4.8

Table 20. Rate of planting and row spacing means for yield, heads/ha, seeds/head, seed weight and lodging percent, Hutchinson 1985.

Item	Yield (kg/ha)	Heads per ha	Seeds per head	Seed weight	Lodging (%)
Row spacing (cm)					
25	3781	198538	1174	18.9	4.40
76	3488	183680	1164	20.0	4.11
LSD 0.05	136	10465	NS	0.2	NS
Population (plants/ha)					
99613	3482	135368	1402	20.0	5.51
231184	3787	246850	937	18.8	3.00
LSD 0.05	136	10465	48	0.2	2.31

St. John 1985

Temperatures for June, July, and August were slightly below normal. Rainfall was: June, 8.9 cm (1.3 cm above normal); July, 6.1 cm (0.6 cm below normal); and August, 11.1 cm (4.3 cm above normal), (Table A-12). An August 6 hail storm reduced the leaf area of both planting dates. Most plots of date 1 were in bloom and date 2 was at the 10 to 13 leaf stage. The second weather phenomenon was a September killing frost which reduced yields more in the second planting date as compared to the first. Overall yields were good due to adequate rainfall throughout the growing season.

Yields ranged from 3046 to 6228 kg/ha (Table A-17) and were affected by date of planting, rate of planting, row spacing and date * hybrid interaction (Table A-18).

The high plant population combination gave the greatest yields by producing 50% more heads and only 40% fewer seeds per head, resulting in about a 10% net advantage in yield over the lower plant population (Table 21). More seeds per head provided the narrow row spacing with a yield increase (Table 21). In the first date of planting, the early maturity hybrid yielded less than the medium and late hybrids in date 2 (Figure 14 and Table 22). The yield reduction was due to the August hail which occurred during bloom of the early maturity hybrid in the first planting date, and bird damage which influenced the final yield, because of fewer seeds in each head for the early maturing hybrid in the first planting date. Treatments in the second date of planting yielded less than treatments in the first date for all

hybrids primarily due to lower seed weights.

Table 21. Rate of planting and row spacing means for yield, heads/ha, seeds/head, seed weight and lodging percent, St. John 1985.

Item	Yield (kg/ha)	Heads per ha	Seeds per head	Seed weight	Lodging (%)
Row spacing (cm)					
25	4555	168194	1456	20.6	0.05
76	3892	164038	1327	20.6	0.13
LSD 0.05	269	NS	88	NS	NS
Population (plants/ha)					
100510	4020	113066	1708	20.7	0.15
222784	4427	219166	1076	20.5	0.03
LSD 0.05	269	8956	88	NS	NS

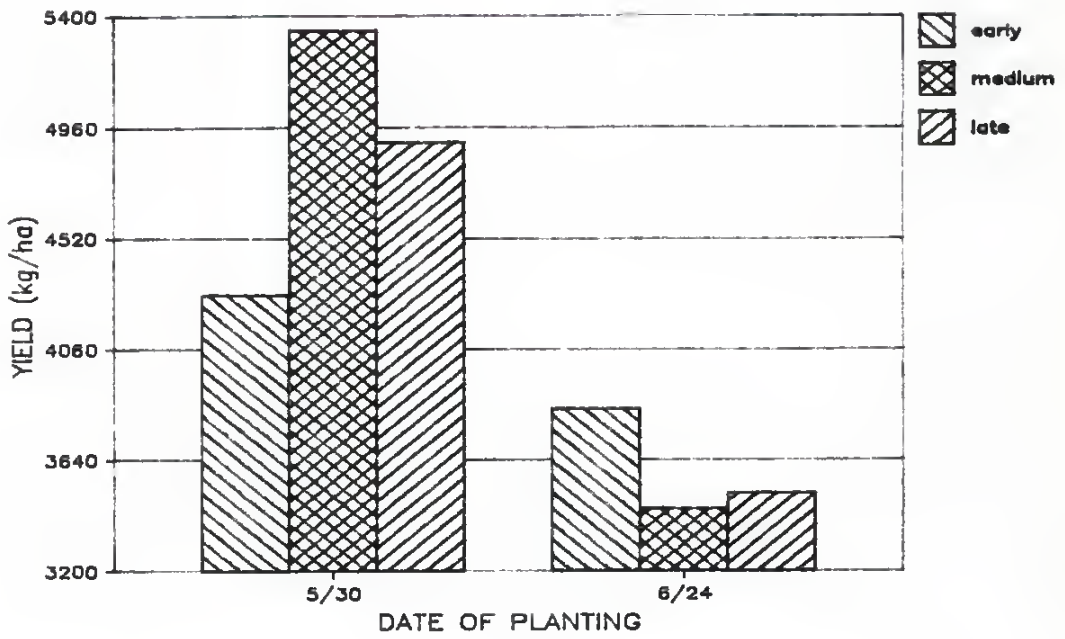


Figure 14. Date of planting * hybrid maturity means for yield, St. John 1985. (LSD 0.05 within dates = 467 and between dates = 748)

Table 22. Date of Planting * Hybrid Maturity means for yield, heads/ha, seeds/head, seed weight and lodging percent, St. John 1985.

Date of Planting	Hybrid (maturity)	Yield (kg/ha)	Plants per ha	Heads per ha	Seeds per head	Seed weight	Lodging (%)
Date 1	Early	4297	196057	210945	822	27.2	0.2
	Medium	5342	146191	152469	1647	22.1	0.3
	Late	4900	208703	207268	1193	22.9	0.0
Date 2	Early	3845	147177	158388	1276	19.1	0.0
	Medium	3447	102872	103051	1992	16.1	0.0
	late	3511	168882	164577	1422	16.1	0.1
LSD 0.05 within dates		467	NS	NS	152	0.8	NS
between dates		748	18120	19489	203	1.0	NS

Tribune 1985

Temperatures for June, July, and August were near normal. Rainfall was: June, 2.6 cm (3.8 cm below normal); July, 5.8 cm (0.1 cm below normal); and August, 4.7 cm (1.1 cm below normal), (Table A-12). Moisture stress seemed to induce lodging and lower yields. The early maturity hybrid lodged more in both dates of planting. A killing frost in September lowered yields of the late maturing hybrid (date 1) and the early and medium hybrids (date 2). The yield of the late maturing hybrid in date 2 was practically zero. For this reason no data were included for this hybrid for this date.

Yields ranged from 733 to 4560 kg/ha (Table A-19) and were affected by date of planting, hybrid maturity, rate of planting, and date * hybrid interaction (Table A-20).

Within a date the number of heads per hectare and seed weight diminished as hybrid maturity increased (Table 23). The interaction date * hybrid shows the major contribution of the early frost, through lower seed weights and slightly lower seed set, which reduced yields of the later hybrids and later planting dates (Figure 15 and Table 23). All hybrids yielded less in the second planting date than they did in the first planting date.

The higher rate of planting gave the highest yield (Table 24). The low population had 20 % more seeds in each head and slightly higher seed weights but these did not counteract the 32 % lower number of heads per hectare in comparison to the high population.

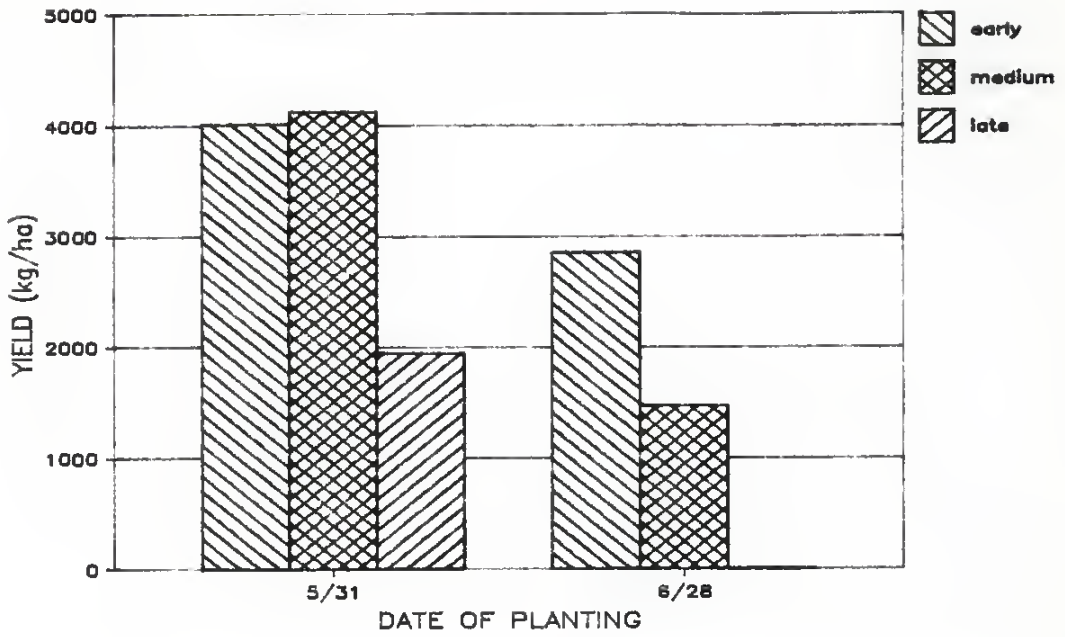


Figure 15. Date of planting * hybrid maturity means for yield, Tribune 1985. (LSD 0.05 within dates = 400 and between dates = 565)

Table 23. Date of Planting * Hybrid Maturity means for yield, heads/ha, seeds/head, seed weight and lodging percent, Tribune 1985.

Date of Planting	Hybrid (maturity)	Yield (kg/ha)	Plants per ha	Heads per ha	Seeds per head	Seed weight	Lodging (%)
Date 1	Early	4019	125114	171034	1418	16.3	7.5
	Medium	4124	84934	131841	2123	14.4	0.0
	Late	1943	91302	104576	1278	14.0	2.2
Date 2	Early	2860	93993	149599	1277	14.5	38.0
	Medium	1470	87266	121078	1195	10.2	2.6
LSD 0.05 within dates		400	15025	14291	296	1.0	6.9
LSD 0.05 between dates		565	18371	18294	381	1.2	10.4

Table 24. Rate of planting means for yield, heads/ha, seeds/head, seed weight and Lodging percent, Tribune 1985.

Item	Yield (kg/ha)	Heads per ha	Seeds per head	Seed weight	Lodging (%)
Population (plants/ha)					
49579	2666	109670	1593	14.2	5.98
143464	3101	161581	1324	13.6	14.14
LSD 0.05	231	9248	192	NS	3.98

Water use study 1985

A limited number of plots (Tables 5 and 6) were planted to compare more detailed measurements of these treatments. The main purpose of the study was to determine if the "superthick" treatment would deplete the soil profile of more total water or if the depletion would occur at different times during the growing season as compared to the "conventional" treatment. If there were differences, the detailed measurements would be used to attempt to explain why the differences exist.

Soil moisture measurements were not taken at planting of the conventional treatment due to delays in installing neutron probe access tubes. Therefore, water use for the conventional treatment was determined using the evaporation and transpiration routine in the SORGF sorghum growth model prior to installation of access tubes.

There was above normal rainfall throughout the growing season for all locations. This provided adequate rainfall to replenish the soil profile at most locations during the growing season, thus, preventing moisture stress.

Manhattan

The superthick sorghum was planted 17 days later than the conventional sorghum at a higher plant population. This combination should promote more rapid growth, on a days after planting basis, as compared to the conventional treatment since higher temperatures would allow faster development and higher plant populations would mean more plants per unit area developing. More rapid plant development would result in more

rapid water use. Rate of cumulative soil water depletion by superthick sorghum up to anthesis was greater than conventional sorghum.

More days were required to reach anthesis in the conventional planting as expected since a later maturity hybrid and a earlier planting date were used. Soil moisture depletion at anthesis was nearly equal and totaled about 19 cm for each planting.

Both plantings showed a reduced rate of water use after anthesis. Runon, from upper slopes, may have replenished the soil profile more than the rainfall used in the cumulative total soil moisture depletion, causing the negative cumulative value. Actual cumulative total soil water depletion values and respective LSD's are listed by treatment in Table A-22.

Conventional planting had a higher leaf area index, and higher plant dry weight than the superthick (Table 25), primarily because the late maturity hybrid produced much longer and wider leaves, more leaves per plant, and larger stalks than the early maturity hybrid. The higher plant population of the superthick treatment did not compensate for the growth of the late maturity hybrid used in the conventional treatment.

The conventional treatment yielded more than the superthick treatment. These values correspond with the main study yields (see footnote [1] Table 25). The conventional treatment yielded more primarily due to lower seed weights in the superthick treatment caused by the early frost (Table 25). All treatment means are listed in Tables A-23 and A-24.

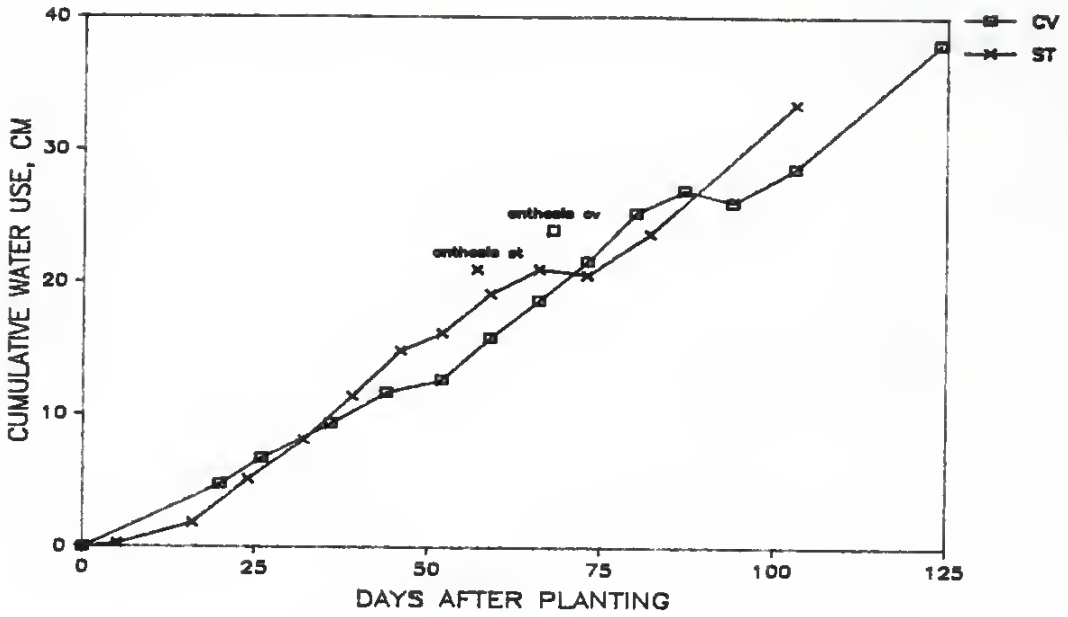


Figure 16. Manhattan 1985cumulativetotal soil moisture depletion from a 110 cm soil profile.

Table 25. Manhattan soil water depletion study 1985. A comparison between the conventional and superthick treatments.

Time/Item	Conventional	Superthick	LSD .05
Planting Date (day of year)	165	182	
Anthesis (day of the year)	233	239	
Leaf Area Index	5.72	3.52	NS
Specific leaf area (cm^2/g)	178.1	185.2	NS
Leaf dry matter (g/m^2)	320.1	188.7	125
Stem dry matter (g/m^2)	410.7	254.1	NS
Head dry matter (g/m^2)	165.2	92.5	64
Maturity			
Yield (kg/ha)[1]	6298	4711	924
Lodging (%)	0.0	0.0	NS
Number of heads/ha	157133	261529	NS
Seeds/head	1913	1116	NS
Seed weight (g)	20.00	15.75	1.32

[1]For comparison the main study conventional and superthick treatments yielded 6120 and 4794 kg/ha, respectively.

Hutchinson

Superthick sorghum used water more rapidly than conventional sorghum (Figure 17). At anthesis about 18 cm of water had been used by the conventional planting (medium maturity hybrid) compared with 21 cm by the superthick. Actual cumulative total soil water depletion values and respective LSDs are listed by treatment in Table A-25.

The conventional planting had a higher leaf area index (Table 26). The medium hybrid, as at Manhattan with the late hybrid, tended to produce longer, wider leaves and tillered more as compared to the superthick (early maturity hybrid). Plant dry weights were higher for the medium maturity hybrid. The differences between dry weights in the early vs medium maturity hybrids at Hutchinson were much less than than the differences found at Manhattan between the early vs late maturity.

The superthick treatment out yielded conventional due to fewer heads per hectare and fewer seeds in each head for the conventional treatment (Table 26). Bird damage to the conventional treatment caused the reduction in seeds per head. Lower seed weights in the superthick treatment were due to the early killing frost. Lodging was high for both treatments. All treatment means are listed in Tables A-26 and A-27.

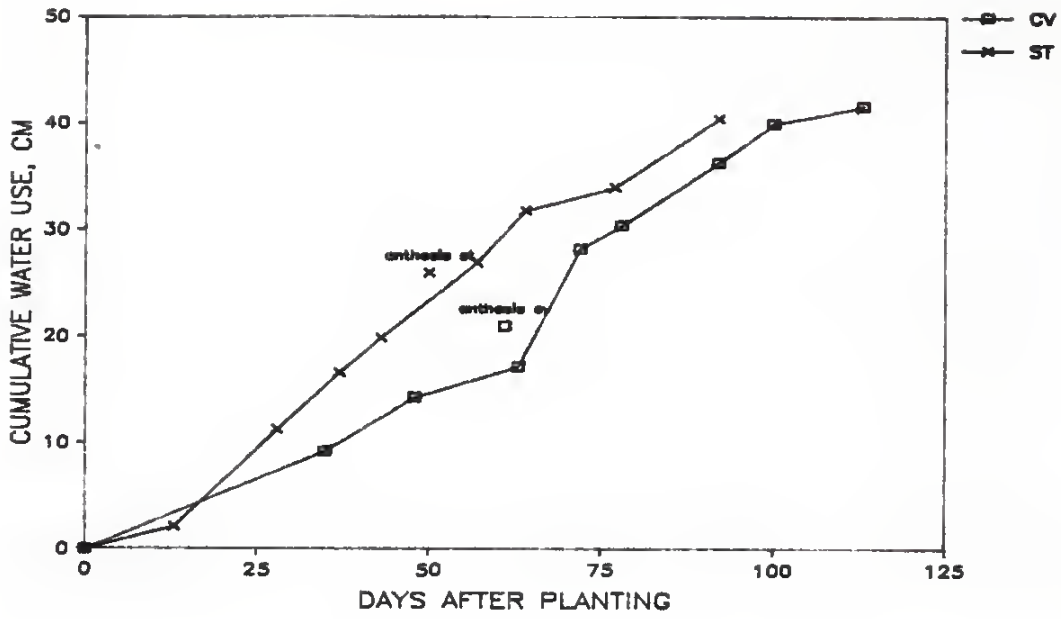


Figure17. Hutchinson 1985cumulativetotal soil moisture depletion from a 240 cm soil profile.

Table 26. Hutchinson soil water depletion study 1985. A comparison between the conventional and superthick treatments.

Time/Item	Conventional	Superthick	LSD .05
Planting date (day of year)	149	175	
Anthesis (day of the year)	210	225	
Leaf Area Index	2.94	1.59	NS
Specific leaf area (cm2/g)	164.0	116.9	NS
Leaf dry matter (g/m^2)	181.1	133.1	NS
Stem dry matter (g/m^2)	388.3	223.2	NS
Maturity			
Yield (kg/ha)[1]	1675	3842	1436
Lodging (%)	32.8	25.0	NS
Number of heads/ha	114083	195878	69071
Seeds/head	615	1114	379
Seed weight (g)	22.50	16.75	2.35

[1]For comparison the main study conventional and superthick treatments yielded 2349 and 4557 kg/ha, respectively.

St. John

The treatments show results similar to those at Manhattan (Figure 18). About 19 cm of water was used by anthesis. Actual cummulative water use values and respective LSDs are listed by treatment in Table A-28.

No leaf area index or plant dry weights were taken at this location due to a 6 August hail storm. Significantly lower seed weight and lower number of seeds per head were offset by a higher number of heads per hectare in the superthick treatment resulting in no significant yield difference (Table 27). All treatment means are listed in Table A-29.

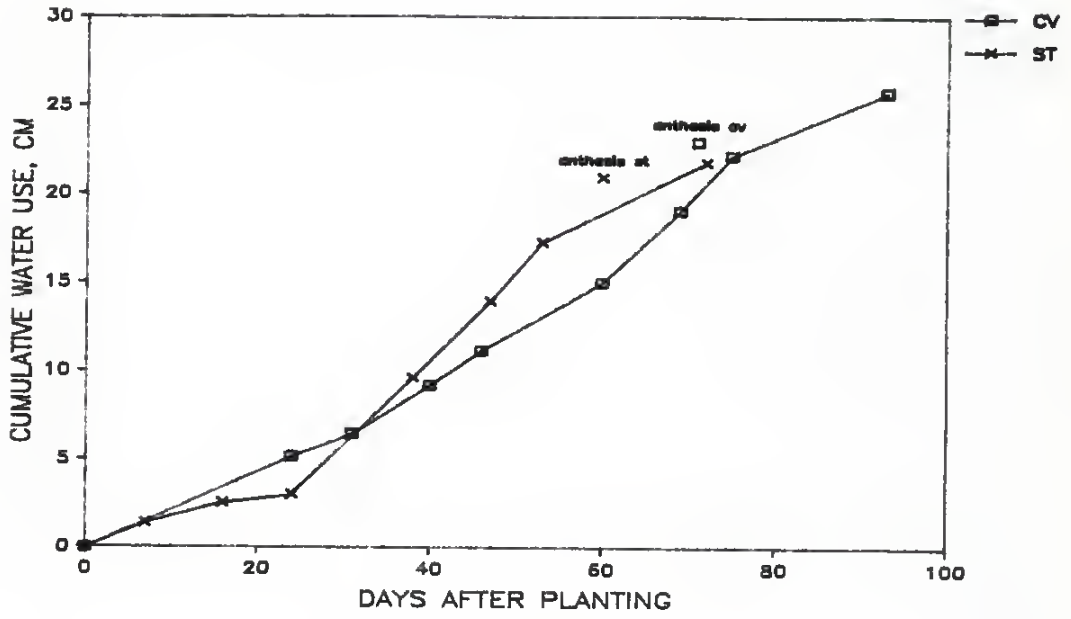


Figure 18. St. John 1985cumulativetotal soil moisture depletion from a 110 cm soil profile.

Table 27. St. John soil water depletion study 1985. A comparison between the conventional and superthick treatments.

Time/Item	Conventional	Superthick	LSD .05
Planting date (day of year)	150	175	
Anthesis (day of the year)	221	235	
Maturity			
Yield (kg/ha)[1]	3553	4449	NS
Lodging (%)	0.0	0.0	NS
Number of heads/ha	88970	214533	111254
Seeds/head	1864	1024	608
Seed weight (g)	20.75	19.00	1.43

[1]For comparison the main study conventional and superthick treatments yielded 4473 and 4535 kg/ha, respectively.

Tribune

Again, as at Manhattan and St. John, the treatments show similar results (Figure 19) with about 19 cm of water being used by anthesis. Actual cumulative total soil water depletion values and respective LSDs are listed by treatment in Table A-30.

There were no significant differences in plant dry weights or LAI between the two treatments. Manhattan and Hutchinson had much larger differences in plant dry weights. Possibly environmental differences between these locations, such as more rainfall in the eastern locations, promoted the growth of the later maturity hybrids used in the conventional treatment.

Significantly more heads per hectare for the superthick and the early frost reducing yield of all the late maturing hybrids gave the superthick a significant yield advantage (Table 28). The early hybrid lodged more in all treatments (Table A-31) and not just the superthick as Table 28 indicates. All treatment means are listed in Table A-31 and A-32.

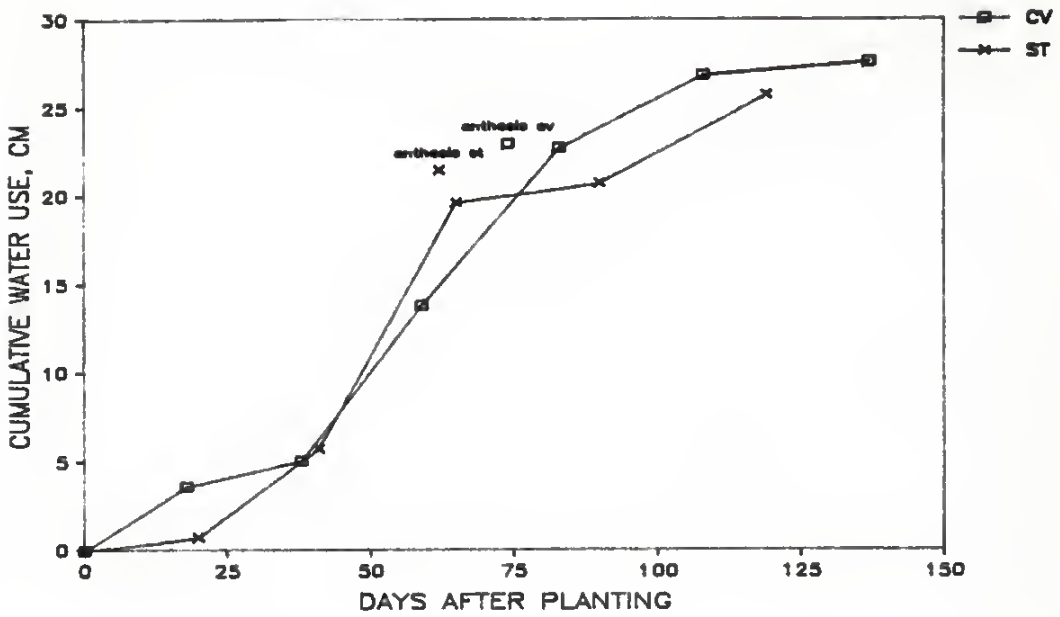


Figure 19. Tribune 1985cumulativetotal soil moisture depletion from a 240 cm soil profile.

Table 28. Tribune soil water depletion study 1985. A comparison between the conventional and superthick treatments.

Time/Item	Conventional	Superthick	LSD .05
Planting date (day of year)	151	179	
Anthesis (day of the year)	225	241	
Leaf Area Index	2.53	2.18	NS
Specific leaf area (cm^2/g)	131.5	144.3	NS
Leaf dry matter (g/m^2)	192.7	158.2	NS
Stem dry matter (g/m^2)	312.7	310.1	NS
Maturity			
Yield (kg/ha)[1]	2185	3624	789
Lodging (%)	0.0	68.9	36.2
Number of heads/ha	78208	159285	28307
Seeds/head	1897	1483	NS
Seed weight (g)	14.00	14.50	NS

[1]For comparison the main study conventional and superthick treatments yielded 3761 and 3604 kg/ha, respectively.

Water depletion study summary

Manhattan, St. John, and Tribune showed similar results between the superthick and conventional treatments. Initially there was less water use by the superthick treatment for about 30 to 35 days. Hutchinson did not strongly indicate the same "less water use" during the initial period, but could have if the SORGF model had predicted a higher first point. All locations had the following items in common after the first 30 to 35 days of growth after planting. During the period between the first 30 to 35 days of initial growth and anthesis, the amount of use rapidly increased for the superthick as compared to the conventional treatment. Anthesis occurred later for the conventional treatment, on a days after planting basis. At each treatment's anthesis, about 19 cm of soil water was used from the soil profile (with the exception of Hutchinson which used about 18 cm conventional and 21 cm superthick).

The leaf area indices were higher and the plant dry weights were heavier in the conventional treatment, possibly due more to hybrid maturity differences than any other factor.

Yield differences were based more on environmental factors (early frost, bird damage, sand blasting from wind blown particles) than treatment effects. The number of seeds per head were similar within a treatment across all locations. Lodging was more of a problem with the early maturity hybrid, especially when planted at the western locations.

SUMMARY

Yield comparisons were made between the superthick vs the conventional management systems as described in the introduction. Hybrid maturity's chosen for the superthick system were the early and medium, and for the conventional, medium and late.

1983

Results from the 1983 study, (Lockhart 1984) are included in the summary to provide a more complete comparison between treatments.

A five location comparison is shown in Figure 20 and Table 29. There was no significant difference between treatments at Powhattan or Manhattan (both are in the more humid eastern part of the state). Sorghum at Hutchinson was lost to bird damage and drought.

St. John had significantly lower yields with the medium maturity hybrids. The superthick (medium) was significantly lower yielding than the superthick (early) or the conventional (late). Most of the yield reduction was due to extremely low seed weights, as a result of a killing frost, and a low number of seeds per head (Table 29). The conventional (medium) yielded significantly lower than its conventional (late) counterpart. All yield components were lower for the conventional (medium) in this comparison.

Tribune showed the superthick (medium) to yield significantly lower than the superthick (early). A lower number of heads per hectare combined with a lower seed weight for the medium hybrid were the factors influencing yields. An early

killing frost contributed to the lower seed weights for the medium hybrid and caused zero yield for the late maturity hybrid in the conventional treatment.

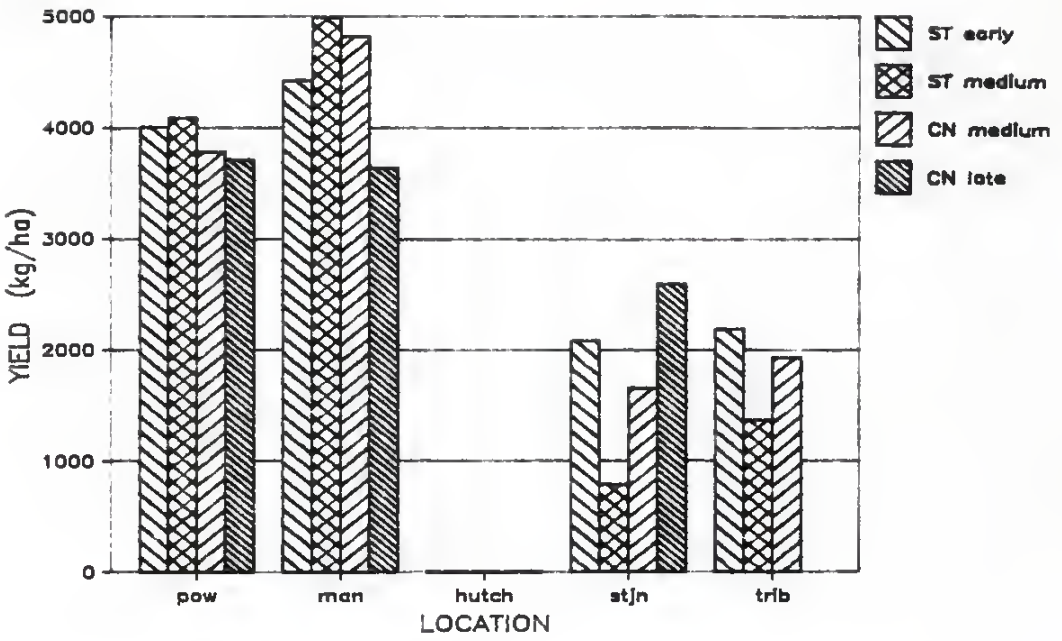


Figure 20. Comparison of yield (kg/ha) of superthick[1] and conventional[2] management systems at five locations, 1983. (Lockhart, 1983) (LSD 0.05 within a system/between systems; Pow=730/842, Man=981/1365, Stjn=664/932 and Trib=716/833)

[1]Superthick = 2 to 3 times plant population (rate), narrow row spacing, earlier maturity hybrid, and a later planting date.

[2]Conventional = Recommended plant population (rate), wide row spacing, later maturity hybrid, and an early planting date.

Hutchinson - all plots lost to bird damage and drought.

Table 29. Comparison of yield (kg/ha), plants per hectare, heads per hectare, seeds per head, seed weight and lodging percent of superthick and conventional management systems at five locations, 1983. (Lockhart, 1983).

Location/ Treatment/ Hybrid maturity	Yield (kg/ha)	Plants per ha	Heads per ha	Seeds per head	Seed weight g/1000	Lodging %
Powhattan						
Superthick[1]						
Early	4011	241833	266231	793	19.0	0.0
Medium	4092	250085	245780	797	20.9	4.8
Conventional[2]						
Medium	3780	115175	113022	1556	21.5	1.5
Late	3707	103335	97594	1557	24.4	0.0
LSD 0.05						
within trt	730	24686	28614		1.1	7.4
between trt	842	25062	29355		1.6	7.7
Manhattan						
Superthick						
Early	4422	235853	217195	1055	19.3	0.0
Medium	4987	223893	203800	1032	23.7	0.0
Conventional						
Medium	4819	150219	145434	1236	26.8	0.0
Late	3631	129647	101899	1371	26.0	0.0
LSD 0.05						
within trt	981	21964	32504		1.6	NS
between trt	1365	22354	31641		2.0	NS
Hutchinson						
Plots lost to bird damage and extreme drought.						
St. John						
Superthick						
Early	2087	123428	119122	908	19.3	0.0
Medium	795	91853	83242	724	13.2	0.0
Conventional						
Medium	1657	70325	68531	1203	20.1	1.0
Late	2599	77501	77142	1440	23.4	6.9
LSD 0.05						
within trt	664	30829	30950		2.5	6.4
between trt	932	32309	34128		2.6	6.5

(next page)

Table 29 (continued).

Location/ Treatment/ Hybrid maturity	Yield (kg/ha)	Plants per ha	Heads per ha	Seeds per head	Seed weight g/1000	Lodging %
Tribune						
Superthick						
Early	2191	62072	82883	2033	13.0	33.5
Medium	1371	57049	61355	2108	10.6	2.1
Conventional						
Medium	1932	58126	57049	2546	13.3	28.7
Late[3]	--	--	--	--	--	--
LSD 0.05						
within trt	716	22730	23445		2.5	22.4
between trt	833	24652	25269		2.6	24.9

[1]Superthick = 2 to 3 times plant population (rate), narrow row spacing, earlier maturity hybrid, and a later planting date.

[2]Conventional = Recommended plant population (rate), wide row spacing, later maturity hybrid, and an early planting date.

[3]Killing frost prevented maturity.

1984

Yields tended to vary considerably in 1984 due to a prolonged midseason drought and a earlier than normal killing frost. Both weather factors were more evident at the western locations (Figure 21 and Table 30).

At Powhattan, sorghum was grown under non moisture stress but a late replant date, compounded with an early killing frost, reduced yields for the superthick (early) treatment by producing fewer seeds in each head and each seed weighing less than in the earlier planted treatments. The superthick (medium) treatment produced zero yield because it was killed before grain maturity by the early frost.

The Manhattan grown sorghum showed no significant difference among treatments.

At Hutchinson, sorghum showed a 3 fold advantage to the superthick (early and medium) systems as compared to the conventional (late) system. These yields are misleading because the early date of planting, which included the conventional treatment, was devastated by birds and the later planting, including the superthick treatment, remained unaffected. The conventional (medium) treatment was significantly different from the conventional (late), but not different from either superthick treatment. From Tables 30 and A-6 no conclusive explanation for the conventional (medium) response can be determined.

At St. John sorghum was grown with very little additional rain fall on the crop from planting to grain fill. Yields were low but the moisture stress was uniform between dates of planting and no significant differences were found between treatments.

Plots at Tribune gave a significant yield advantage to the conventional (medium) treatment. The early killing frost reduced yields of the later planted superthick treatments, by lowering seed weights. The later planted treatments also had reducing seed set. The later maturity hybrid in the conventional treatment did not tiller as much as the medium maturity hybrid so fewer heads were produced. Early and medium maturing hybrids in the superthick treatment, lodged excessively at this location.

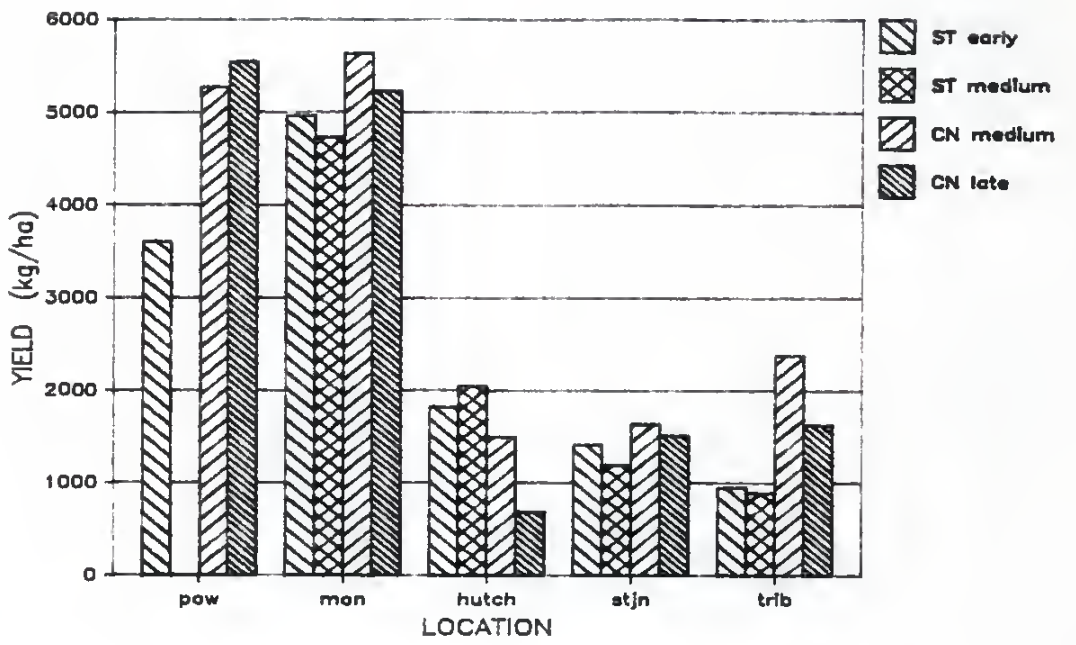


Figure 21. Comparison of yield (kg/ha) of superthick[1] and conventional[2] management systems at five locations, 1984. (LSD 0.05 within a system/between systems; Pow=634/752, Man=921/1148, Hutch=546/668, Stjn=582/759 and Trib=678/835)

[1]Superthick = 2 to 3 times plant population (rate), narrow row spacing, earlier maturity hybrid, and a later planting date.

[2]Conventional = Recommended plant population (rate), wide row spacing, later maturity hybrid, and an early planting date.

Table 30. Comparison of yield (kg/ha), plants per hectare, heads per hectare, seeds per head, seed weight, and lodging percent of superthick and conventional management systems at five locations, 1984.

Location/ Treatment/ Hybrid maturity	Yield (kg/ha)	Plants per ha	Heads per ha	Seeds per head	Seed weight g/1000	Lodging %
Powhattan						
Superthick[1]						
Early	3605	288794	290229	845	14.3	0.0
Medium	--[3]	--	--	--	--	--
Conventional[2]						
Medium	5275	H[4]	158209	1563	21.0	8.4
Late	5546	H	186550	1486	20.1	2.0
LSD 0.05						
within trt	634	18218	45872	394	1.9	14.7
between trt	752	NA	56635	399	2.4	16.8
Manhattan						
Superthick						
Early	4966	238210	240362	1264	16.1	0.0
Medium	4733	250766	242874	1100	17.5	0.0
Conventional						
Medium	5632	104564	108247	1962	25.8	0.0
Late	5218	100259	96767	2111	24.9	0.0
LSD 0.05						
within trt	921	26306	37568	250	1.8	NS
between trt	1148	35692	46661	303	2.2	NS
Hutchinson						
Superthick						
Early	1826	132136	113911	1210	14.1	27.7
Medium	2050	92199	85024	1763	14.0	0.0
Conventional						
Medium	1492	96862	88611	1113	14.4	0.6
Late	683	102961	52378	659	19.0	0.0
LSD 0.05						
within trt	546	31627	26188	356	2.1	9.3
between trt	668	41171	33205	671	2.6	10.7

(next page)

Table 30 (continued).

Location/ Treatment/ Hybrid maturity	Yield (kg/ha)	Plants per ha	Heads per ha	Seeds per head	Seed weight g/1000	Lodging %
St. John						
Superthick						
Early	1416	230318	143141	495	18.8	8.3
Medium	1188	176864	100091	719	15.6	0.3
Conventional						
Medium	1639	131927	71767	958	19.7	0.0
Late	1516	113053	75667	959	19.9	0.0
LSD 0.05						
within trt	582	59476	43642	178	3.7	3.7
between trt	759	73735	54222	548	8.2	4.2
Tribune						
Superthick						
Early	955	85741	160361	539	10.8	98.2
Medium	866	69598	114800	768	11.0	66.1
Conventional						
Medium	2381	63140	128432	1415	12.6	0.3
Late	1627	53095	89329	1375	13.5	0.0
LSD 0.05						
within trt	678	20343	27279	330	1.8	18.4
between trt	835	24341	44165	369	2.2	21.2

[1]Superthick = 2 to 3 times plant population (rate), narrow row spacing, earlier maturity hybrid, and a later planting date.

[2]Conventional = Recommended plant population (rate), wide row spacing, later maturity hybrid, and an early planting date.

[3]Killing frost prevented maturity.

[4]Hail damage before stand counts could be taken.

1985

1985 had above average rainfall, below average temperatures and an early September killing frost for the state as a whole. Yields are higher than 1984 for all locations, with the exception of Powhattan which was lost to a 6 August hail storm (Figure 22 and Table 31).

The Manhattan sorghum was affected by the early frost, which lowered the seed weights and reduced the yields of the superthick treatment. Within the superthick treatment, the medium maturity hybrid had the lowest seed weight, resulting in lower yields than the early maturity hybrid.

As in 1983 and 1984, Hutchinson plots were affected by bird damage. The conventional treatment, planted earlier, resulted in significantly lower yields due to the reduction of seeds in each head by bird damage and fewer heads produced per hectare.

At St. John, sorghum received adequate rainfall for the growing season and was slightly affected by the early frost in the superthick treatment. There was no significant difference among any treatments.

At Tribune, the medium and late maturing hybrids were delayed more in maturity than the earlier maturity hybrid. This was true even when the early maturity hybrid was planted at a later date when compared to a earlier planted late maturity hybrid. The conventional (late) and superthick (medium) plots yielded significantly less because they were later maturity hybrids in their respective planting date, which was more affected by the early September frost.

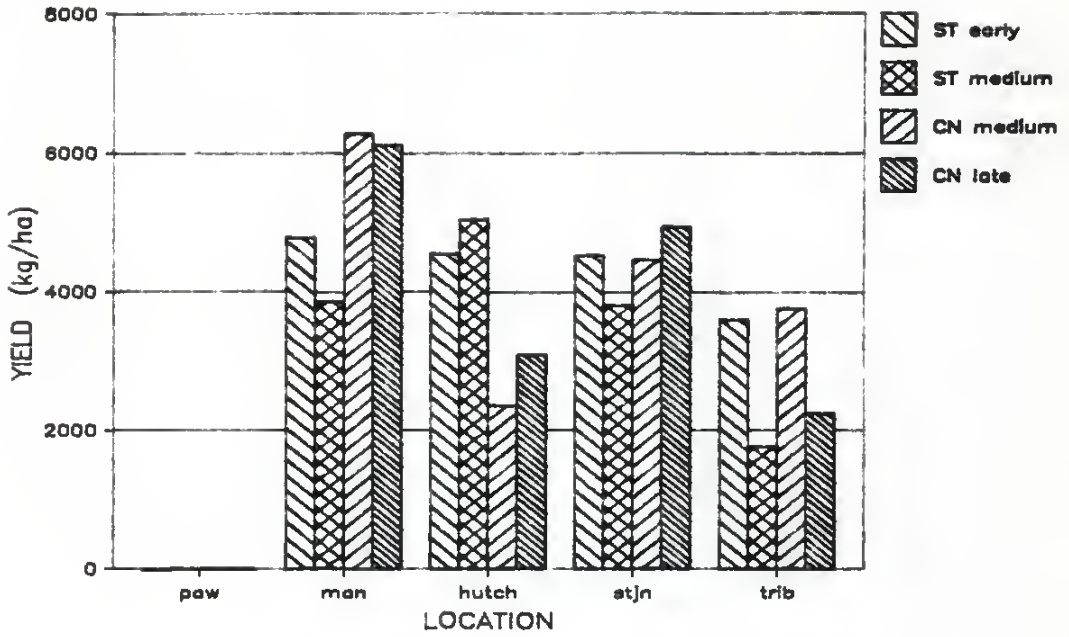


Figure 22. Comparison of yield (kg/ha) of superthick[1] and conventional[2] management systems at five locations, 1985. (LSD 0.05 within a system/between systems; Man=554/736, Hutch=880/1057, Stjn=933/1497 and Trib=800/1131)

[1]Superthick = 2 to 3 times plant population (rate), narrow row spacing, earlier maturity hybrid, and a later planting date.

[2]Conventional = Recommended plant population (rate), wide row spacing, later maturity hybrid, and an early planting date.

Powhattan = All plots lost to hail damage.

Table 31. Comparison of yield (kg/ha), plants per hectare, heads per hectare, seeds per head, seed weight, and lodging percent of superthick and conventional management systems at five locations, 1985.

Location/ Treatment/ Hybrid maturity	Yield (kg/ha)	Plants per ha	Heads per ha	Seeds per head	Seed weight g/1000	Lodging %
Powhattan						
Plots lost to hail damage.						
Manhattan						
Superthick[1]						
Early	4794	268704	253636	1255	15.4	0.0
Medium	3867	309601	225295	1102	14.9	0.0
Conventional[2]						
Medium	6280	120181	138478	1954	22.3	0.8
Late	6120	139554	142424	2128	19.4	0.0
LSD 0.05						
within trt	554	35167	32303	361	1.2	1.8
between trt	736	42240	37999	447	2.7	2.2
Hutchinson						
Superthick						
Early	4557	193725	221708	1134	17.4	10.2
Medium	5050	147803	158926	1819	16.8	0.4
Conventional						
Medium	2349	97580	114800	829	23.8	16.1
Late	3093	102244	121975	1137	21.4	1.2
LSD 0.05						
within trt	880	26875	36250	166	2.0	8.0
between trt	1057	31285	44056	255	2.4	9.6
St. John						
Superthick						
Early	4535	171841	190138	1211	19.0	8.3
Medium	3797	128433	118388	1910	15.8	0.3
Conventional						
Medium	4473	92558	100091	1983	21.9	0.7
Late	4948	101885	113365	1830	23.3	0.0
LSD 0.05						
within trt	933	30132	31026	304	1.5	0.6
between trt	1497	36240	38977	406	1.9	0.7

(next page)

Table 31 (continued).

Location/ Treatment/ Hybrid maturity	Yield (kg/ha)	Plants per ha	Heads per ha	Seeds per head	Seed weight g/1000	Lodging %
Tribune						
Superthick						
Early	3604	136684	198748	1266	13.5	73.6
Medium	1762	104038	137760	1153	10.4	0.6
Conventional						
Medium	3761	44844	115159	2169	14.9	0.0
Late	2241	45920	91123	1554	14.3	0.0
LSD 0.05						
within trt	800	30020	28554	590	2.0	2.0
between trt	1131	36035	36035	751	2.4	2.7

[1]Superthick = 2 to 3 times plant population (rate), narrow row spacing, earlier maturity hybrid, and a later planting date.

[2]Conventional = Recommended plant population (rate), wide row spacing, later maturity hybrid, and an early planting date.

Yields reduced due to early frosts and bird damage are the only points that deviate from a one to one comparison line between conventional and superthick plantings (Table 32 and Figures 23, 24, 25, and 26). Treatments unaffected by abnormal damage show no yield difference between the superthick and conventional management systems.

Figure 23 has three points influenced by earlier than normal frost. Powhattan 1984 and Manhattan 1985 show an advantage to planting conventional sorghum if frost is a factor. The earlier date of planting of the conventional treatment is the reason frost damage was avoided. Tribune 1985 is the exception to the frost influence in Figures 23-26. The conventional (late) planted at the first date of planting did not develop as rapidly as the superthick (early) planted at the second date of planting. The difference was enough for frost to lower the seed weights more in the conventional treatment than the superthick. This is the only case where the superthick treatment yielded higher when frost was an influence.

Figure 24 contains three points influenced by earlier than normal frosts: Tribune 1984, Powhattan 1984, and Manhattan 1985. Figure 25 has four points influenced by early frost: St. John 1983, Tribune 1984, Tribune 1985, and Manhattan 1985. Figure 26 adds another two points influenced by frost: St. John 1983 and Manhattan 1985. All show an advantage to the conventional system planted at the first date of planting.

Hutchinson plot yields in 1984 and 1985 were significantly lowered (Figures 23 and 26) due to more bird damage in the conventional treatment (first planting date effect). In Figures

24 and 25, sorghum at Hutchinson in 1985 showed the conventional treatment with significantly lower yields. The early date of planting bloomed earlier than most grain sorghum fields in the area and attracted birds to those plots. The second planting date had abundant other grain sorghum fields in the area, so it was not damaged. All damage by birds was due to the date of planting effect and is shown in Figures 23-26 as lower yields in the conventional treatment.

Table 32. Factors influencing yield of superthick vs conventional treatments for five locations 1983, 1984, and 1985. A summary of tables 29, 30, and 31.

Year	Location	ST(early) vs CV(late)	ST(early) vs CV(medium)	ST(medium) vs CV(medium)	ST(medium) vs CV(late)
1983	Powhattan	NS	NS	NS	NS
	Manhattan	NS	NS	NS	NS
	St. John	NS	NS	Frost	Frost
	Tribune	Killed	NS	NS	Killed
1984	Powhattan	Frost	Frost	Killed	Killed
	Manhattan	NS	NS	NS	NS
	Hutchinson	Bird	NS	NS	Bird
	St. John	NS	NS	NS	NS
	Tribune	NS	Frost	Frost	NS
1985	Manhattan	Frost	Frost	Frost	Frost
	Hutchinson	Bird	Bird	Bird	Bird
	St. John	NS	NS	NS	NS
	Tribune	Frost	NS	Frost	NS

NS = No significant difference between comparisons.
Frost = Yield reduction due to lower seed weights caused by a early frost.
Killed = Plants killed by early frost before seed was set.
Bird = Bird damage causing fewer seeds in each head.

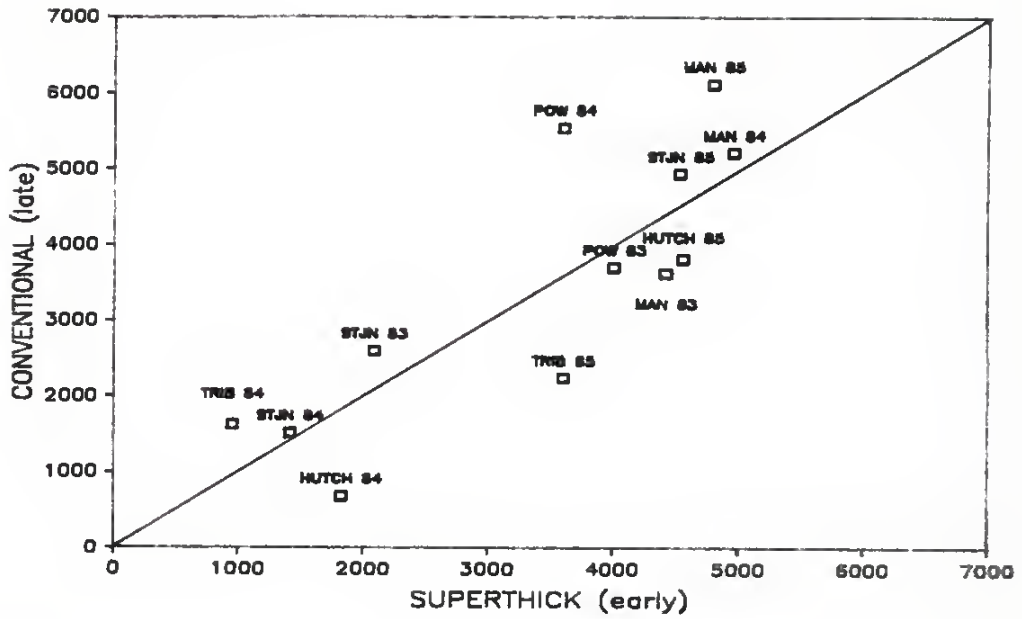


Figure 23. Yields of superthick (early)[1] compared to conventionally grown (late) grain sorghum for five locations. 1983[2], 1984 and 1985 data.

[1](maturity of the hybrid)

[2]Lockhart (1983)

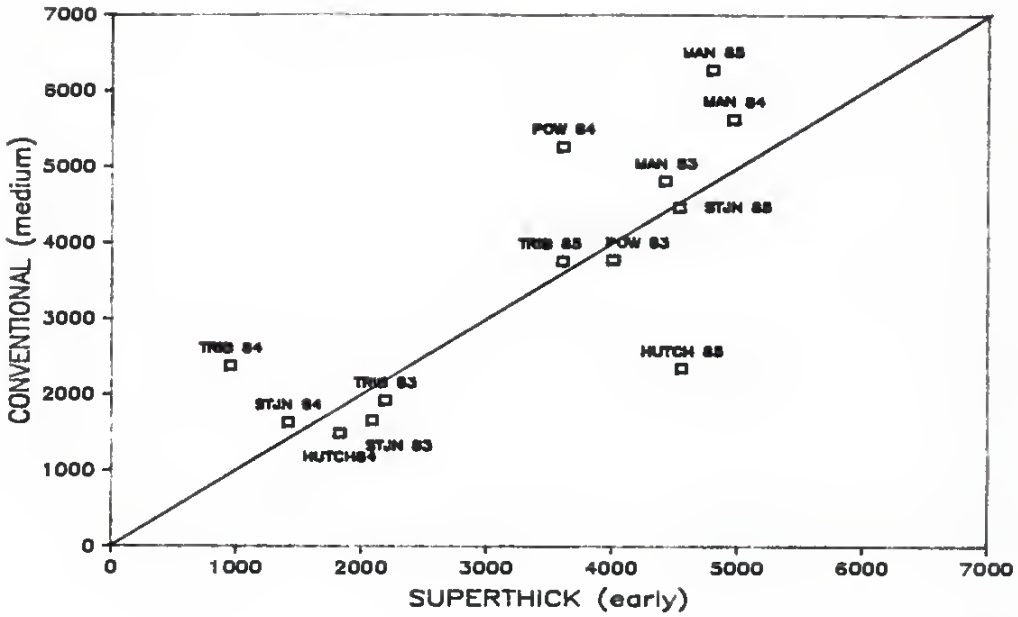


Figure 24. Yields of superthick (early)[1] compared to conventionally grown (medium) grain sorghum for five locations. 1983[2], 1984 and 1985 data.

[1](maturity of the hybrid)

[2]Lockhart (1983)

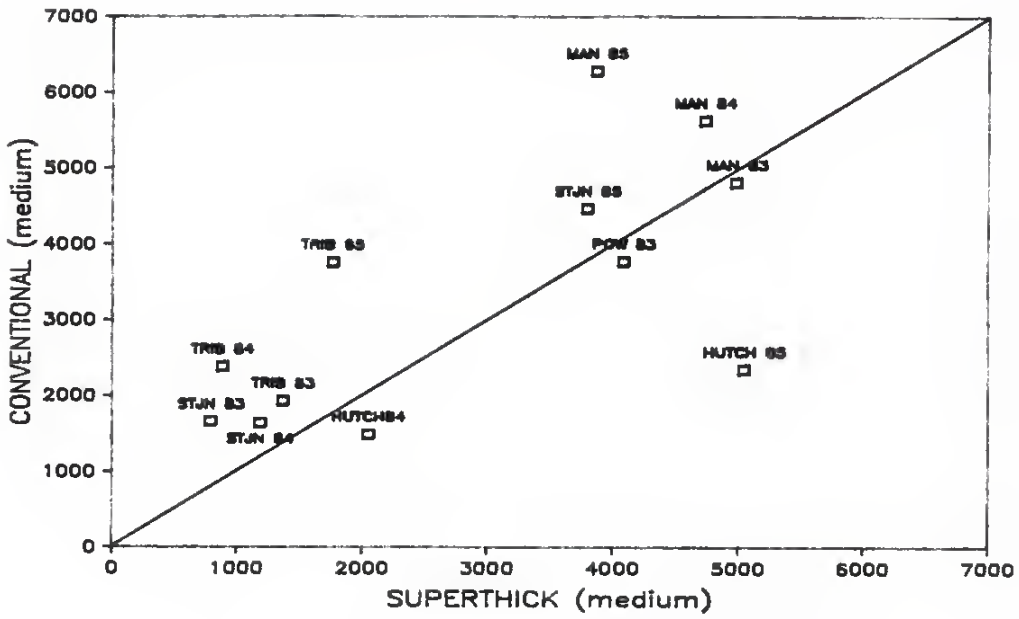


Figure 25. Yields of superthick (medium)[1] compared to conventionally grown (medium) grain sorghum for five locations. 1983[2] 1984 and 1985 data.

[1](maturity of the hybrid)

[2]Lockhart (1983)

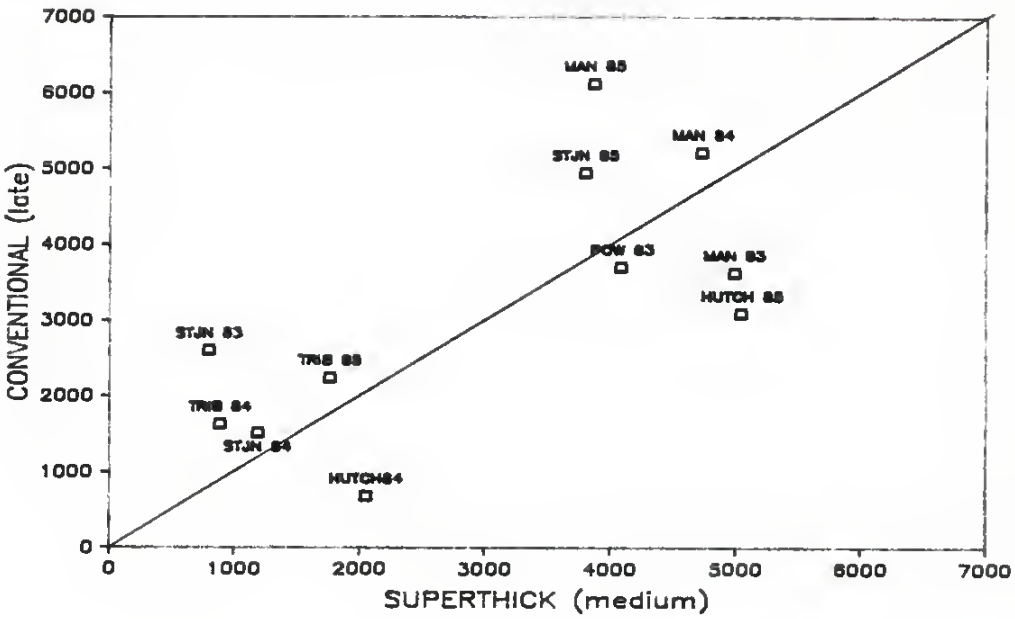


Figure 26. Yields of superthick (medium)[1] compared to conventionally grown (late) grain sorghum for five locations. 1983[2], 1984 and 1985 data.

[1](maturity of the hybrid)

[2]Lockhart (1983)

The main study consisted of 24 treatments, which included all possible combinations of 2 planting dates, 3 hybrid maturities, 2 planting rates, and 2 row spacings. The purpose of the study was to compare two management systems. The summary has been devoted primarily to four of the treatments that fit the conventional and superthick definitions. Table 33 looks at the treatment combination that yielded highest (not necessarily significantly) at each location each year that this study was conducted.

Row spacing did not show any trend in Table 33. About 50% of the time each row spacing was a part of the highest yielding combination.

If conditions showed favorable moisture, the high plant population tended to be a part of the combination producing the highest yield, e.g. 1985. Conversely, droughty conditions tended to favor the normal plant population, e.g. most locations in 1983.

Seven out of thirteen times the the early maturity hybrid was involved in the highest yielding combination, with the remaining six times being equally split between the medium and late maturities. The early hybrid dominated in 1985, but no pattern developed over the three year period.

All three years had earlier than normal killing frosts so it is not surprising that the earlier planting date was favored in eight of the thirteen experiments.

Figure 33. Highest yielding combination mean yields (kg/ha) and respective treatment combination for three years and five locations.

Year/ Location	Yield (kg/ha)	Planting Date	Hybrid Maturity	Planting Rate	Row Spacing
1983					
Powhattan	4214	late	early	normal	25 cm
Manhattan	5773	late	medium	normal	76 cm
St. John	2599	early	late	normal	76 cm
Tribune	2191	late	early	high	25 cm
1984					
Powhattan	5768	early	late	high	76 cm
Manhattan	6440	early	early	high	76 cm
Hutchinson	2389	late	medium	normal	25 cm
St. John	1948	early	late	high	25 cm
Tribune	3527	early	early	normal	25 cm
1985					
Manhattan	6932	early	early	high	76 cm
Hutchinson	4557	late	early	high	25 cm
St. John	6228	early	medium	high	25 cm
Tribune	4560	early	early	high	76 cm

Conclusions

The growing seasons for 1983 and 1984 were hot and dry resulting in lower than expected yields at all locations. Above normal rainfall and lower than expected temperatures prevailed during the 1985 growing season. All three years experienced earlier than normal killing frosts. Yields of the later planting date and later maturing hybrids were reduced at most locations due to the influence of the early frost. The higher plant population tended to produce higher yields at locations significant for this factor. In most cases the yield advantage to higher plant populations was shown at location(s) or year(s) with the least moisture stress. No consistant row spacing effect was found.

A three year comparison of the two management systems found no significant differences in yield, except in the instances when yields were influenced by the earlier than normal frosts or bird damage. It should be noted that the chances of three consecutive years of a early frost was less than 5%, but does prove caution must be used in selecting a hybrid maturity and later planting date when using the superthick system.

Results of this study indicate that the superthick system could be an alternate method of producing grain sorghum with little fear of yield loss, if planting date and hybrid maturity combinations are used to provide adequate time for vegetative growth and allow maturation before frost.

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APPENDIX

Table A-1. Climatic data for Powhattan, Manhattan, Hutchinson, St. John, and Tribune 1984.

Location and Month	Temperature				Precipitation			
	Average Max.	Average Min.	Average	Departure from Normal	Total	Departure from Normal	Greatest Day	Date
	°C				cm			
Powhattan								
June	28.0	17.2	22.6	-4.5	40.10	26.22	13.88	6/10
July	31.2	18.2	24.7	-1.0	4.22	-6.95	2.80	7/04
August	32.1	17.9	25.0	0.4	4.92	-5.66	3.05	8/08
September	24.8	12.0	18.4	-1.5	4.15	-6.95	1.88	9/02
October	17.6	6.8	12.2	-1.5	5.78	-1.62	1.72	10/16
Manhattan								
June	29.8	17.6	23.7	-0.1	28.42	15.19	8.50	6/09
July	32.7	18.1	25.4	-1.2	3.35	-6.55	1.95	7/17
August	34.7	18.6	26.6	0.5	2.30	-5.65	1.78	8/21
September	26.8	13.6	20.2	-0.5	13.85	3.75	10.45	9/14
October	19.2	8.3	13.8	-0.8	9.70	2.47	2.50	10/16
Hutchinson								
June	31.2	17.5	24.3	0.2	9.18	-2.32	2.30	6/13
July	34.8	19.2	27.0	0.2	1.68	-6.67	1.45	7/17
August	35.8	19.6	27.7	1.4	0.08	-7.00	N.S.	N.S.
September	29.3	13.1	21.2	0.0	1.25	-6.33	0.52	9/27
St. John								
June	31.6	17.6	24.6	0.3	6.05	-1.50	1.58	6/12
July	34.7	19.4	27.1	0.0	0.60	-5.95	0.60	7/16
August	34.8	19.3	27.1	1.0	2.45	-4.30	1.08	8/26
September	27.3	12.7	20.0	-1.2	2.08	-5.27	1.58	9/02
October	18.6	7.2	12.8	-2.2	9.62	4.22	3.38	10/09
Tribune								
June	31.5	13.2	22.4	0.5	3.98	-2.45	3.28	6/02
July	33.4	15.7	24.6	-0.5	8.25	2.37	2.15	7/28
August	34.1	15.3	24.7	1.0	1.38	-4.40	0.78	8/07
September	27.4	8.0	17.7	-1.2	0.60	-2.73	0.40	9/02
October	16.9	3.9	10.4	-2.1	10.00	8.27	1.95	10/25

Table A-2. Means for yield, lodging percent, plants per hectare, heads per hectare, seeds per head, seed weight, and half bloom date. Powhattan 1984.

Dateof Planting	Hybrid (maturity)	Desired Population (plants/ha)	Row Spacing (cm)	Yield (kg/ha)	Lodging (%)	Plants/Ha	Heads/Ha	Seeds per Head	Seed weight (g/1000)	Bloom Date (Day of Year)
6/1/84	Early	135,800	25	4526	15.3	H[1]	156056	1695	17.50	217
			76	4232	23.9	H	158926	1313	20.00	217
		271,600	25	4823	17.9	H	181528	1504	19.12	219
			76	4509	28.1	H	225654	1042	18.88	217
	Medium	135,800	25	5424	5.6	H	214174	1307	20.12	225
			76	5275	8.4	H	158209	1563	21.00	222
		271,600	25	5229	9.9	H	206999	1213	20.50	224
			76	5028	23.3	H	237134	1039	20.18	224
	Late	135,800	25	5330	1.5	H	152828	1699	20.38	227
			76	5446	2.1	H	186550	1486	20.12	226
		271,600	25	4730	2.1	H	181886	1333	19.25	226
			76	5768	2.5	H	234981	1224	19.62	226
7/9/84	Early	135,800	25	3461	0.0	139912	153545	1541	14.12	242
			76	3492	0.0	118746	130944	1652	15.75	242
		271,800	25	3605	0.0	288794	290229	845	14.25	242
			76	3480	0.0	283412	269421	809	15.50	242
	LSD 0.05 within dates			634	14.7	18218	45872	394	1.90	3
	LSD0.05 between dates			752	16.8	NA	56635	399	2.40	3

[1]H = Plants that were damaged by hail before stand counts could be taken.

Table A-3. Analysis of variance for yield and yield components, Powhattan 1984, Mean Squares.

Source of variation	Degrees of freedom	Yield (kg/ha)	Lodging (%)	Number of heads/ha	Seeds per Head	Seed weight
Date	1	8206020 **	3626.8 **	7438950312	250008	126.00 **
Error (A)	6	166785	74.9	1908415369	52972	3.88
Hybrid	2	3194328 **	1481.8 **	2282693813	101197	10.10 **
Rate	1	183931	61.9	59141056401 **	2454913 **	1.40
Date x Rate	1	97325	23.3	16737638203 **	580684 **	0.19
Hybrid x Rate	2	324233	85.1	111241050	8806	1.10
Spacing	1	253696	13.5	169571459	19164	3.30
Date x Spacing	1	132843	179.2	4086532013	422623 *	0.19
Hybrid x Spacing	2	1018302 **	93.2	3263142316	214752	1.30
Rate x Spacing	1	66392	20.7	1702750272	56774	0.01
Date x Rate x Spacing	1	9181	1.3	778644453	2179	2.80
Hybrid x Rate x Spacing	2	245973	32.5	1157069947	73568	2.90
Error (B)	42	196998	105.7	1031397979	76089	1.80

* Significant at the 0.05 level
** Significant at the 0.01 level

Table A-4. Means for yield, lodging percent, plants per hectare, heads per hectare, seeds per head, seed weight, and half bloom date. Manhattan 1984.

Date of Planting	Hybrid (maturity)	Desired Population (plants/ha)	Row Spacing (cm)	Yield (kg/ha)	Lodging (%)	Plants/Ha	Heads/Ha	Seeds per Head	Seed weight (g/1000)	Bloom Date (Day of Year)
6/4/84	Early	123,500	25	4993	0.0	84474	96049	2227	22.28	211
			76	5252	0.0	122501	129054	1616	24.03	211
		246,900	25	5437	0.0	172726	162059	1555	20.78	211
			76	6440	0.0	234383	220033	1324	21.67	211
	Medium	123,500	25	5285	0.0	140152	128193	1642	24.83	218
			76	5632	0.0	104564	108247	1962	25.78	217
		246,900	25	5973	0.0	259257	237253	1127	22.33	217
			76	4916	0.2	288435	209032	1033	22.83	217
	Late	123,500	25	4851	1.1	113891	111834	1806	23.53	224
			76	5218	0.0	100259	96767	2111	24.93	221
		246,900	25	5146	0.0	268871	244572	930	22.38	223
			76	5942	0.0	358272	321440	842	21.57	222
6/28/84	Early	123,500	25	5333	0.0	101168	126998	2158	19.00	231
			76	5062	0.0	127715	135608	1995	18.38	231
		246,900	25	4966	0.0	238210	240362	1264	16.12	232
			76	5059	0.0	250408	245744	1210	16.62	230
	Medium	123,500	25	3293	0.0	96862	102961	1904	15.88	243
			76	4598	0.0	125921	133814	1843	18.00	239
		246,900	25	4733	0.0	250766	242874	1100	17.50	240
			76	4867	0.0	277672	253636	1007	18.62	238
	Late	123,500	25	3196	0.0	96504	108342	2059	13.62	246
			76	4190	0.0	135249	135966	1893	15.62	244
		246,900	25	3852	0.0	298839	269780	918	15.62	243
			76	4526	0.0	320364	289870	873	17.25	241
	LSD 0.05 within dates			921	0.3	26306	37568	250	1.77	2
	LSD 0.05 between dates			1148	0.4	35692	46661	303	2.19	3

Table A-5. Analysis of variance for yield and yield components, Manhattan 1984, Mean Squares.

Source of variation	Degrees of freedom	Yield (kg/ha)	Lodging (%)	Number of heads/ha	Seeds per Head	Seed weight
Date	1	13286797 **	.129	5002758961 *	240	568.90 **
Error (A)	5	293315	.024	439785251	28640	.71
Hybrid	2	2810757 **	.116	4698654476 **	397104 **	11.85 **
Date x Hybrid	2	1273831	.116	1260287086	3422	12.20 **
Rate	1	2897641 *	.087	273896083900 **	11893710 **	18.60 **
Date x Rate	1	10173	.087	652605696	101435	26.70 **
Hybrid x Rate	2	49831	.165 *	7952150182 **	263425 **	5.38 *
Date x Hybrid x Rate	2	1310716	.165 *	1221432809	46600	9.04 **
Spacing	1	2631478 *	.097	5272623011 **	116894	15.90 **
Date x Spacing	1	179630	.097	203411	4018	.53
Hybrid x Spacing	2	455093	.158	1600515321	144512 *	.47
Date x Hybrid x Spacing	2	1179232	.158 *	2609800264 *	126198 *	3.31
Rate x Spacing	1	218628	.197 *	714479732	6138	1.67
Date x Rate x Spacing	1	94536	.197 *	2297861613	46167	1.26
Hybrid x Rate x Spacing	2	1380811 *	.120	1193075296	90536	.72
Date x Hybrid x Rate x Spacing	2	93247	.120	793644923	62892	.78
Error (B)	48	424311	.049	705684610	31241	1.57

* Significant at the 0.05 level
** Significant at the 0.01 level

Table A-6. Means for yield, lodging percent, plants per hectare, heads per hectare, seeds per head, seed weight, and half bloom date. Hutchinson 1984.

Date of Planting	Hybrid (maturity)	Desired Population (plants/ha)	Row Spacing (cm)	Yield (kg/ha)	Lodging (%)	Plants/Ha	Heads/Ha	Seeds per Head	Seed weight (g/1000)	Bloom Date (Day of Year)
6/6/84	Early	86,400	25	1811	7.5	88252	86818	1079	17.75	211
			76	1806	6.0	99374	102961	1016	16.00	211
		246,900	25	1181	2.7	168254	126998	604	14.25	212
			76	1958	3.6	215968	193366	589	16.25	212
	Medium	86,400	25	1111	0.0	84306	64216	1102	15.25	221
			76	1492	0.0	96862	88611	1113	14.38	219
		246,900	25	469	0.6	164666	54171	515	15.12	226
			76	1089	0.0	201259	132020	559	13.75	221
	Late	86,400	25	1109	0.0	86459	60629	855	20.25	224
			76	683	0.0	102961	52378	659	19.00	224
		246,900	25	221	0.0	198748	30494	500	18.12	229
			76	638	0.0	222784	85024	403	17.38	223
6/26/84	Early	86,400	25	1878	36.1	69596	79284	1541	14.75	225
			76	1687	32.6	81436	88611	1255	14.88	226
		246,900	25	1826	27.7	132136	113911	1210	14.10	226
			76	1587	15.4	159002	154559	913	13.43	227
	Medium	86,400	25	2389	0.0	62064	71391	2108	15.38	232
			76	1951	0.4	76197	73184	1732	15.32	233
		246,900	25	2050	0.0	92199	85024	1763	14.00	236
			76	2150	1.1	121468	99649	1447	14.12	235
	Late	86,400	25	2381	2.6	66260	88065	1470	18.21	239
			76	1986	0.0	71391	72826	1587	16.88	236
		246,900	25	1906	0.0	86818	107625	1073	16.88	240
			76	1910	0.0	105114	90046	1264	16.38	238
	LSD 0.05 within dates			546	9.3	31627	26188	356	2.10	2
	LSD 0.05 between dates			668	10.7	41171	33205	671	2.57	3

Table A-7. Analysis of variance for yield and yield components, Hutchinson 1984, Mean Squares.

Source of variation	Degrees of freedom	Yield (kg/ha)	Lodging (%)	Number of heads/ha	Seeds per Head	Seed weight
Date	1	15160847 **	1351.02 **	319017057	9854091 **	25.68 *
Error (A)	6	204094	14.34	784213089 *	163152 *	3.63
Hybrid	2	957774 **	2476.04 **	15874813912 **	858859 **	83.90 **
Date x Hybrid	2	3485258 **	1215.08 **	4816775720 **	622994 **	7.32 *
Rate	1	1573302 **	168.39	17117297174 **	3440741 **	29.45 **
Date x Rate	1	376248	63.74	17490324	27419	.22
Hybrid x Rate	2	85367	155.33 *	4746595564 **	29038	.66
Date x Hybrid x Rate	2	44009	44.38	471412233	45515	1.67
Spacing	1	54490	48.63	10351171195 **	325460 *	5.89
Date x Spacing	1	1262444 **	36.77	5764145629 **	106839	.42
Hybrid x Spacing	2	128787	37.03	1872598259 **	92102	1.41
Date x Hybrid x Spacing	2	117085	35.63	374768122	258254 *	1.10
Rate x Spacing	1	1115958 **	2.13	6380202872 **	1558	2.31
Date x Rate x Spacing	1	139388	8.06	2285269848 *	9702	1.83
Hybrid x Rate x Spacing	2	34775	9.84	53250649	13730	1.17
Date x Hybrid x Rate x Spacing	2	141899	26.24	239403156	10319	3.79
Error (B)	59	149188	42.92	342914173	63253	2.15

* Significant at the 0.05 level
** Significant at the 0.01 level

Table A-8. Means for yield, lodging percent, plants per hectare, heads per hectare, seeds per head, seed weight, and half bloom date. Saint John 1984.

Date of Planting	Hybrid (maturity)	Desired Population (plants/ha)	Row Spacing (cm)	Yield (kg/ha)	Lodging (%)	Plants/Ha	Heads/Ha	Seeds per Head	Seed weight (g/1000)	Bloom Date (Day of Year)
6/6/84	Early	86,400	25	1212	0.0	79642	70674	689	23.62	219
			76	1494	0.0	77521	88964	608	27.59	218
		246,900	25	1363	0.0	231394	148522	374	24.00	219
			76	1158	0.0	295251	157491	358	20.62	225
	Medium	86,400	25	1040	0.0	92349	54046	864	21.59	231
			76	1639	0.0	131927	71767	958	19.72	225
		246,900	25	1171	0.0	176505	79642	685	20.25	232
			76	1260	0.0	205205	124845	484	20.00	230
	Late	86,400	25	992	0.0	99294	35487	932	21.94	236
			76	1516	0.0	113053	75667	959	19.94	232
		246,900	25	1948	0.0	75270	55171	1252	21.16	230
			76	1295	0.0	173643	76967	854	19.35	227
6/27/84	Early	86,400	25	1584	6.2	72109	60629	1258	20.62	231
			76	1351	3.8	99732	91122	735	20.00	231
		246,900	25	1416	8.3	230318	143141	495	18.75	233
			76	1484	2.3	246102	173276	423	20.00	233
	Medium	86,400	25	1693	1.2	75696	61346	1554	16.88	239
			76	594	0.0	90046	46638	748	16.62	241
		246,900	25	1188	0.3	176864	100091	719	15.62	240
			76	847	0.0	166101	68880	737	15.88	240
	Late	86,400	25	735	0.0	82871	48072	1010	13.88	243
			76	273	0.0	100809	33364	511	13.75	245
		246,900	25	377	0.0	221349	27624	1005	13.95	245
			76	239	0.0	216685	26189	471	11.88	245
	LSD 0.05 within dates			582	3.7	59476	43642	178	3.74	4
	LSD 0.05 between dates			759	4.2	73735	54222	548	8.17	6

Table A-9. Analysis of variance for yield and yield components, Saint John 1984, Mean Squares.

Source of variation	Degrees of freedom	Yield (kg/ha)	Lodging (%)	Number of heads/ha	Seeds per Head	Seed weight
Date	1	2169272	56.76 *	2948832760	49471	448.71 **
Error (A)	6	515914 *	4.83	1673214862	107197	4.43
Hybrid	2	1194137 **	51.42 **	28507601408 **	495306 **	157.69 **
Date x Hybrid	2	1978404 **	51.42 **	1090017396	352110 **	16.17
Rate	1	16685	.01	23288633034 **	1041575 **	25.51
Date x Rate	1	113785	.01	272159427	109695	1.32
Hybrid x Rate	2	58300	.20	9220620739 **	329701 **	3.83
Date x Hybrid x Rate	2	159242	.20	408636271	11445	3.95
Spacing	1	283036	11.28	2610603869	1027427 **	5.51
Date x Spacing	1	927452 *	11.28	2710970439	389585 *	1.64
Hybrid x Spacing	2	55754	7.55	497160254	44813	4.61
Date x Hybrid x Spacing	2	376297	7.55	2213643415	4036	.47
Rate x Spacing	1	75673	.95	1754064	41334	3.15
Date x Rate x Spacing	1	1530000 **	.95	1364277	433706 *	4.28
Hybrid x Rate x Spacing	2	949666	2.40	42404815	104571	5.59
Date x Hybrid x Rate x Spacing	2	51879	2.40	476748129	60719	15.99
Error (B)	53	169233	6.72	952309628	63532	6.99

* Significant at the 0.05 level
** Significant at the 0.01 level

TableA-10. Means for yield,lodging percent,plantsper hectare, heads per hectare seeds per head, seed weight, and half bloom date. Tribune 1984.

Date of Planting	Hybrid (maturity)	Desired Population (plants/ha)	Row Spacing (cm)	Yield (kg/ha)	Lodging (%)	Plants/Ha	Heads/Ha	Seeds per Head	Seed weight (g/1000)	Bloom Date (Day of Year)
6/7/84	Early	49,400	25	3527	53.3	53095	152828	1719	13.12	221
			76	2783	53.5	55248	162872	1305	12.75	220
		148,200	25	2982	53.0	82871	166101	1276	13.50	220
			76	2945	48.4	92916	175788	1259	12.88	220
	Medium	49,400	25	2336	3.0	69598	120181	1489	12.25	227
			76	2381	0.3	63140	128432	1415	12.62	228
		148,200	25	2283	4.6	77490	139912	1332	12.00	227
			76	2537	5.2	85382	127715	1475	12.88	225
	Late	49,400	25	1475	1.2	58835	85024	1173	14.50	233
			76	1627	0.0	53095	89329	1375	13.50	233
		148,200	25	1814	0.6	99732	122692	1156	12.88	233
			76	1679	0.0	84665	105472	1111	14.00	233
6/27/84	Early	49,400	25	1242	94.4	36234	144576	660	12.12	238
			76	1194	96.3	48072	153186	683	11.00	238
		148,200	25	955	98.2	85741	160361	539	10.75	237
			76	1274	98.3	87535	136325	744	12.00	236
	Medium	49,400	25	802	42.4	41974	123769	623	10.50	245
			76	820	14.7	46279	120899	646	10.12	244
		148,200	25	886	66.1	69598	114800	768	11.00	243
			76	1078	48.5	97580	116594	845	10.75	246
	LSD 0.05 within dates			678	18.4	20343	27279	330	1.76	3
	LSD 0.05 between dates			835	21.2	24341	44165	369	2.24	4

Table A-11. Analysis of variance for yield and yield components, Tribune 1984, Mean Squares.

Source of variation	Degrees of freedom	Yield (kg/ha)	Lodging (%)	Number of heads/ha	Seeds per Head	Seed weight
Date	1	45718339 **	28521.30 **	2668755600	8303511 **	47.27 *
Error (A)	6	355709	300.76	3966639357 **	46080	3.65 *
Hybrid	2	7927832 **	25026.26 **	19766929780 **	245694 *	9.50 **
Date x Hybrid	1	656969	104.45	131790400	2767	.25
Rate	1	39572	993.15 *	1369305118	39066	.01
Date x Rate	1	43236	967.36 *	886625064	189063	.02
Hybrid x Rate	2	228136	509.18	371625762	79253	.76
Date x Hybrid x Rate	1	951	396.41	6306377	58	1.00
Spacing	1	9980	600.72	110705208	19261	.01
Date x Spacing	1	233073	337.46	260620664	118793	.14
Hybrid x Spacing	2	152296	254.56	155192634	55458	.28
Date x Hybrid x Spacing	1	325857	614.67	361522689	98572	2.25
Rate x Spacing	1	154198	15.90	1050540666	28836	6.29 *
Date x Rate x Spacing	1	35198	24.16	12870156	35865	1.27
Hybrid x Rate x Spacing	2	244804	50.45	78293450	114309	1.61
Date x Hybrid x Rate x Spacing	1	23081	3.58	823690000	614	2.25
Error (B)	54	230031	168.41	372065095	54351	1.54

* Significant at the 0.05 level
** Significant at the 0.05 level

Table A-12. Climatic data for Manhattan, Hutchinson, St John, and Tribune 1985.

Location and Month	Temperature				Precipitation			
	Average Max.	Average Min.	Average	Departure from Normal	Total	Departure from Normal	Greatest Day	Date
	°C				cm			
Manhattan								
June	27.1	14.1	20.6	-3.2	9.90	-3.33	2.70	6/03
July	33.3	18.7	26.0	-0.6	3.20	-6.70	1.30	7/21
August	28.5	18.8	22.6	-3.5	13.10	5.15	5.40	8/03
September	24.3	13.9	19.1	-1.6	12.90	2.80	3.30	9/22
October	19.2	7.4	13.3	-1.3	8.20	0.97	5.50	10/09
Hutchinson								
June	28.2	15.7	21.9	-2.2	13.20	1.70	4.45	6/11
July	34.9	19.4	27.1	0.3	10.85	2.50	6.20	7/29
August	30.7	18.0	24.3	-2.0	8.98	1.90	2.25	8/14
September	26.9	15.2	21.3	0.1	15.00	7.42	4.43	9/21
St. John								
June	28.4	15.3	22.3	-2.0	8.88	1.33	2.85	6/26
July	34.4	19.5	26.9	-0.2	6.05	-0.50	3.75	7/29
August	31.4	17.4	24.4	-1.7	11.05	4.30	3.55	8/18
September	25.8	13.6	19.7	-1.5	9.55	2.20	4.03	9/20
Tribune								
June	30.8	12.2	21.5	-0.4	1.60	-4.83	1.50	6/25
July	33.8	16.6	25.2	0.1	4.80	-1.08	2.60	7/28
August	31.5	15.4	23.4	-0.3	3.70	-2.08	1.30	8/14
September	25.2	9.2	17.2	-1.7	3.40	0.07	1.60	9/11
October	18.7	3.1	10.9	-1.6	4.20	2.47	2.20	10/11

Table A-13. Means for yield, lodging percent, plants per hectare, heads per hectare seeds per head, seed weight, and half bloom date. Manhattan 1985.

Date of Planting	Hybrid (maturity)	Desired Population (plants/ha)	Row Spacing (cm)	Yield (kg/ha)	Lodging (%)	Plants/Ha	Heads/Ha	Seeds per Head	Seed weight (g/1000)	Bloom Date (Day of Year)
6/14/85	Early	123,500	25	5630	4.6	111213	153545	1689	20.75	220
			76	6186	0.0	112289	152469	1697	23.25	220
		246,900	25	6589	0.0	226730	213456	1286	23.13	219
			76	6932	0.2	223501	224936	1229	24.50	219
	Medium	123,500	25	6037	0.0	134531	151034	1775	21.63	230
			76	6280	0.8	120181	138478	1954	22.25	229
		246,900	25	5913	0.2	224936	169330	1559	21.63	230
			76	6433	0.9	215250	186550	1504	22.13	229
	Late	123,500	25	5543	0.3	130226	135608	1930	20.88	234
			76	6120	0.0	139554	142424	2128	19.38	232
		246,900	25	5830	0.0	310319	203770	1410	19.50	232
			76	6328	0.0	300991	228524	1371	19.37	232
7/1/85	Early	123,500	25	4437	0.3	121258	135249	1817	17.25	239
			76	4165	0.0	126639	127715	2103	16.33	239
		246,900	25	4794	0.0	268704	253636	1255	15.38	239
			76	4580	0.0	308884	299198	880	16.63	238
	Medium	123,500	25	4560	0.2	110495	147088	1976	14.88	243
			76	3700	0.0	116953	120540	1976	15.00	243
		246,900	25	3867	0.0	309601	225295	1102	14.88	243
			76	4113	0.0	344400	255071	939	16.38	243
	Late	123,500	25	3949	0.0	140630	144218	1789	15.25	245
			76	3553	0.0	132379	144218	1765	13.25	246
		246,900	25	3959	0.0	311754	281978	962	13.88	246
			76	4023	0.0	365925	290946	871	15.13	245
	LSD 0.05 within dates			554	1.8	35167	32303	361	1.15	1
	LSD 0.05 between dates			736	2.2	42240	37999	447	2.67	1

Table A-14. Analysis of variance for yield and yield components, Manhattan 1985, Mean Squares.

Source of variation	Degrees of freedom	Yield (kg/ha)	Lodging (%)	Number of heads/ha	Seeds per Head	Seed weight
Date	1	97003026 **	6.81 *	17607145959 **	730923 *	516.99 **
Error (A)	6	541932 **	0.80	204349481	105864	3.86
Hybrid	2	2036539 **	2.90	4979227501 **	89648	53.48 **
Date x Hybrid	2	174222	2.39	805221326	325739 **	3.63
Rate	1	1707827 **	4.01	216640851926 **	1128634 1 **	0.98
Date x Rate	1	264700	2.61	31405326276 **	1130221 **	2.56
Hybrid x Rate	2	934131	3.60	3853989740 **	25301	1.14
Date x Hybrid x Rate	2	109802	3.26	187947182	80745	7.92 *
Spacing	1	283612	2.40	1563723984	2931	3.49
Date x Spacing	1	2896930 **	1.35	2145026	59955	0.79
Hybrid x Spacing	2	44475	4.75	230954954	4152	5.97
Date x Hybrid x Spacing	2	132	4.48	317914310	9766	3.01
Rate x Spacing	1	431093	4.78	5319750384 **	341195 *	7.99
Date x Rate x Spacing	1	448170	3.25	562940634	20852	7.43
Hybrid x Rate x Spacing	2	304393	3.93	451935537	24494	2.02
Date x Hybrid x Rate x Spacing	2	39455	3.55	325679304	86399	0.45
Error (B)	66	153996	1.66	523825760	65258	2.32

* Significant at the 0.05 level
** Significant at the 0.01 level

Table A-15. Means for yield, lodging percent, plants per hectare, heads per hectare, seeds per head, seed weight, and half bloom date. Hutchinson 1985.

Date of Planting	Hybrid (maturity)	Desired Population (plants/ha)	Row Spacing (cm)	Yield (kg/ha)	Lodging (%)	Plants/Ha	Heads/Ha	Seeds per Head	Seed weight (g/1000)	Bloom Date (Day of Year)
5/29/85	Early	86,400	25	2042	3.3	109778	200541	393	24.63	207
			76	2018	0.5	99015	169330	478	24.38	206
		246,900	25	2537	3.2	293099	383863	281	22.75	207
			76	2116	3.5	265116	327539	262	24.75	206
	Medium	86,400	25	2351	17.5	102244	136684	780	21.13	211
			76	2349	16.1	97580	114800	829	23.75	210
		246,900	25	2947	7.2	208075	213456	632	21.25	212
			76	2741	3.9	251843	245385	488	22.00	212
	Late	86,400	25	3375	0.0	95786	134531	1275	19.13	217
			76	3093	1.2	102244	121975	1137	21.38	215
		246,900	25	3830	0.4	268345	230184	745	17.75	219
			76	3348	0.3	290946	283413	738	15.88	216
6/24/85	Early	86,400	25	4320	8.3	111213	149958	1509	18.25	224
			76	4209	0.0	92558	117311	1634	21.13	224
		246,900	25	4557	10.2	193725	221708	1134	17.38	224
			76	4116	0.3	200183	209869	1024	18.50	224
	Medium	86,400	25	4717	2.2	88611	131661	2089	16.50	229
			76	4258	16.6	88611	104755	2143	18.25	229
		246,900	25	5050	0.4	147803	158926	1819	16.75	229
			76	4765	6.6	158568	148881	1745	17.75	228
	Late	86,400	25	4687	0.0	118746	137760	2147	15.13	231
			76	4362	0.3	88970	105114	2406	16.50	230
		246,900	25	4963	0.0	230676	233188	1288	15.75	231
			76	4481	0.0	265834	255789	1089	15.50	231
	LSD 0.05 within dates			880	8.0	26875	36250	166	1.96	1
	LSD 0.05 between dates			1057	9.6	31285	44056	255	2.44	2

Table A-16. Analysis of variance for yield and yield components, Hutchinson 1985, Mean Squares.

Source of variation	Degrees of freedom	Yield (kg/ha)	Lodging (%)	Number of heads/ha	Seeds per Head	Seed weight
Date	1	78767444 **	24.42	67581726725 **	23938809 **	440.00 **
Error (A)	6	336095 *	28.88	763822323	117814 *	3.49
Hybrid	2	4845165 **	591.45 **	34727564060 **	2623953 **	152.45 **
Date x Hybrid	2	2159998 **	95.35	11616367079 **	520171 **	13.65 **
Rate	1	2245750 **	150.70 *	298275330659 **	5181215 **	33.25 **
Date x Rate	1	138061	17.37	23334644344 **	722990 **	5.75
Hybrid x Rate	2	154185	224.06 **	10760930693 **	587539 **	3.65
Date x Hybrid x Rate	2	11287	19.81	1736205529	142862 **	9.16 *
Spacing	1	2063527 **	2.07	5298407375 **	2407	29.82 **
Date x Spacing	1	77948	13.16	3625094	8717	0.94
Hybrid x Spacing	2	59211	168.44 **	1982926424	5564	3.30
Date x Hybrid x Spacing	2	35786	215.45 **	1013803658	8126	1.04
Rate x Spacing	1	207066	17.34	3146517250 *	162117 **	10.34 **
Date x Rate x Spacing	1	39813	17.37	390930996	71300 *	0.02
Hybrid x Rate x Spacing	2	60602	18.73	941473380	46	4.89
Date x Hybrid x Rate x Spacing	2	17510	7.48	1062367048	56579 *	5.87
Error (B)	66	110686	32.02	659675459	13772	1.92

* Significant at the 0.05 level
** Significant at the 0.01 level

Table A-17. Means for yield, lodging percent, plants per hectare, heads per hectare, seeds per head, seed weight, and half bloom date. Saint John 1985.

Date of Planting	Hybrid (maturity)	Desired Population (plants/ha)	Row Spacing (cm)	Yield (kg/ha)	Lodging (%)	Plants/Ha	Heads/Ha	Seeds per Head	Seed weight (g/1000)	Bloom Date (Day of Year)
5/30/85	Early	86,400	25	4337	0.2	96863	132379	1119	27.88	210
			76	3729	0.3	107625	126280	1039	27.00	209
		246,900	25	4823	0.1	284130	287000	608	26.88	209
			76	4302	0.0	295610	298121	523	27.00	207
	Medium	86,400	25	5642	0.3	98656	118746	2050	22.38	218
			76	4473	0.7	92558	100091	1983	21.88	218
		246,900	25	6228	0.0	186550	204129	1335	22.38	217
			76	5024	0.2	206999	186909	1217	21.75	216
	Late	86,400	25	4324	0.0	99733	121975	1474	22.75	224
			76	4948	0.0	101885	113365	1830	23.25	222
		246,900	25	5854	0.0	323593	312830	800	22.63	223
			76	4475	0.0	309601	280901	667	22.89	222
6/24/85	Early	86,400	25	3996	6.2	120181	135249	1491	18.88	233
			76	3141	3.8	95428	99733	1500	19.88	232
		246,900	25	4535	8.3	171841	190138	1211	19.00	232
			76	3707	2.3	201259	208434	903	18.75	233
	Medium	86,400	25	3828	1.2	80719	92199	2413	16.63	242
			76	3046	0.0	85383	88611	2012	15.88	243
		246,900	25	3797	0.3	128433	118388	1910	15.75	243
			76	3114	0.0	116953	113006	1632	16.25	243
	Late	86,400	25	3557	0.0	120181	118029	1791	16.00	242
			76	3222	0.3	106908	110136	1791	15.63	242
		246,900	25	3741	0.0	178299	187268	1274	15.63	242
			76	3525	0.0	270139	242874	830	17.13	241
	LSD 0.05 within dates			933	0.6	30132	31026	304	1.50	2
	LSD 0.05 between dates			1497	0.7	36240	38977	406	1.87	4

Table A-18. Analysis of variance for yield and yield components, Saint John 1985, Mean Squares.

Source of variation	Degrees of freedom	Yield (kg/ha)	Lodging (%)	Number of heads/ha	Seeds per Head	Seed weight
Date	1	37235045 *	0.35 *	55808622594 **	2817450 **	1155.09 **
Error (A)	6	4450901 **	0.05	962108531	173082 **	2.05
Hybrid	2	842486	0.09	35321650472 **	4915411 **	160.00 **
Date x Hybrid	2	4286245 **	0.30	203241218	101166	8.92 **
Rate	1	3971043 **	0.39	270174631502 **	9583857 **	0.67
Date x Rate	1	438643	0.12	32399352794 **	203304 *	0.26
Hybrid x Rate	2	125475	0.04	15861631018 **	258311 **	0.86
Date x Hybrid x Rate	2	164566	0.17	246227540	25129	0.57
Spacing	1	10547521 **	0.13	414440482	399837 **	0.04
Date x Spacing	1	51725	0.01	1438904919	280043 *	1.26
Hybrid x Spacing	2	809994	0.07	345585146	52832	1.33
Date x Hybrid x Spacing	2	267192	0.13	1532342254 *	36830	0.16
Rate x Spacing	1	485243	0.10	2048092315 *	233667 *	1.04
Date x Rate x Spacing	1	803974	0.00	2407255475 *	1502	0.26
Hybrid x Rate x Spacing	2	647664	0.01	640998132	128038	0.47
Date x Hybrid x Rate x Spacing	2	729195	0.06	1018050810	31594	2.74
Error (B)	66	437052	0.16	483229517	46275	1.33

* Significant at the 0.05 level
** Significant at the 0.01 level

TableA-19. Means for yield,lodging percent, plantsper hectare, heads per hectare, seeds per hectare, seed weight, and half bloom date. Tribune 1985.

Date of Planting	Hybrid (maturity)	Desired Population (plants/ha)	Row Spacing (cm)	Yield (kg/ha)	Lodging (%)	Plants/Ha	Heads/Ha	Seeds per Head	Seed weight (g/1000)	Bloom Date (Day of Year)
5/31/85	Early	49,400	25	3920	6.4	59911	130944	1743	16.25	219
			76	3578	16.2	50584	136684	1542	16.25	219
		148,200	25	4019	3.7	201976	214533	1162	15.38	220
			76	4560	3.7	187985	201976	1226	17.50	218
	Medium	49,400	25	4319	0.0	65651	120181	2344	14.63	226
			76	3761	0.0	44844	115159	2169	14.88	225
		148,200	25	4502	0.0	125563	156415	1994	13.75	225
			76	3915	0.0	103679	135608	1984	14.25	226
	Late	49,400	25	1795	0.0	59553	81795	1464	14.00	236
			76	2241	0.0	45920	91123	1554	14.25	238
		148,200	25	1684	0.5	139913	127356	956	13.00	239
			76	2053	8.4	119823	118029	1137	14.63	237
6/28/85	Early	49,400	25	2921	16.9	39463	125204	1491	14.88	241
			76	1831	12.4	41615	103320	1068	16.13	242
		148,200	25	3604	49.3	136684	198748	1266	13.50	241
			76	3083	73.6	158209	171124	1284	13.38	241
	Medium	49,400	25	1558	8.0	44126	105473	1783	10.50	246
			76	733	0.0	44126	86818	772	9.88	246
		148,200	25	1762	0.6	104038	137760	1153	10.38	246
			76	1827	1.8	156774	154263	1073	10.13	246
	LSD 0.05 within dates			800	2.0	30020	28554	590	1.96	2
	LSD 0.05 between dates			1131	2.7	36035	36035	751	2.36	3

Table A-20. Analysis of variance for yield and yield components, Tribune 1985, Mean Squares.

Source of variation	Degrees of freedom	Yield (kg/ha)	Lodging (%)	Number of heads/ha	Seeds per Head	Seed weight
Date	1	58170729 **	4387.08 *	4146796519	4569195 *	145.50 **
Error (A)	6	1772927 **	731.60 **	894854814	408201 *	2.17
Hybrid	2	27459760 **	3692.62 **	20882498837 **	2071863 **	87.66 **
Date x Hybrid	1	8939121 **	3120.06 **	455635707	2475721 **	20.82 **
Rate	1	3536018 **	1933.73 **	50279815073 **	1277690 **	7.22
Date x Rate	1	822470	2660.75 **	315351004	299362	2.07
Hybrid x Rate	2	577157	973.23 **	2544585405 **	14775	0.71
Date x Hybrid x Rate	1	2920	3272.41 **	639678941	116281	9.38 *
Spacing	1	1032311	193.36	1283263403	478219	4.27
Date x Spacing	1	508417	2.62	90380672	344935	1.72
Hybrid x Spacing	2	583491	168.05	189218110	130099	1.49
Date x Hybrid x Spacing	1	1205920	70.69	1101202744	101742	0.10
Rate x Spacing	1	898831	410.84	40930575	751150 *	1.02
Date x Rate x Spacing	1	91483	572.05	1008022813	222904	2.85
Hybrid x Rate x Spacing	2	128357	66.54	236408683	24329	0.01
Date x Hybrid x Rate x Spacing	1	379843	216.24	368376047	86979	3.29
Error (B)	54	318887	94.67	406445096	174555	1.94

* Significant at the 0.05 level
** Significant at the 0.05 level

Table A-21. Analysis of variance for yield and yield components, leaf area index, specific leaf area, and dry matters for Manhattan, Hutchinson, St. John and Tribune 1985, Mean Squares.

Source of Variation	Degrees of Freedom	Yield (kg/ha)	Lodging (%)	Number of Heads/ha	Seeds per Head	Seed Weight	Leaf Area Index	Specific Leaf Area	Leaf Dry Matter	Stem Dry Matter	Grain Dry Matter
Manhattan											
Error(a)	2	66341	.00	1527237092	310544	.06	.31	11.41	920	2605	628
Date	1	8235894 **	.00	1279357882	44882	72.00 **	.12	67.69	721	1974	94
Treatment	1	391307 *	.00	12515004288	839167 **	6.13 *	7.65	3.37	25277 *	31356	8669 *
Date*trt	1	328208	.00	4383639569	119084	.50	2.13	132.76	4690	187	492
Error(b)	2	118227	.00	1392872660	6939	.31	1.21	74.75	2470	3377	244
Hutchinson											
Error(a)	2	382677	1.10	348523832	22604	.78	.05	.12	2667	387	
Date	1	4216652	.18	5337511200	3420577 **	116.28 **	5.70 **	3.48	4471	119685 **	
Treatment	1	1023144 *	1.17	35620474050 *	1310322 **	7.03 *	.23	.01	1	12621	
Date*trt	1	2237469 *	18.32	1566040613	847836 **	11.28 *	1.26	.01	9625	34665	
Error(b)	2	62866	54.06	682118281	8441	.41	.94	1442.98	2990	17134	
St. John											
Error(a)	2	485227	.50	746469063	28482	.03					
Date	1	207645	1.00	2892181513	110975	69.03 **					
Treatment	1	2967803	1.00	53523376200 *	2312723 *	34.03 *					
Date*trt	1	2515547	1.00	696018050	169796	1.53					
Error(b)	2	2304261	.03	1927434600	51251	.41					
Tribune											
Error(a)	2	30684	141.53	98134942	58456	3.78	.02	1214.00 *	1716	5314	
Date	1	98781	2168.44	14478926	69453	34.03	1.30 *	.35	4362	6484	
Treatment	1	5520533 *	2589.48 *	12289004345 **	103203	42.78	.43	348.75	299	5922	
Date*trt	1	3557618 *	2168.44	605476501	984569 *	.28	.67	1988.91 *	15	863	
Error(b)	2	103749	141.53	74968660	17691	5.78	.05	38.69	423	1213	

* Significant at the .05 level
** Significant at the .01 level

Table A-22. Mean cumulative total soil water depletion (-(swd) + cumulative rainfall). Manhattan 1985.

Day of Year	Cumulative Rainfall	Treatment Number[1] with corresponding total soil water depletion (cm water/110cm soil profile). 1113	1121	1123[a]	1211	1213	1221	2113	2121	2123	2211[b]	2213	2221	LSD .05
165		.00	.00	.00	.00	.00	.00							
185	.00	4.79[2]	4.79	4.79	4.79	4.79	4.79	.00	.00	.00	.00	.00	.00	
191	.00	6.53	6.08	6.76	5.80	7.09	5.95	-.19	.52	.28	.63	.07	.19	1.22
201	.70	9.30	7.72	9.38	9.38	10.61	8.24	1.22	1.62	1.86	1.82	1.36	1.35	1.60
209	3.20	12.54	11.02	11.72	12.98	13.56	11.24	4.04	4.79	5.15	5.22	4.98	5.13	3.34
217	8.80	12.26	12.67	12.69	14.46	16.57	13.83	7.50	8.32	8.13	7.99	6.81	8.14	3.68
224	11.00	14.64	15.04	15.86	16.87	19.08	17.12	10.89	11.42	11.43	11.29	10.74	11.88	3.84
231	15.10	17.75	18.60	18.68	20.24	22.76	21.48	15.49	16.11	14.87	15.04	13.76	15.51	3.66
238	16.30	21.00	20.95	21.63	22.57	24.32	23.47	17.83	18.46	16.21	16.81	16.68	18.07	3.36
245	16.30	25.11	23.56	25.27	24.90	26.35	26.38	20.09	20.84	19.16	19.50	19.77	20.27	3.28
252	16.30	27.01	25.04	26.99	27.26	27.54	28.08	22.27	22.57	21.03	21.55	21.68	21.57	3.81
259	19.60	24.06	25.05	26.06	26.52	27.44	27.16	22.49	22.79	20.56	20.73	20.62	22.22	3.72
268	25.70	28.85	28.63	28.61	30.28	30.96	31.00	23.63	24.22	23.69	24.07	25.29	25.23	2.15
289	36.70	38.93	38.74	38.01	39.65	37.28	39.33	34.34	33.63	33.45	34.47	33.21	33.69	1.82

[1]Treatment number $x^a x^b x^c x^d$ where x^a = Date of planting; 1=first, 2=second
x^b = Rate of planting; 1=low, 2=high
x^c = Row spacing; 1=25cm, 2=76cm
x^d = Hybrid maturity; 1=early, 2=medium, 3=late

[2]The 4.79 cm of soil water depletion between dates 165 and 185 was determined using the SORGF computer model.

[a]Conventional
[b]Superthick

Table A-23. Means for yield, lodging percent, plants per hectare, heads per hectare seeds per head, seed weight, and half bloom date. Manhattan 1985.

Date of Planting	Hybrid (maturity)	Desired Population (plants/ha)	Row Spacing (cm)	Yield (kg/ha)	Lodging (%)	Plants/Ha	Heads/Ha	Seeds per Head	Seed weight (g/1000)	Bloom Date (Day of Year)
6/14/85	Early	123,500	76	5725	0.0	116235	185115	1285	23.00	219
		246,900	25	6335	0.0	144218	189420	1913	21.25	220
		246,900	76	7549	0.0	189.42	217403	1446	23.00	219
	Late	123,500	25	5112	0.0	111930	148523	1732	19.00	235
		123,500	76	6298	0.0	144218	157133	1510	20.00	233
		246,900	25	5725	0.0	278390	223860	1254	19.50	233
7/1/85	Early	123,500	76	4713	0.0	111930	116235	2036	19.00	238
		246,900	25	4711	0.0	211663	261529	2008	15.75	239
		246,900	76	4718	0.0	307090	299198	969	15.50	237
	Late	123,500	25	3709	0.0	90405	116235	2328	13.00	246
		123,500	76	3863	0.0	137043	135608	1116	13.50	245
		246,900	25	2772	0.0	179375	200183	909	14.50	246

Table A-24. Means for leaf area index, specific leaf area, leaf dry matter, stem dry matter and grain dry matter. Manhattan, 1985.

Date of Planting	Hybrid (maturity)	Desired Population (plants/ha)	Row Spacing (cm)	Leaf Area Index	Specific Leaf area (cm2/g)	Leaf DM (g/m2)	Stem DM (g/m2)	Grain DM (g/m2)
6/14/85	Early	123,500	76	2.51	172.1	146.1	254.8	101.4
		246,900	25	2.73	171.3	159.2	275.8	115.1
		246,900	76	3.53	172.4	204.7	366.9	142.8
	Late	123,500	25	5.13	172.5	297.3	332.3	129.8
		123,500	76	5.72	178.1	320.1	410.7	165.2
		246,900	25	5.63	180.5	312.1	379.6	147.9
7/1/85	Early	123,500	76	2.77	176.3	157.3	244.9	101.4
		246,900	25	3.52	185.2	188.7	254.1	92.5
		246,900	76	4.15	195.0	212.9	329.5	131.1
	Late	123,500	25	5.05	175.9	287.4	382.7	178.4
		123,500	76	4.44	175.8	252.7	369.6	174.0
		246,900	25	5.44	181.9	299.3	380.1	152.4

Table A-25. Mean cumulative total soil water depletion (-(swd) + cumulative rainfall). Hutchinson 1985.

Day of Year	Cumulative Rainfall	Treatment Number[1] with corresponding total soil water depletion (cm water/240cm soil profile). 1112	1121	1122[a]	1211	1212	1221	2112	2121	2122	2211[b]	2212	2221	LSD .05
149		.00	.00	.00	.00	.00	.00							
184	.00	9.24[2]	9.24	9.24	9.24	9.24	9.24	.00	.00	.00	.00	.00	.00	
197	.00	14.68	19.48	14.30	13.32	14.12	14.80	.62	1.04	3.27	2.12	2.58	.96	6.00
212	10.82	20.28	28.70	17.20	22.63	20.70	23.06	10.20	10.36	13.36	11.24	12.62	11.46	16.78
221	13.27	25.19	32.29	28.27	27.15	27.19	28.81	15.03	15.35	17.89	16.60	16.71	16.65	2.95
227	16.62	28.58	32.76	30.42	28.15	29.96	31.98	17.78	15.90	20.88	19.87	19.80	21.20	4.67
241	19.80	35.88	40.12	36.34	35.08	36.88	38.50	25.04	21.12	28.14	26.95	26.02	25.22	3.30
249	19.80	38.74	45.12	39.99	37.62	39.82	41.06	29.60	27.54	32.49	31.86	30.26	28.66	3.53
262	23.52	40.48	46.14	41.65	38.64	41.98	43.96	31.70	29.98	36.36	34.01	35.34	32.44	2.74
277	34.80							37.38	36.64	43.12	40.46	40.46	39.98	15.50

[1]Treatment number $x^a x^b x^c x^d$ where x^a = Date of planting; 1=first, 2=second
x^b = Rate of planting; 1=low, 2=high
x^c = Row spacing; 1=25cm, 2=76cm
x^d = Hybrid maturity; 1=early, 2=medium, 3=late

[2]The 9.24 cm of soil water depletion between dates 149 and 184 was determined using the SORGF computer model.

[a]Conventional
[b]Superthick

Table A-26. Means for yield, lodging percent, plants per hectare, heads per hectare, seeds per head, seed weight, and half bloom date. Hutchinson 1985.

Date of Planting	Hybrid (maturity)	Desired Population (plants/ha)	Row Spacing (cm)	Yield (kg/ha)	Lodging (%)	Plants/Ha	Heads/Ha	Seeds per Head	Seed weight (g/1000)	Bloom Date (Day of Year)
5/29/85	Early	86,400	76	820	3.0	73185	142065	239	23.00	206
		246,900	25	3448	4.9	253995	275520	615	26.75	207
		246,900	76	1709	11.2	202335	281260	219	26.50	206
	Medium	86,400	25	2999	29.6	114800	154980	841	22.00	211
		86,400	76	1675	32.8	90405	114083	457	22.50	210
		246,900	25	3753	22.0	179375	169330	1058	20.00	212
6/24/85	Early	86,400	76	4289	2.0	91840	107625	1774	21.50	223
		246,900	25	3842	25.0	149958	195878	2574	16.75	225
		246,900	76	4606	2.3	182245	189420	1255	18.50	225
	Medium	86,400	25	4289	2.0	86100	105473	2358	16.50	229
		86,400	76	4184	8.3	76773	90405	1114	17.25	229
		246,900	25	4187	0.0	120540	144218	1684	16.50	228

Table A-27. Means for leaf area index, specific leaf area, leaf dry matter and stem dry matter. Hutchinson 1985.

Date of Planting	Hybrid (maturity)	Desired Population (plants/ha)	Row Spacing (cm)	Leaf Area Index	Specific Leaf area (cm2/g)	Leaf DM (g/m2)	Stem DM (g/m2)
5/29/85	Early	86,400	76	1.78	119.0	149.5	439.1
		246,900	25	4.07	169.3	239.2	599.4
		246,900	76	3.24	206.0	157.1	375.6
	Medium	86,400	25	4.03	156.5	257.7	386.5
		86,400	76	2.94	164.0	181.1	388.3
		246,900	25	4.30	174.3	247.0	470.4
6/24/85	Early	86,400	76	1.85	128.8	143.7	259.3
		246,900	25	1.59	116.9	133.1	223.2
		246,900	76	2.71	156.0	173.9	293.3
	Medium	86,400	25	4.54	154.1	294.4	526.4
		86,400	76	2.05	116.2	192.6	275.4
		246,900	25	3.40	150.0	226.9	385.0

Table A-28. Mean cumulative total soil water depletion (-(swd) + cumulative rainfall). St. John 1985.

Day of Year	Cumulative Rainfall	Treatment Number[1] with corresponding total soil water depletion (cm water/110cm soil profile). 1112	1121	1122[a]	1211	1212	1221	2112	2121	2122	2211[b]	2212	2221	LSD .05
150		.00	.00	.00	.00	.00	.00							
176	.00	5.18[2]	5.18	5.18	5.18	5.18	5.18	.00	.00	.00	.00	.00	.00	
183	3.85	6.25	6.79	6.46	7.81	7.21	6.65	2.01	2.05	1.66	1.43	2.01	1.35	3.55
192	3.85	9.65	8.97	9.21	11.60	12.09	9.43	2.73	3.55	2.56	2.56	2.89	2.87	3.15
198	3.85	14.53	9.79	11.17	13.74	14.23	10.39	3.29	4.81	3.62	3.03	3.33	3.81	3.82
212	8.90	19.52	13.78	15.05	19.89	18.20	12.04	8.92	7.22	8.31	9.63	9.34	9.14	2.94
221	12.75	22.01	16.95	19.10	22.35	22.79	15.51	11.61	10.81	12.23	13.97	13.11	11.93	2.17
227	14.13	25.39	19.73	22.23	25.43	26.03	18.27	15.33	13.61	14.41	17.32	15.89	15.19	2.78
246	19.95	27.63	23.67	25.79	27.00	29.21	22.29	20.53	18.05	20.35	21.84	22.87	20.45	3.49

[1]Treatment number $x^a x^b x^c x^d$ where x^a = Date of planting; 1=first, 2=second
x^b = Rate of planting; 1=low, 2=high
x^c = Row spacing; 1=25cm, 2=76cm
x^d = Hybrid maturity; 1=early, 2=medium, 3=late

[2]The 5.18 cm of soil water depletion between dates 150 and 176 was determined using the SORGF computer model.

[a]Conventional
[b]Superthick

Table A-29. Means for yield, lodging percent, plants per hectare, heads per hectare, seeds per head, seed weight, and half bloom date. Saint John 1985.

Date of Planting	Hybrid (maturity)	Desired Population (plants/ha)	Row Spacing (cm)	Yield (kg/ha)	Lodging (%)	Plants/Ha	Heads/Ha	Seeds per Head	Seed weight (g/1000)	Bloom Date (Day of Year)
5/30/85	Early	86,400	76	1966	0.0	114800	103320	690	26.50	217
		246,900	25	3649	0.3	297045	271215	1864	25.75	211
		246,900	76	2446	0.7	268345	222425	398	26.50	215
	Medium	86,400	25	3660	0.0	96145	101885	1606	21.50	220
		86,400	76	3553	0.0	87535	88970	497	20.75	221
		246,900	25	4666	0.0	208075	219555	975	21.00	220
6/24/85	Early	86,400	76	2179	0.0	97580	103320	1035	19.50	238
		246,900	25	4449	0.0	175788	214533	1808	19.00	235
		246,900	76	2720	0.0	196595	175070	763	19.50	236
	Medium	86,400	25	4444	0.0	107625	173635	1501	16.50	244
		86,400	76	2109	0.0	73903	69598	1024	15.75	245
		246,900	25	4256	0.0	101885	109060	2352	16.00	240

Table A-30. Mean cumulative total soil water depletion (-(swd) + cumulative rainfall). Tribune 1985.

Day of Year	Cumulative Rainfall	Treatment Number[1] with corresponding total soil water depletion (cm water/240cm soil profile). 1112	1121	1122[a]	1211	1212	1221	2112	2121	2122	2211[b]	2212	2221	LSD .05
151		.00	.00	.00	.00	.00	.00							
179	.00	3.62[2]	3.62	3.62	3.62	3.62	3.62	.00	.00	.00	.00	.00	.00	
199	.60	5.38	5.26	5.08	8.08	7.30	7.58	.14	1.02	.19	.76	.32	.12	11.64
220	6.00	13.92	13.62	13.88	16.64	15.64	16.28	5.12	6.22	4.01	5.76	5.02	5.64	9.99
248	8.50	26.72	25.16	22.76	24.89	26.08	26.92	15.24	18.36	15.77	19.68	18.70	15.58	12.07
270	11.70	27.02	27.00	26.85	28.03	30.22	28.30	15.50	20.64	20.00	20.76	21.88	18.04	15.08
299	16.10	32.04	32.86	27.60	29.16	30.32	33.46	22.52	27.60	22.33	25.74	22.20	23.62	9.65

[1]Treatment number $x^a x^b x^c x^d$ where x^a = Date of planting; 1=first, 2=second
x^b = Rate of planting; 1=low, 2=high
x^c = Row spacing; 1=25cm, 2=76cm
x^d = Hybrid maturity; 1=early, 2=medium, 3=late

[2]The 3.62 cm of soil water depletion between dates 151 and 179 was determined using the SORGF computer model.

[a]Conventional
[b]Superthick

TableA-31. Means for yield,lodging percent, plantsper hectare, heads per hectare, seeds per hectare, seed weight, and half bloom date. Tribune 1985.

Date of Planting	Hybrid (maturity)	Desired Population (plants/ha)	Row Spacing (cm)	Yield (kg/ha)	Lodging (%)	Plants/Ha	Heads/Ha	Seeds per Head	Seed weight (g/1000)
5/31/85	Early	49,400	76	3235	0.0	48790	74620	1996	21.00
		148,200	25	2512	3.1	178658	139195	1897	18.25
		148,200	76	3693	0.0	185115	127715	1836	15.00
	Medium	49,400	25	2937	0.0	67445	73185	2640	14.50
		49,400	76	2185	0.0	49508	78208	969	14.00
		148,200	25	2530	0.0	137760	110495	1558	14.00
6/28/85	Early	49,400	76	2081	10.0	50225	107625	1101	16.50
		148,200	25	3624	68.9	107625	159285	1009	14.50
		148,200	76	2390	75.0	109060	111930	1339	15.00
	Medium	49,400	25	1050	3.2	33005	66728	1274	11.50
		49,400	76	629	2.3	45203	63499	1484	9.50
		148,200	25	2618	0.0	106190	137760	1773	10.00

Table A-32. Means for leaf area index, specific leaf area, leaf dry matter and stem dry matter. Tribune 1985.

Date of Planting	Hybrid (maturity)	Desired Population (plants/ha)	Row Spacing (cm)	Leaf Area Index	Specific Leaf area (cm2/g)	Leaf DM (g/m2)	Stem DM (g/m2)
5/31/85	Early	49,400	76	1.86	145.5	128.1	274.1
		148,200	25	3.57	176.2	202.2	346.3
		148,200	76	3.18	213.6	148.9	211.2
	Medium	49,400	25	2.84	125.6	225.8	369.3
		49,400	76	2.53	131.5	192.7	312.7
		148,200	25	4.39	142.1	309.1	424.5
6/28/85	Early	49,400	76	2.05	157.2	130.1	225.3
		148,200	25	2.18	144.3	158.2	310.1
		148,200	76	3.29	179.4	183.4	165.8
	Medium	49,400	25	2.43	136.0	178.4	245.3
		49,400	76	2.30	162.6	143.3	235.0
		148,200	25	4.05	165.0	245.7	391.2

COMPARISON OF SUPERTHICK AND CONVENTIONAL GRAIN SORGHUM MANAGEMENT SYSTEMS AND RELATED COMPONENTS

by

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Abstract

Grain sorghum has normally been grown in wide row spacings, at low plant populations, with a full season maturity hybrid, and as early a planting date as possible. A new management system was developed in the western half of Kansas called "superthick". This system is planted in narrow row spacings, at 2 to 3 times the normal "low" populations, utilizes an earlier maturity hybrid, and is planted 3 to 4 weeks later in the growing season.

The superthick management system reduces the exposed soil surface and could contribute to less erosion. Other possible advantages may include, planting with a grain drill and distributing the work load more uniformly over the season. There is interest in expanding this system into grain sorghum producing areas in other parts of the state.

From 1983 to 1985 research was conducted at five locations across Kansas. The objective of the experiment was to compare the yields of the superthick and conventional management systems over a diverse range of environmental conditions. Two row spacings (25 and 76 cm), two seeding rates (normal and 2 to 3 times normal), and three hybrid maturities (early, medium, and late) were planted at two times (late May to early June, and late June to early July) at all locations.

The growing seasons for 1983 and 1984 were hot and dry resulting in lower than expected yields. Above normal rainfall and lower than normal temperatures prevailed in 1985. All three years experienced earlier than normal killing frosts. Yields of

the later maturing hybrids and the late planting date were frequently reduced by the early frost. The higher plant population usually produced higher yields under good moisture conditions. No yield trend was established for the two row spacings.

Comparison of the two management systems found no significant differences in yield except when yields were reduced by early frosts or bird damage. Results of this study show that the superthick system could be an alternate method of producing grain sorghum with little fear of yield loss, if planting date and hybrid maturity combinations were used to allow maturation before frost.