THE INFLUENCE OF PRODUCTION PRACTICES ON AGRONOMIC PERFORMANCE AND COMPONENTS OF YIELD AND EXAMINATION OF GENETIC DIVERSITY FOR LEAF CANOPY TEMPERATURE IN SOYBEANS

by

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CHAPTER I

THE INFLUENCE OF PLANTING DATE, IRRIGATION, ROW WIDTH AND GROWTH HABIT ON AGRONOMIC PERFORMANCE OF TWENTY SOYBEAN GENOTYPES

INTRODUCTION

Soybeans are grown in different production systems in Kansas. Row widths vary from approximately 18 to 76 centimeters. Conventional planting dates occur in late May with planting dates for soybeans grown as a double crop ranging from late June to mid July. Soybeans are also grown with or without supplemental irrigation. Within each of these production systems or with a combination of these practices, differences in varietal response may exist.

In several instances researchers have found a yield advantage when reducing row spacings to less than 50 cm (6, 7, 4, 13, 14). Gilman (10) however, found yields to be higher at the intermediate spacing (76 cm) when compared to 25, 50 and 101 cm spacings. Genotype x row spacing interactions have been significant in some studies (4, 17, 15) and not significant in others (6, 10). From the conflicting reports it may be assumed that environmental conditions play a key role in yield response to narrow rows (12). Several studies have examined the effect of planting date on soybean seed yield and most researchers agreed that a delay in planting reduces yield, however, not all genotypes respond the same. Carter (3) reported that early maturing varieties suffered less yield reduction than did late maturing varieties when planting was delayed two weeks. Planting date x variety interactions were also reported by Cooper (5), Carter (4) and Gilman (9).

Williams (18) and Smith (16) testing determinate soybeans and Costa (7) and Cooper (6) when testing indeterminate types found an increase in yield at the narrower row spacings.

It has been postulated that yield of indeterminate soybean types may be reduced due to competition between vegetative and reproductive growth but that this extended flowering period may result in more total photosynthate production and thus compensate for this competition (8). With this information in mind, the type of growth habit may play a role in the genotype x production system response.

This experiment was conducted to better define the magnitude of genotype by production system interactions and determine what changes in a breeding program might be necessitated by their existence. This is of special importance to the soybean breeder interested in developing lines, whether determinate or indeterminate, for particular production system needs.

MATERIALS AND METHODS

The experiment was conducted at the Ashland Agronomy Research Farm in Manhattan, Kansas in 1980 and 1981. In 1980, the soybean plots were planted in a Muir silt loam soil classified as a Pachic Haplustoll, fine-silty, mixed, mesic. No fertilizer was applied. In early May, prior to planting, approximately 2.47 liters/ha of Trifluralin were applied and at planting 3.36 kg/ha of Chloramben (3-amino-2, 5-dichlorobenzoic acid) were applied. In 1981, the study was planted in an Eudora silt loam soil classified as a Fluventic Hapludoll, coarse-silty, mixed, mesic. Approximately 111 kg/ha of 18-46-0 fertilizer was applied late in April. At mid-April 2.47 liters/ha of Trifluralin were applied and at planting 3.36 kg/ha of Chloramben were applied. Total average montly rainfall from May to September in 1980 was below normal for each month and throughout the season. In 1981, however, monthly rainfall averages were above normal in May, June and July, one cm below normal in August, and 6.6 cm below normal in September. Average monthly and average maximum and minimum temperatures were above normal from June to September in 1980. Average temperatures in 1981 for the same period, were near or below normal temperatures (Appendix Table A-1).

The experimental design of this study was a split-split-plot with irrigation and dates as whole plots, row widths as sub-plots and genotypes as sub-sub-plots. There were two planting dates (1980; May 25 and June 30, 1981; May 21, and July 1) and two irrigation treatments (an irrigated treatment and a dryland treatment). There were two row widths, wide rows (76 cm) and narrow rows (25 cm). Twenty genotypes consisting of fourteen cultivars and six experimental lines were chosen to represent both determinate and indeterminate growth habits from maturity groups III, IV and V (Table 1.1). Maturity group IV was further divided into early maturity group IV's (IV-E) and late maturity group IV's (IV-L) for analysis.

Table 1.1. Twenty soybean genotypes categorized by growth habit and maturity group.

MGIII	MGIV-E	MGIV-L	MGV
	Indeterminates		
Calland	Cutler 71	Crawford	
Cumberland	DeSoto	Douglas	
Williams 79		C1573	
	Determinates		
Hobbit	Pixie	V76-482	Essex
K-74-108	K1049	V76-398	Dare
Elf		K1048	Forrest
			Bedford

The narrow row plots consisted of ten rows 5.8 meters long with plant populations of 60,362 plants/hectare with the center six rows machine harvested for seed yield. The wide row plots consisted of four rows of each genotype 5.8 meters long with plant populations of 50,331 plants/hectare and the two center rows machine harvested for seed yield. Harvest row length was 4.3 meters in both 76 and 25 cm spacings. Agronomic data recorded, including seed yield, consisted of date of maturity (date when 95% of the pods have ripened or turned brown), lodging (as a score of from one to five, 1 = all plants erect, 5 = all plants prostrate), and plant height in cm.

The data were analyzed by maturity group for individual years and a combined analysis over years (Appendix Tables A-2 - A-5) using an analysis of variance procedure with yield, maturity, lodging, and height as dependent variables and genotypes, row widths, irrigation, and planting date, and their interactions as independent variables.

RESULTS AND DISCUSSION

Years

Years were significantly different for yield, maturity, and lodging in all maturity groups and for plant height in maturity group IV-L (Table 1.2). Yields were significantly higher in 1981 than in 1980 with yields in 1980 reaching only 53 to 61% of the 1981 yields. Maturity dates differed by one or two days across years. In maturity group III dates of maturity averaged two days later in 1980 than in 1981. In maturity group IV-E, however, maturity dates were approximately one day earlier in 1980, as compared to 1981. Lodging scores were significantly higher in 1981 in all maturity groups due to growing conditions being much improved over 1980. Plants tended to be taller in 1981 in all maturity groups, but only significantly so in maturity group IV-L.

In general, in 1981, with improved climatic conditions, plants were taller, lodging scores were greater and yields were improved.

Row Width

No significant row width or variety by row width response existed for yield, maturity, or height in any of the maturity groups tested. A significant variety by row width response was seen for lodging scores in maturity group IV-E only. In this maturity group, lodging scores across row widths were not significantly different for any genotypes. The interaction comes from the difference in response of the indeterminates, DeSoto and Cutler 71 which had higher lodging scores in the narrow rows, and the determinates, Pixie and K1049. Pixie had the same score in both row spacings and K1049 showed an increase in lodging in the wide rows.

Table 1.2. Seed yield, plant maturity, lodging scores, and plant height of 20 soybean genotypes across years.

Year	Maturity Group III	Maturity Group IV-E	Maturity Group IV-L	Maturity Group V
		YIELD		
		kg/ha		
1980	2923[+]a[‡]	2923a	2863a	2211a
1981	1788b	1788b	1559b	1176b
		MATURITY		
		month/day		
1980	10/1a	10/3b		
1981	9/29b	10/4a		
		LODGING		
		score		
1980	1.3a	1.4a	1.8a	2.6a
1981	1.6b	1.6b	2.3b	3.1b
		HEIGHT		
		cm		
1980	69a	75a	85a	96a
1981	71b	80b	92b	97a

[+]Means are averaged over two planting dates, two row widths, and two irrigation treatments.

[‡]Means within a column followed by the same letter are not significantly different at the 0.05 level of probability.

The year by row width interaction was significant for yield in maturity group IV-E; the average yield of wide row plots was greater than that of narrow row plots in 1980 and the opposite was true in 1981. This year by row width interaction was also significant for maturity in maturity group III. In 1980, the row width effect was not significant for maturity but was in 1981 with the narrow row plots less than one day later in maturity date than the wide row plots.

For lodging scores, the year by row width interaction was significant in maturity groups III and IV-E. In maturity group III, in both 1980 and 1981, lodging scores across row widths were significantly different. However, in 1980, lodging was significantly greater in the wide rows than the narrow rows and in 1981, the opposite was true. No significant year by row width interaction was seen for plant height.

Planting Dates

In the two-year analysis, planting dates were significant for yield, maturity, lodging and height in all maturity groups. Yields were consistently larger in the first planting date with yield reductions of 21, 21, 20, and 42% in maturity groups III, IV-E, IV-L, and V, respectively. Maturity dates were delayed approximately 16 days in maturity groups III and IV-E, which represents a one day delay in maturity for every two days planting was delayed. Maturity dates for the late group IV and group V genotypes were not included in the analyses because of frost occurring October 12, 1980 and October 19, 1981. Lodging scores decreased significantly in the late planted material in maturity groups III, IV-L and V. In maturity group IV-E, the same trend existed, with higher lodging scores at the early date of planting but the averages across dates were not significantly different.

The widest range in lodging scores was seen to exist in the later maturity groups, IV-L and V. Plant height was significantly reduced when planting was delayed which accounted for the lower lodging socres. This reduction in plant height was significant in all maturity groups with the largest range again in the later maturity groups, IV-L and V.

In general, delaying planting approximately five weeks caused a reduction in yield of from 20 to 40%, a two week delay in maturity, a decrease in the amount of lodging and reduced plant heights.

Year x Planting Date

A year by planting date interaction was significant for yield, maturity, and plant height in all maturity groups and for lodging in maturity groups IV-L and V (Table 1.3). The greatest differences in yield between dates were seen in 1981 when conditions were more condusive to high yields. This is further emphasized by the fact that in maturity group IV-L in 1980 yield was not significantly reduced by a delay in planting. In both years, maturity date was delayed with a delayed planting date, however, in 1980 in both maturity group III and IV-E, maturity date was delayed 15 days and in 1981 the delay was 18 and 19 days in maturity groups III and IV-E, respectively. The planting dates were not the same for both years. In 1981, plots were planted four days earlier and one day later than plots planted in 1980. This would explain the earlier maturity date of the material planted at the conventional or early planting in 1981 and the slightly later maturity of the delayed planting in the same year. Only in maturity groups IV-L and V was the year by date interaction significant for lodging. A greater difference in lodging scores between the early and late plantings was observed in 1981 than in 1980. Plant height responded in

Table 1.3. Seed yield, plant maturity, lodging scores, and plant height of 20 soybean genotypes across planting dates, within years.

Planting Date	Maturity Group III	Maturity Group IV-E	Maturity Group IV-L	Maturity Group V
	YIELD			
	kg/ha			
1980				
Early	1935a+	1902a	1734a	1519a
Late	1646b	1539b	1384b	840b
1981				
Early	3333a	3279a	3192a	2775a
Late	2520b	2567b	2540b	1646b
	MATURITY			
	month/day			
1980				
Early	9/23a	9/25a		
Late	10/8b	10/10b		
1981				
Early	9/20a	9/24a		
Late	10/8b	10/13b		
	LODGING			
	score			
1980				
Early	1.4a	1.5a	2.1a	2.7a
Late	1.3b	1.4b	1.5b	2.5b
1981				
Early	1.8a	1.8a	2.9a	3.6a
Late	1.5b	1.5b	1.8b	2.7b
	HEIGHT			
	cm			
1980				
Early	71a	80a	92a	102a
Late	66b	70b	78b	89a
1981				
Early	82a	90a	107a	111a
Late	61b	69b	77b	84b

+Means across planting dates within a year, followed by the same letter are not significantly different at the 0.05 level of probability.

much the same way as did lodging. The range of plant heights between planting dates in 1980 was less than in 1981.

The differences in climatic conditions in 1980 and 1981 were enough to cause a significant year by date interaction. In 1980, plants were under both moisture and heat stress. This stress reduced the differences caused by delaying planting for seed yield, lodging, and plant height. Maturity date differences were affected more by the differences in planting dates of the two years than by planting dates within a year.

Irrigation

Irrigation treatment was significant in the two-year analysis in all maturity groups for yield, maturity, and plant height and in maturity groups III, IV-L and V for lodging (Table 1.4). Seed yields were reduced approximately 20% when grown under non-irrigated conditions. This reduction occurred in all maturity groups. Maturity date was delayed approximately two days when plots were irrigated, a small but significant delay. In all maturity groups lodging scores were larger when plots were irrigated with the greatest increase in MGIV-L and MGV. This increase was accompanied by a significant increase in plant height under irrigation. It should be noted that these later maturity groups, IV-L and V, which showed the greatest lodging response to irrigated conditions, were also the tallest plants and had the lowest yields.

Irrigation is used to decrease plant moisture stress, however, during rapid vegetative growth excess moisture can prove to be detrimental to yield. In the case of later maturing genotypes, if early lodging problems are encountered (6), this vegetative growth continues

Table 1.4. Seed yield, plant maturity, lodging scores, and plant height of 20 soybean genotypes across irrigation treatments.

Irrigation Treatment	Maturity Group III	Maturity Group IV-E	Maturity Group IV-L	Maturity Group V
	YIELD			
	kg/ha			
Irrigated	2621[+]a[‡]	2607a	2439a	1902a
Non-irrigated	2090b	2036b	1982b	1485b
	MATURITY			
	month/day			
Irrigated	10/1a	10/4a		
Non-irrigated	9/29b	10/2b		
	LODGING			
	score			
Irrigated	1.6a	1.6a	2.3a	3.4a
Non-irrigated	1.4b	1.5a	1.9b	2.4b
	HEIGHT			
	cm			
Irrigated	73a	81a	93a	99a
Non-irrigated	67b	73b	83b	94a

[+]Means are averaged over two years, two planting dates, and two row widths.

[‡]Means within a column followed by the same letter are not significantly different at the 0.05 level of probability.

for a longer time before the initiation of flowering. Here irrigation applied to earlier genotypes may prove to be beneficial, and at the same time detrimental to later maturing genotypes.

Year x Irrigation

A significant year by irrigation effect was seen to exist for yield, maturity and lodging in all maturity groups and for height in maturity group III (Table 1.5). In all cases where this interaction was significant, the response to irrigation in 1980 was much greater than the response in 1981. For example, yields under non-irrigated conditions in 1980 were only approximately 60% of the yields of plots under irrigation. In 1981, however, non-irrigated plots yielded from 88% (in maturity group IV-E) to 95% (in maturity group III) of their irrigated counterparts. The differences in maturity dates between irrigated and non-irrigated plots in 1980 were greater than the same comparisons in 1981. Significant differences in lodging scores across irrigation treatments existed in 1980 in all maturity groups. Only in maturity group V, in 1981, were these differences significant. In maturity group III, where the year by irrigation interacton was significant for plant height, an 11.4 cm difference across irrigation treatments in 1980 existed and only a 1.5 cm difference existed in 1981.

The magnitude of the stress under non-irrigated conditions in 1980 was greater than the stress encountered under the same conditions in 1981, therefore causing a significant year by irrigation interaction. The trend which existed for the significant irrigation effect also exists in this year by irrigation effect with the difference in years mainly being the degree of change within a maturity group across irrigated and non-irrigated conditions for a given agronomic trait.

Table 1.5. Seed yield, plant maturity, lodging scores, and height of soybean genotypes within a maturity group, across irrigation treatments, within a year.

Irrigation Treatment	Maturity Group III	Maturity Group IV-E	Maturity Group IV-L	Maturity Group V
		YIELD		
		kg/ha		
1980				
Irrigated	2237a+	2123a	1915a	1512a
Non-irrigated	1344b	1323b	1202b	846b
1981				
Irrigated	3003a	3097a	2970a	2291a
Non-irrigated	2842a	2748b	2755b	2130a
		MATURITY		
		month/day		
1980				
Irrigated	10/2a	10/4a		
Non-irrigated	9/29b	10/1b		
1981				
Irrigated	9/29a	10/4a		
Non-irrigated	9/29a	10/3b		
		LODGING		
		score		
1980				
Irrigated	1.5a	1.6a	2.3a	3.4a
Non-irrigated	1.1b	1.2b	1.4b	1.9b
1981				
Irrigated	1.5a	1.6a	2.2a	3.4a
Non-irrigated	1.7a	1.7a	2.4a	2.9b
		HEIGHT		
		cm		
1980				
Irrigated	74a	80a	93a	100a
Non-irrigated	63b	70b	77b	92b
1981				
Irrigated	72a	82a	94a	99a
Non-irrigated	71a	78a	90a	95a

+Letters used to indicate significant differences within a year. Means followed by the same letter are not significantly different at the .05 level of probability.

Date x Variety

A significant date by variety interaction in the two year analysis was observed for yield in all four maturity divisions (Table 1.6a) accompanied by a significant year by date by variety interaction in maturity groups IV-E and IV-L (Table 1.6b). In maturity group III, Hobbit, a variety with a determinate growth habit, moved up in yield rank from fifth at the early planting date to first when planting was delayed. This yield, however, was not significantly different from that of Cumberland at the delayed planting date. Hobbit was the only genotype within maturity group III which had yields which did not differ significantly across planting dates. The rankings across planting dates of the other genotypes showed little change. Yields in maturity group V, at the late planting date, were influenced by a frost prior to physiological maturity. Bedford, which matures latest of the four varieties, had the greatest reduction in yield thus giving rise to a date by variety interaction in maturity group V. A significant year by date by variety interaction for yield occurred in maturity group IV-E. In 1981, the date by variety interaction was not significant. The relative yield of all genotypes was the same at both planting dates. In 1980, however, yields of the two determinate genotypes, Pixie and K1049, did not differ significantly across planting dates and rose in yield rank at the late planting date. Certain genotypes in maturity group IV-L had yields from the delayed planting which were influenced by a frost prior to physiological maturity. In both 1980 and 1981 the year by date interaction was significant for late group IV genotypes, however, the interaction in 1980 was not the same as that in 1981.

The two genotypes, Crawford and V76-398, in 1980 which were killed by frost prior to physiological maturity were the only genotypes which

Table 1.6a. Yield of soybean genotypes across planting dates with yields representing two-year averages.

Maturity Group III Genotype	YIELD Early	Rank	Late	Rank	Maturity Group V Genotype	YIELD Early	Rank	Late	Rank
	kg/ha		kg/ha			kg/ha		kg/ha	
Cumberland	2917	1	2191	2 *	Essex	2594	1	1747	1 * F[+]
Calland	2520	6	1956	6 *	Forrest	2197	2	1142	3 * F
Williams 79	2661	2	2056	3 *	Dare	1969	3	1257	2 * F
Hobbit	2520	5	2258	1	Bedford	1821	4	827	4 * F
K74 - 108	2587	4	2023	4 *					
Elf	2594	3	2016	5 *					
LSD within columns	164					131			
LSD between colums	306					262			

*Means across dates within a maturity group are significant at the 0.05 level.

+,F indicates genotypes killed by frost prior to physiological maturity in the second planting date.

Table 1.6b. Yield of soybean genotypes across planting dates within years.

		YIELD							
		1980				1981			
Genotype	Maturity Group	Early	Rank	Late	Rank	Early	Rank	Late	Rank
		kg/ha		kg/ha		kg/ha		kg/ha	
DeSoto	IV-E	2117	1	1344	4 *	3340	2	2688	1 *
Cutler 71	IV-E	1841	3	1405	3 *	3024	4	2433	4 *
Pixie	IV-E	1969	2	1888	1	3481	1	2527	3 *
K1049	IV-E	1673	4	1525	2	3259	3	2621	2 *
LSD within columns		223				243			
LSD between columns		241				303			
Crawford	IV-L	1828	2	1196	5 * F	2755	6	2574	3 F+
Douglas	IV-L	1909	1	1573	2	3703	1	2816	1 * F
C1573	IV-L	1700	4	1411	3	3421	2	2621	2 * F
V76 - 482	IV-L	1552	6	1337	4	3246	3	2460	4 * F
V76 - 398	IV-L	1599	5	1129	6 * F	3091	4	2318	6 * F
K1048	IV-L	1808	3	1646	1	2943	5	2439	5 *
LSD within columns		205				205			
LSD between columns		401				258			

*Means across dates within a year are significantly different at the 0.05 level.

+,F indicates genotypes killed by frost prior to physiological maturity in the second planting date.

had significantly lower yields in the late planting compared to the early date. In 1981, yields were higher and yield reductions were significant at the late planting date for all genotypes with the exception of Crawford. It should be noted however, that this genotype had the lowest yield at the conventional planting date. The rankings of these genotypes across planting dates and across years differed little with the exception of K1048 which ranked third and first across dates in 1980 and fifth and fifth across dates in 1981.

The difference in the magnitude of environmental stress in 1980 and 1981 was the apparent cause of the year by date by variety interaction. Under more favorable growing conditions which existed in 1981, a larger range in yields across planting dates resulted, as compared to the range in 1980.

As stated earlier, an average delay of 16 days in maturity occurred when planting was delayed from late May to early July. Genotypic responses to the delayed planting differed within a maturity group (Table 1.7). A significant year by date by variety interaction existed in both maturity group III and IV-E. In maturity group III, the short determinate genotypes, Hobbit and Elf, had the least delay in maturity at the late planting date in both years. This trend was also seen in maturity group IV-E, where Pixie, the short determinate in this maturity group had the least delay in maturity across planting dates in both years. The trend in this case is for the short determinates (Elf and Hobbit in maturity group III and Pixie in maturity group IV-E) within a maturity group to show less of a delay in maturity date than the taller determinates or indeterminates when planting is delayed. The delays in maturity across years differ due to differences in planting dates. In

Table 1.7. Maturity dates for soybean genotypes in maturity groups III and IV-E, across planting dates, within years.

		MATURITY					
	Maturity	1980			1981		
Genotype	Group	Early	Late	Delay	Early	Late	Delay
		month/day		days	month/day		days
Cumberland	III	9/22	10/08	16 *	9/20	10/06	16 *
Calland	III	9/19	10/11	22 *	9/16	10/10	24 *
Williams	III	9/23	10/11	18 *	9/21	10/09	18 *
Hobbit	III	9/25	10/05	10 *	9/19	10/06	17 *
K74-108	III	9/25	10/10	15 *	9/22	10/10	18 *
Elf	III	9/26	10/05	9 *	9/23	10/09	16 *
LSD (.05) within columns		2			1		
LSD (.05) between columns		2			1		
Desoto	IV-E	9/25	10/11	16 *	9/25	10/13	18 *
Cutler 71	IV-E	9/25	10/10	15 *	9/23	10/13	20 *
Pixie	IV-E	9/24	10/08	14 *	9/23	10/09	16 *
K1049	IV-E	9/27	10/12	15 *	9/26	10/16	20 *
LSD (.05) within columns		1			1		
LSD (.05) between columns		2			1		

*Means across dates within a year are significantly different at the 0.05 level of probability.

1981, plots were planted four days earlier and one day later, at the early and late planting dates, respectively, than plots planted in 1980.

The date by variety interaction was significant for lodging in maturity groups III, IV-E and IV-L (Table 1.8a). A year by date by variety interaction was also significant for lodging score in maturity group IV-E and V (Table 1.8b). All indeterminate genotypes decreased significantly in lodging score at the late planting date. The later maturing determinate genotypes, in maturity group IV-L and V, followed the same trend for height and lodging as did the indeterminates. In maturity group III, the date by variety interaction appears to be due to the difference in lodging score response of the determinate and indeterminate genotypes across planting dates. One determinate genotype in maturity group IV-L, V76-398, had no significant difference in lodging score across planting dates. All other genotypes in this maturity group had lodging scores which were reduced significantly when planting was delayed. In maturity group IV-E, the variety by date interaction was significant for lodging in both 1980 and 1981. In 1980 lodging scores for the Pixie short determinate, and K1049, the tall determinate, were the same across planting dates. In 1981, however, Pixie was the only genotype with lodging scores which did not change across planting dates. Ranges in lodging across dates for the remaining genotypes were greater in 1981 than in 1980. In both 1980 and 1981, all genotypes in maturity group V, were killed by frost prior to physiological maturity when planting was delayed. Essex, in 1980, was the only genotype with significantly different lodging scores across planting dates. All genotypes, in 1981, had significantly lower lodging scores at the late planting with Bedford suffering the greatest reduction. The greater response of Bedford is probably due to the fact

Table 1.8a. Lodging scores for soybean genotypes across planting dates, with scores representing two-year averages.

LODGING

Maturity Group III Genotype	Planting Date Early	Planting Date Late	Maturity Group IV-L Genotype	Planting Date Early	Planting Date Late
	—— score ——			—— score ——	
Cumberland	2.0	1.4 *	Crawford	3.1	1.9 * F+
Calland	2.2	1.8 *	Douglas	2.4	1.2 * F
Williams	2.1	1.5 *	C1573	2.6	1.7 *
Hobbit	1.0	1.0	V76-482	3.0	2.0 * F
K74 - 108	1.2	1.6 *	V76-398	2.1	1.8 F
Elf	1.0	1.0	K1048	1.8	1.2 * F
LSD (.05) within columns		.2		.3	
LSD (.05) between colums		.4		.5	

* Means across planting dates, within a maturity group, are significant at the 0.05 level of probability.

+,F indicates genotypes killed by frost prior to physiological maturity in the second planting date.

Table 1.8b. Lodging scores for soybean genotypes across planting dates, with scores representing two-year averages.

LODGING

Maturity Group IV-E Genotype	1980 Early	1980 Late	1981 Early	1981 Late
	score		score	
DeSoto	1.8	1.4 *	2.4	1.6 *
Cutler 71	2.1	1.7 *	2.5	1.8 *
Pixie	1.0	1.0	1.0	1.0
K1049	1.2	1.4	1.1	1.8 *
LSD (.05) within columns		0.4	0.3	
LSD (.05) between columns		0.4	0.4	
Maturity Group V Genotype				
Essex	3.0	2.0 * F	2.9	2.3 * F+
Forrest	2.5	2.9 F	3.8	2.5 * F
Dare	2.3	2.2 F	3.8	3.2 * F
Bedford	3.2	3.1 F	4.0	2.8 * F
LSD (.05) within columns		0.4	0.5	
LSD (.05) between columns		0.5	0.6	

* Means across dates within a year are significantly different at the 0.05 level of probability.

+,F indictes genotypes killed by frost prior to physiological maturity in the second planting date.

that it has the latest maturity date of these four genotypes, and thus was influenced the most by frost.

The year by date by variety interaction was significant for plant height in all maturity groups (Table 1.9). In maturity group III, Hobbit, a determinate genotype, was the only entry which increased in plant height at the delayed planting date. This increase occurred in both years, but was significant only in 1980. The indeterminate genotypes (Cumberland, Calland, and Williams 79) were significantly shorter when planting was delayed, in both years. The determinates, K74-108 and Elf, showed no significant difference across dates in either year. In maturity group IV-E the two indeterminate genotypes, DeSoto and Cutler 71, were significantly shorter at the late planting date in both years. Pixie, a short determinate, did not differ significantly across dates in either year. However, K1049, a tall determinate, decreased in plant height when planting was delayed in both years, but not significantly in 1980. The two determinates in maturity group IV-L, V76-482 and V76-398, in 1980, were the only genotypes which did not decrease significantly in plant height when planting was delayed. In 1981, all genotypes were significantly shorter at the late date. In maturity group V, all genotypes tended to have reduced plant heights at the late planting date in both years. Only Essex and Dare in 1980, were not significantly reduced. The plant height response seems to be dependent upon growth habit, maturity group and environmental conditions. In all cases, with less environmental stress in 1981, the difference in plant height across dates was greater than was observed in 1980 when heat and moisture stress prevailed. The difference in plant height response of the early and late maturity groups seems to be due to the difference in length of the growing season prior to flowering. When

Table 1.9. Plant heights for 20 soybean genotypes across planting dates, within years.

		PLANT HEIGHT					
	Maturity	1980			1981		
Genotype	Group	Early	Late	Difference	Early	Late	Difference
		cm					
Cumberland	III	92	79	13 *	106	71	31 *
Calland	III	97	86	11 *	120	77	43 *
Williams	III	98	83	15 *	116	75	41 *
Hobbit	III	41	50	-9 *	44	48	-4
K74-108	III	56	59	3	64	54	10
Elf	III	41	40	1	42	40	2
LSD (.05) within columns		7			6		
LSD (.05) between columns		7			11		
Desoto	IV-E	99	82	17 *	116	80	36 *
Cutler 71	IV-E	106	87	19 *	124	88	36 *
Pixie	IV-E	43	41	2	44	43	1
K1049	IV-E	71	69	2	77	65	12 *
LSD (.05) within columns		5			5		
LSD (.05) between columns		7			10		
Crawford	IV-L	112	78	34 *	131	92	39 *
Douglas	IV-L	98	81	17 *	117	80	37 *
C1573	IV-L	106	87	19 *	124	80	44 *
V76-482	IV-L	76	75	1	90	71	19 *
V76-398	IV-L	81	74	7	94	72	22 *
K1048	IV-L	77	69	8 *	88	62	26 *
LSD (.05) within columns		6			6		
LSD (.05) between columns		8			13		
Essex	V	76	76	0	94	76	18 *
Forrest	V	105	90	15 *	109	85	24 *
Dare	V	100	92	8	114	82	32 *
Bedford	V	130	99	31 *	128	91	37 *
LSD (.05) within columns		8			7		
LSD (.05) between columns		8			9		

* Means across dates within a year are significantly different at the 0.05 level of probability.

planting is delayed, the earlier maturing genotypes reach their proper photoperiod for flower initiation after a relatively short period of vegetative growth. The later maturing genotypes have a longer period of vegetative growth before the photoperiod for flower initiation is reached due to the shorter photoperiod required.

The date by variety and year by date by variety interaction for yield appears to be due to the difference in response of the indeterminate and determinate genotypes to the delayed planting. Yields of the determinate genotypes tended to change the least across planting dates enabling them to move up in yield ranking at the late planting. This move however, did not always place them in the highest position which was dominated most often by indeterminate genotypes whose rank changed very little if at all across planting dates. The only exception to this was Pixie, in 1980, whose yield at the delayed planting was significantly higher than all other genotypes in maturity group IV-E. Maturity responses of genotypes varied and were influenced by growth habit. The short determinate genotypes showed the least delay in maturity date at the late planting date, with the tall determinates and indeterminates delayed by the greatest number of days when planting was delayed. Differences in ranges in days delayed in 1980 and 1981 were influenced by the differences in actual planting dates in each year. Lodging and height responses were influenced by growth habit, maturity group and environmental conditions. In the early maturity groups, III and IV-E, the variety by date interaction for lodging score was influenced primarily by differences in responses of short determinate genotypes and indeterminate and tall determinate genotypes. The later maturing genotypes, in maturity groups IV-L and V, with a longer time period prior to flowering, showed greater reductions in lodging scores due to the killing frost prior to physiological maturity when planting was delayed. Plant height responses of genotypes followed the same trends as did lodging score responses. Differences in the early maturing genotypes were due to differences in growth habit. Differences in the later maturing genotypes across planting dates were influenced by frost when physiological development was not complete. Both lodging scores and plant heights were greater in 1981 with less environmental stress in 1981 than in 1980.

Variety x Irrigation

A significant variety by irrigation interaction for yield existed in maturity group III. A significant year by variety by irrigation interaction for yield existed in maturity group IV-E. In maturity group III, the inconsistent varietal response for yield to irrigation was due to the fact that Williams 79 did not differ significantly in yield under either irrigated or dryland conditions. Yields of other genotypes, however, increased 24 to 31% under irrigation. In maturity group IV-E, the variety by irrigation interaction was significant for yield in 1980 and not in 1981. In 1980, all genotypes had significantly lower yields under non-irrigated conditions than when irrigated. The magnitude of this reduction, however was not the same for all genotypes.

The two indeterminate genotypes, Cutler 71 and DeSoto, were reduced in yield 29 and 34% respectively when grown under dryland conditions. The determinate genotypes, Pixie and K1049, had yield reductions of 42 and 44%, respectively when non-irrigated. The yield rankings of these genotypes changed little across irrigation treatments. In 1981, all genotypes, with the exception of Pixie, had significantly lower yields under non-irrigated conditions. In this case, Pixie had a 20% yield reduction under dryland conditions while DeSoto, Cutler 71 and K1049 had yield reductions of 11, 15, and 13%, respectively.

The magnitude of the maturity date response to irrigation treatments was much greater in 1980 than in 1981. In both maturity group III and IV-E the variety by irrigation interaction was significant for maturity in 1980 and not in 1981. The varietal differences in maturity date across irrigation treatments was minimal in 1981 when the difference in the treatments themselves was small (Table 1.10). In maturity group III in 1980, the maturity dates of the short determinates genotypes, Hobbit and Elf, were significantly delayed under irrigated conditions, therefore, slightly lengthening the growing season of these genotypes. Although all genotypes in maturity group IV-E in 1980 differed significantly across irrigation treatments, the same trend exists that was seen in maturity group III. Pixie, the only short determinate in this maturity group showed the greatest delay in maturity due to irrigation. This maturity response of the short determinates to irrigation is evidently inherent in their growth habit characteristics. In a study conducted by Egli and Leggett (8), a comparison was made of dry matter accumulation patterns in determinate and indeterminate soybeans. In this study it was found that at initial bloom the indeterminate genotype had produced between 43 and 61% of its vegetative material and the determinate genotype had produced between 77 and 80%. The leaf tissue of the determinates would therefore tend to be older than that of the indeterminates. In another study conducted by Vaadia (20) the rate of incorporation of amino acids into protein in leaf discs was measured under the assumption that the processes of enhanced leaf senescence and proteolysis are retarded by cytokinins. An interaction was found between leaf age and water stress whereby incorporation of

Table 1.10. Maturity dates for soybean genotypes across planting dates, within years.

Genotype	Maturity Group	MATURITY DATE 1980 Early	1980 Late	1980 Delay	1981 Early	1981 Late	1981 Delay
		month/day		days	month/day		days
Cumberland	III	9/30	9/29	1 *	9/28	9/28	0
Calland	III	9/30	9/30	0	9/28	9/27	1
Williams 79	III	10/02	10/01	1	9/30	9/30	0
Hobbit	III	10/04	9/26	8 *	9/27	9/27	0
K74-108	III	10/03	10/02	1	10/01	10/01	0
Elf	III	10/04	9/26	8 *	10/01	10/01	0
LSD (.05) within columns		2			1		
LSD (.05) between columns		2			1		
Desoto	IV-E	10/04	10/02	2 *	10/04	10/04	0
Cutler 71	IV-E	10/04	10/02	2 *	10/04	10/02	2 *
Pixie	IV-E	10/04	9/29	5 *	10/01	10/01	0
K1049	IV-E	10/05	10/03	2 *	10/06	10/06	0
LSD (.05) within columns		1			1		
LSD (.05) between columns		2			1		

* Means across dates within a year are significantly different at the 0.05 level of probability.

C^{14}L-leucine into protein in tobacco leaf discs was reduced due to age as well as due to stress. From this information it could be concluded that irrigation of determinates would allow maintenance of higher levels of cytokinins under irrigation therefore producing a greater response in delaying maturity than would be seen from irrigation of indeterminate types, since indeterminate types tend to have young leaf tissue throughout the growing season.

A significant year by date by variety interaction for lodging score existed in maturity groups III, IV-E and IV-L. In all three maturity groups a variety by irrigation interaction was significant in 1980 and not in 1981. In 1980, when the difference across irrigation treatments was significant, genotypes had lower lodging scores under dryland conditions (Table 1.11). In maturity group III, Elf and Hobbit did not differ in lodging score across dates. In maturity IV-E, Pixie and K1049 did not differ significantly in lodging score across treatments. The difference in growth habit response to irrigation provided this interaction for lodging score seen in these maturity groups in 1980. All genotypes in maturity group IV-L had significantly lower lodging scores under non-irrigated conditions in 1980. In this case, V76-482 with the highest lodging score under irrigation, had the greatest lodging score reduction across treatments.

For plant height, a variety by irrigation interaction was seen in maturity group V and a year by variety by irrigation interaction in maturity group III and IV-E. Genotypes in maturity group V, with the exception of Bedford, had plant heights which were not significantly different across irrigation treatments (Table 1.12). In maturity groups III and IV-E where the year by variety by irrigation interaction was significant for plant height, the variety by irrigation interaction was

Table 1.11 Lodging scores for soybean genotypes across irrigated and non-irrigated treatments, within years.

Genotype	Maturity Group	LODGING SCORE 1980 Irrigated	1980 Non-Irrigated	1981 Irrigated	1981 Non-Irrigated
		cm			
Cumberland	III	1.9	1.3	1.5	2.1
Calland	III	1.8	1.3 *	2.3	2.5
Williams 79	III	2.2	1.3 *	1.8	2.0
Hobbit	III	1.0	1.0	1.0	1.0
K74-108	III	1.3	1.0 *	1.8	1.4
Elf	III	1.0	1.0	1.0	1.0
LSD (.05) within columns		.2		.4	
LSD (.05) between columns		.3		.4	
DeSoto	IV-E	1.9	1.3 *	2.0	2.0
Cutler 71	IV-E	2.2	1.6 *	2.0	2.3
Pixie	IV-E	1.0	1.0	1.0	1.0
K1049	IV-E	1.3	1.3	1.4	1.4
LSD (.05) within columns		.3		.3	
LSD (.05) between columns		.4		.4	
Crawford	IV-L	2.7	1.6 *	2.8	2.9
Douglas	IV-L	2.1	1.5 *	1.8	1.9
C1573	IV-L	2.2	1.3 *	2.3	2.9
V76-482	IV-L	3.1	1.5 *	2.7	2.8
V76-398	IV-L	2.2	1.2 *	2.3	2.2
K1048	IV-L	1.7	1.1 *	1.6	1.7
LSD (.05) within columns		.4		.4	
LSD (.05) between columns		.5		.6	

* Means across irrigation treatments within a year are significantly different at the 0.05 level of probability.

Table 1.12. Plant heights for 20 soybean genotypes across irrigated and non-irrigated treatment, within years.

		PLANT HEIGHT			
		1980		1981	
Genotype	Maturity Group	Irrigated	Non-Irrigated	Irrigated	Non-Irrigated
		cm			
Cumberland	III	94	77 *	90	88
Calland	III	99	83 *	100	97
Williams 79	III	101	80 *	96	95
Hobbit	III	48	42	46	45
K74-108	III	58	57	59	58
Elf	III	45	37 *	41	41
LSD (.05) within columns		7		6	
LSD (.05) between columns		7		11	
Desoto	IV-E	99	82 *	100	96
Cutler 71	IV-E	106	87 *	109	103
Pixie	IV-E	43	41	44	43
K1049	IV-E	72	68	74	68
LSD (.05) within columns		5		5	
LSD (.05) between columns		7		10	
Crawford	IV-L	104	86 *	115	109
Douglas	IV-L	98	81 *	101	96
C1573	IV-L	107	86 *	103	101
V76-482	IV-L	82	68 *	82	80
V76-398	IV-L	83	73 *	87	79
K1048	IV-L	82	65 *	75	74
LSD (.05) within columns		7		6	
LSD (.05) between columns		8		14	
Essex	V	78	73	87	82
Forrest	V	100	95	97	96
Dare	V	98	94	97	99
Bedford	V	122	106 *	116	103 *
LSD (.05) within columns		8		7	
LSD (.05) between columns		8		9	

* Means across dates within a year are significantly different at the 0.05 level of probability.

significant in 1980 and not in 1981. All indeterminates in these two maturity groups were significantly shorter when grown under non-irrigated conditions in 1980. The determinate genotypes, however, with the exception of Elf, did not differ significantly across irrigation treatments. In 1981, no significantly different plant heights across irrigation treatments existed. The determinate genotypes in maturity groups III and IV-E, with the shortest average height, were less affected by the irrigation treatments than were the indeterminates. Egli and Legget (8) found that the determinate genotype had reached 84% of its maximum height at initial flowering as compared with 64% for the indeterminate. The determinate showed a considerable increase in stem dry weight following flowering in spite of the little increase in length. Therefore, a moisture stress on a determinate genotype might show up as a decrease in stem dry weight, but not necessarily influence stem length. The indeterminate, on the other hand, with stem elongation continuing past initial flowering would be expected to show a greater response to a moisture deficit with decreased plant height.

Variety x Date x Irrigation

A significant variety x date x irrigation interaction for maturity date existed in maturity groups III and IV-E. The trend was similar in both maturity groups. The short determinate genotypes, Pixie in maturity group IV-E and Hobbit and Elf in maturity group III, showed the greatest delay in maturity under irrigation at the late planting date (Table 1.13). At the conventional planting time, very little response due to irrigation treatment was seen for maturity date.

For lodging, a significant variety by date by irrigation interaction existed in maturity groups III, IV-E, and V (Table 1.14).

Table 1.13. Maturity date of soybean genotypes across irrigation treatments within each planting date.

Genotype	Maturity Group	MATURITY DATE 1980 Irrigated	1980 Non-Irrigated	1981 Irrigated	1981 Non-Irrigated
		month/day			
Cumberland	III	9/21	9/21	10/08	10/07
Calland	III	9/17	9/18	10/11	10/10
Williams 79	III	9/22	9/22	10/10	10/10
Hobbit	III	9/22	9/21	10/09	10/02 *
K74-108	III	9/24	9/23	10/10	10/10
Elf	III	9/25	9/23 *	10/11	10/04 *
Desoto	IV-E	9/26	9/24 *	10/12	10/12
Cutler 71	IV-E	9/26	9/23 *	10/12	10/10
Pixie	IV-E	9/25	9/23 *	10/10	10/06 *
K1049	IV-E	9/27	9/26	10/14	10/13

* Dates across irrigation treatments within a planting date are significant at the 0.05 level of probability.

Table 1.14. Lodging scores of soybean genotypes across irrigation treatments within each planting date.

		LODGING SCORE			
		1980		1981	
Genotype	Maturity Group	Irrigated	Non-Irrigated	Irrigated	Non-Irrigated
		score			
Cumberland	III	1.9	2.1	1.5	1.3
Calland	III	2.2	2.3	2.0	1.5 *
Williams 79	III	2.2	2.1	1.8	1.2 *
Hobbit	III	1.0	1.0	1.0	1.0
K74-108	III	1.1	1.0	2.1	1.2 *
Elf	III	1.0	1.0	1.0	1.0
Desoto	IV-E	2.3	1.8	1.6	1.4
Cutler 71	IV-E	2.3	2.3	1.8	1.6
Pixie	IV-E	1.0	1.0	1.0	1.0
K1049	IV-E	1.0	1.3	1.8	1.4
Essex	V	3.4	2.5 *	2.7	1.7 *
Forrest	V	3.4	2.8 *	3.6	1.8 *
Dare	V	3.3	2.8	3.2	2.2 *
Bedford	V	4.0	3.2 *	3.7	2.2 *

* Dates across irrigation treatments within a planting date are significantly different at the 0.05 level of probability.

Genotypes in maturity group III showed no significant lodging response at the early planting date. At the late date however, Hobbit, Elf and Cumberland were the only genotypes which did not differ significantly across irrigation treatments with Calland, William 79 and K74-108 having significantly lower scores under dryland conditions. In maturity group IV-E Desoto, at the early planting date had significantly lower lodging scores under dryland conditions than under irrigated conditions. All other genotypes showed no significant difference across irrigation treatments. At the late date of planting there were no significant differences in lodging scores for any genotype. In maturity group V, Dare, at the early planting, showed no significant difference in lodging scores across irrigation treatments with the remaining genotypes having significantly lower scores under dryland conditions. At the late date of planting, all genotypes had significantly lower lodging scores under dryland conditions as compared to their scores under irrigation. Lodging scores in maturity group V were consistently higher in all treatments. This is probably related to the fact that the growing season of these genotypes is longer than that of the earlier maturing genotypes, therefore, allowing for more vegetative dry matter accumulation and thus making them more susceptible to lodging. In maturity group III, when planting is delayed, the period prior to floral initiation is cut short and plants are generally smaller. This coupled with a moisture deficit would allow for less lodging.

CONCLUSIONS

In this study no row width, genotype x row width or year x row width response was significant. Delayed planting dates caused significant yield reductions with the greatest yield reduction occurring in the maturity group V genotypes. Maturity dates were delayed approximately one day for every two days planting was delayed in maturity groups III and IV-E. Both lodging scores and plant heights were reduced by the delayed planting date. The year x date interactions were significant due to the considerable difference in growing conditions in 1980 and 1981 with hot dry conditions prevelant in 1980 and relatively cool temperatures and ample rainfall in 1981. These differences also influenced the year x irrigation interaction which existed due to the difference in irrigation response across years. In 1980, the total amount of rainfall received in the period from May to September was 28 cm, which was 25 cm below normal. For this same period in 1981 however, the rainfall received was 59 cm which was 6 cm above normal (normal rainfall being 53 cm). The significant date x variety interactions were mainly due to the difference in response of the short determinate and indeterminate genotypes to delayed planting. The difference between the yields, maturity, lodging and plant height in the early vs. late planting dates were less for the determinates than the indeterminates. Although these genotypes showed the least yield reduction at the late planting, they did not tend to outyield the indeterminates within the same maturity group. The entries in maturity groups IV-L and V suffered greater yield reductions at the late planting date due to the occurrence of frost prior to physiological maturity.

A variety x irrigation interaction was seen for yield, maturity, lodging and height. For yield, this interaction was significant only in maturity group III. This was due to one genotype, Williams 79, performing consistently across irrigation treatments. Maturity date of the determinates was delayed more under irrigation than was maturity date of the indeterminates This is thought to be due to the difference in age of the leaf tissue of determinates and indeterminates with the tissue of determinates being considerably older. From the study conducted by Vaadia (20) it could be concluded that irrigation of determinates would allow them to maintain higher levels of cytokinins under irrigation, therefore producing a greater response in delaying maturity than would be seen from irrigation of indeterminate types which tend to have young leaf tissue throughout the growing season. Plant height response was associated with growth habit with the indeterminates decreasing significantly under non-irrigated conditions and the determinates decreasing but not significantly.

The year x variety x irrigation interaction occurred in response to differences in response of genotypes to years, with irrigation response in 1980 much greater than that seen in 1981. The differences in yield, maturity date, lodging score and plant height across irrigation treatments were much more pronounced in 1980 than in 1981 due to the abundance of moisture in 1981 and the mosture stress incurred in 1980. The trends, however, remained the same as seen in the variety x irrigation interaction responses.

From this study, the results suggest that differences in response of yield, maturity, lodging and height due to row width, date of planting, and irrigated versus dryland treatments are not sufficient to warrant changes in a breeding program for development of soybeans for different production systems. Selection for high yielding genotypes made from wide rows proved to be sufficient for genotypes which will produce well in narrow rows. The same trend follows for selection for soybeans to be grown in a double-cropping system from soybeans planted at the conventional time and for soybean to be grown under dryland conditions selected from irrigated material.

LITERATURE CITED

1. Bernard, R.L. 1972. Two genes affecting stem termination in soybeans. Crop Sci. 12:235-239.

2. Camper, H.M., Jr., C.F. Genter, and K.E. Loope. 1972. Double cropping following winter barley harvest in eastern Virginia. Agron. J. 64:1-3.

3. Carter, T.L. 1958. Time of planting studies. Soybean Dig. 18(7):12-14.

4 Carter, T.E., Jr. and H.R. Boerma, 1978. Implications of genotype x planting date and row spacing interactions in double-cropped soybean cultural development. Crop Sci. 19:607-610.

5. Cooper, R.L. 1971. Influence of soybean production practices on lodging and seed yield in highly productive environments. Agron. J. 63:490-493.

6. Cooper, R.L. 1971. influence of early lodging on yield of soybean [Glycine max (L.) Merr.]

7. Cooper, R.L. 1977. Response of soybean cultivars to narrow rows and planting rates under weed-free conditions Agron. J. 69:89-92.

8. Costa, J.A., E.S. Oplinger, and J.W. Pendleton. 1980. Response of soybean cultivars to planting patterns. Agron. J. 72:153-156.

9. Egli, D.B. and J.E. Leggett. 1973. Dry matter accumulation patterns in determinate and indeterminate soybeans. Crop Sci. 13:220-222.

10. Gilman, D.F. and J.G. Marshall. 1976. Soybean variety x date of planting test at Alexandria Louisiana Agricultural Experiment Station, Department of Agronomy. Rep. Proj. La. Agric. Exp. Ata. Dept. Agron. p. 55-57.

11. Gilman, D.F., W. Hall, D.S. Fontenot, and R.F. Jemison. 1976. Planting date x row spacing x soybean variety test at Baton Rouge. Louisiana Agricultural Experiment Station, Department of Agronomy. Rep. Proj. La. Exp. Stn. Dept. Agron. p. 58-60.

12. Hartwig, E.E. 1958. Time of planting soybeans in the south. Soybean Digest. 18(7):16-19.

13. Johnson, J.J., D.E. Green, and C.W. Jordan. 1982. What is the best soybean row width? Crops and Soils. 43(4):10-13.

14. Lehman, W.F. and J.W. Lambert. 1960. Effects of spacing of soybean plants between and within rows on yield and its components. Agron. J. 57:84-86.

15. Ryder, G.J. and J.E. Beuerlein. 1979. A study of soybean production systems. Wooster, Ohio Agricultural Research and Development Center Ohio report on research and development in agriculture, home economics and natural resources. 64(2):19-22.

16. Shibles, R.M. and D.E. Green. 1969. Soybean breeding a conference held at Iowa State University. p. 2-12.

17. Smith, R.L. Effect of date of planting and row width on yield of soybeans. 1968. Soil and Crop Sci. Soc. of Fla. Proceedings. 28:130-133.

18. Weber, C.R., R.M. Shibles, and D.E. Byth. 1966. Effect of plant population and row spacing on soybean development and production. Agron. J.58:99-102.

19. Williams, C., J.J. Daigle, Lee Mason, and D.L. Robinson. 1972. Response of three soybean varieties to varying plant population density and row spacing. Louisiana Agric. Expt. Stn. Dept. Agron. Rep. Proj. p. 176-183.

20. Vaadia, Y. 1976. Plant hormones and water stress. Phil. Trans. R. Soc. Lond. B. 273:513-522.

CHAPTER II

GENETIC DIVERSITY IN SOYBEANS FOR LEAF CANOPY TEMPERATURE AND THE ASSOCIATION OF LEAF CANOPY TEMPERATURE WITH YIELD

INTRODUCTION

The search for a simple and reliable method of screening for drought tolerance in crops continues as plant breeders seek tools for use in the development of drought tolerant varieties. Much attention has been given to the use of the hand-held infrared thermometer for leaf canopy temperature measurements. The canopy minus air temperature differential has been used by many researchers as a means of measuring the magnitude of water stress in an actively growing crop. Ehler (3) working with sorghum, found that six days following irrigation, leaf temperatures were considerably below air temperature throughout most of the 24 hour reading period. Prior to irrigation, however, the leaf temperatures of plants in dry soil remained above air temperature essentially from dawn to dusk. Ehler (4), when working with wheat, found that the differences between wet and dry plots occurred not only in the magnitude of ΛT (ΔT = canopy temperature-air temperature) which was greater at any given time in dry than in wet plots, but also in the rate of rise of ΔT. This value increased as solar radiation and air temperature increased, increasing more rapidly in dry than in wet plots. This difference was explained by partial stomatal closure in the dry plots. Clark and Hiler (2) found that when the crop was well watered the leaves were cooler than the air temperature. Once a water deficit occurred in the stress treatment, the leaf minus air temperature differential became positive.

In a study conducted by Carlson (1), two soybean varieties were grown under controlled irrigation. Differences in daily canopy temperatures were attributed mainly to differences in vapor pressure deficit and differences in air temperatures. When vapor pressure deficit was low or when relative humidity high, the ability of the leaf to cool by evaporative mechanisms was restricted as the air surrounding the leaf became more saturated with water vapor. It has been reported that stomatal aperature increases with increasing air temperature (10).

Many researchers have used canopy temperature as a means of determining plant water stress due to inadequate soil moisture (8, 9, 11). Idso (6, 7) further worked to link leaf temperature and air temperature to yield.

The ease of using a hand-held infrared thermometer coupled with the ability of the instrument to interpret the water status of a crop, makes this instrument attractive to a plant breeder whose interests lie in screening for drought tolerance. Before such work can begin, however, genetic variation for leaf temperature must be found, and the association made between leaf canopy temperature and yield and between leaf canopy temperature and drought tolerance studied.

MATERIALS & METHODS

This experiment was conducted at the Ashland Agronomy Research Farm in Manhattan, Kansas in 1980 and 1981. The soybean plots were planted in a Muir silt loam soil classified as a Pachic Haplustoll, fine-silty, mixed mesic. No fertilizer was applied. In early May, prior to planting, one-half liter of Trifluralin (α,α,α,ael-trifluoro-2, 6-dinitro-N,Ndipropyl-p-toluidine) per hectare was applied and at planting .06 kilograms of Chloramben (3-amino-2, 5-dichlorobenzoic acid) were applied. In 1981, the study was conducted in a field having a Eudora silt loam soil classified as a Fluventic Hapludoll, coarse-silty, mixed, mesic. Approximately 18 kilograms of 18-46-0 fertilzer per hectare were applied late in April. In mid-April, Trifluralin was applied and at planting Chloramben was applied in amounts equivalent to the amounts applied in 1980. Total and average monthly rainfall from May to September in 1980 was below normal for each month and throughout the season. In 1981, however, monthly rainfall averages were above normal in May, June and July, one cm below normal in August and 6.6 cm below normal in September. Average monthly, average maximum and average minimum temperatures were above normal from June to September in 1980. Average temperatures in 1981, for the same period, were near or below the normal temperatures (Appendix Table A-1).

The experimental design was a split-split-plot with irrigation as the whole plot, row widths as the subplots and soybean genotypes as the sub-sub plots. There were two irrigation treatments (an irrigated treatment and a dryland treatment), two row widths (76 cm and 25 cm), and twenty genotypes. The twenty genotypes, consisting of fourteen cultvars and six experimental lines, were chosen to represent both determinate and indeterminate growth habits from maturity groups III, IV and V to insure a broad spectrum of genetic material (Table 2.1). Irrigation was achieved with a movable overhead sprinkler system. Total water received in the irrigated and dryland treaments in 1980 was 43 and 35 cm, respectively. In 1981 the irrigated treatment received 59 cm of water and the dryland treatment received 55.2 cm of water, with the difference between treatments one 3.8 cm irrigation.

Plots consisted of four rows of each genotype in wide row plots (76 cm) and ten rows of each genotype in narrow row plots (25 cm), 5.8 meters long. The wide row plots had plant populations of 50,500 plants/hectare with the two center rows machine harvested for seed yield. The narrow row plots had plant populations of approximately 60,400 plants/hectare with the center six rows machine harvested for seed yield. Harvest row length was 4.3 meters in all plots.

Infrared canopy temperatures were measured with a hand held Barnes Model PR-10 infrared thermometer. Canopies were viewed at an angle (less than 45 degress) following closure of the soybean canopy to avoid interference from the soil surface. The measurements were taken every three to five days depending on climatic conditions (no readings were made when cloudy conditions or intermittant cloudiness prevailed), between 1200 and 1300 hours when the least change in solar radiation intensity occurred. A total of fifteen measurements were taken per plot in 1980 and a total of nine per plot in 1981. Air temperature (T_A), at the time canopy temperatures (T_C) were measured, was subtracted from the canopy temperature to obtain a canopy temperature differential ($T_d = T_C - T_A$). The total (SUM) of both positive and negative values of T_d, per plot for each genotype, was determined and recorded as was seed yield and yield ratio (non-irrigated yield/irrigated yield).

Table 2.1. Soybean genotypes represented in this study, classified by maturity group and growth habit.

	Maturity Group III	Maturity Group IV-E	Maturity Group IV-L	Maturity Group V
Indeterminate	Cumberland	Cutler 71	Crawford	
	Calland	DeSoto	Douglas	
	Williams 79		C1573	
Determinate	Hobbit	Pixie	V76-482	Essex
	K74-108	K1049	V76-398	Forrest
	Elf		K1048	Dare
				Bedford

Statistical analyses included an analysis of variance with varieties, row widths, and irrigation treatment as independent variables and T_d, for reading dates one through fifteen in 1980 and one through nine in 1981, as well as SUM and yield as dependent variables. Single year analyses as well as the two year combined analysis were made. Product moment correlations between yield, ratio, SUM, and T_d values were determined using values averaged over varieties and row widths, within irrigation treatments.

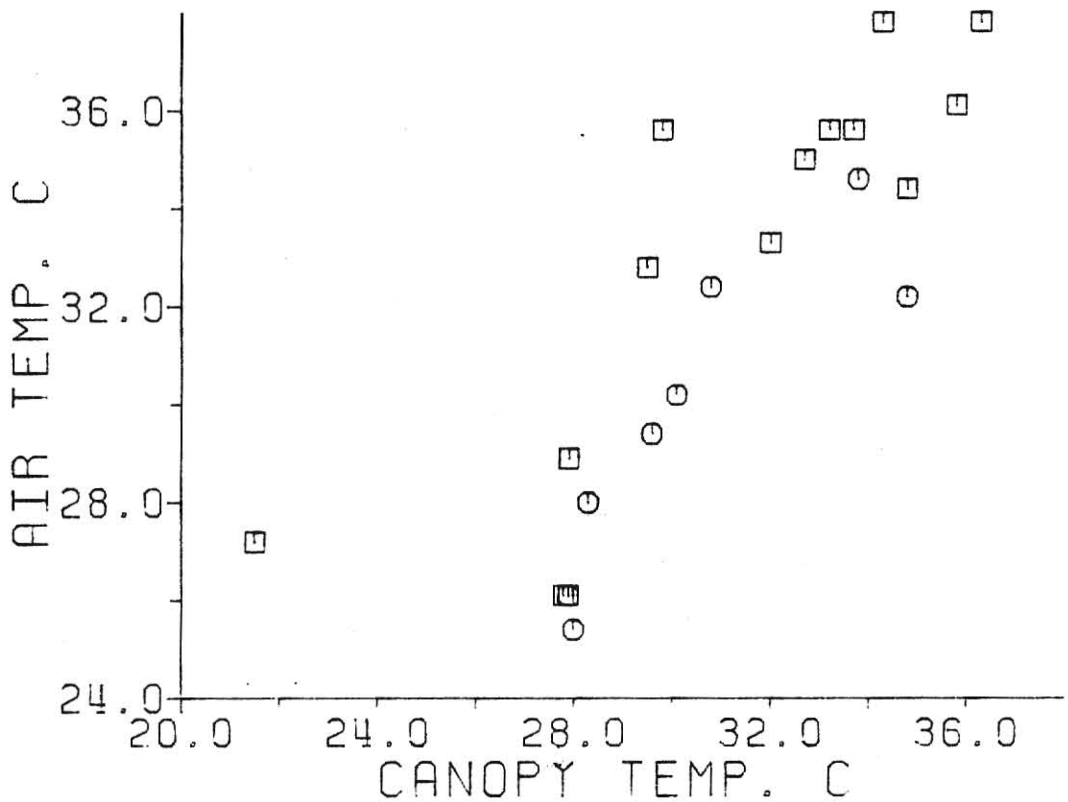
RESULTS AND DISCUSSION

Years

In the two year analysis, canopy temperature SUM was found to be significantly different across years. The average SUM value in 1980 was -21.7, compared to 9.8 in 1981. This difference across years stems from the fact that in 1980, on eleven of the fourteen days that TC readings were made, values of T_d were negative indicating canopy temperatures were cooler than air temperature. In 1981, however, on six of the nine reading days canopies had higher temperatures than air temperature. The differences in canopy and air temperatures (T_d) were relatively small on a given day ranging from -6.1 to 2.6 in 1980 and from -1.9 to 5.2 in 1981. The value of T_d averaged across all reading dates in 1980 was -1.79 and in 1981 was 1.09.

Air temperature and canopy temperature were found to be significantly correlated in both 1980 and 1981 (Figure 2.1). With higher temperatures occurring in 1980 as compared with 1981, evaporative demand was greater and canopies cooler than air presumably due to increased transpirational cooling. In a study conducted by Stalfelt (10), comparisons were made on the effect of temperatures on the opening of stomatal cells. The rate of opening was measured at 5, 10, 15, 25, 30, 35, 40 and 45 degrees C and compared with the rate at 20 degrees C. When working with <u>Vicia faba</u>, stomatal opening was inappreciable at 5 degrees C. The rate of opening increased, however, as temperature increased with optimal movements within the 35 to 40 degrees C range. When testing other experimental plants, the opening rates at 20 degrees and 30 degrees C showed no uniform difference. This would support the

Figure 2.1. Relationship of air temperature and canopy temperature in 1980 and 1981.



□ 1980 r = .842**

○ 1981 r = .866**

conclusion that cooler canopies result from incresed transpirational cooling with greater stomatal openings at the higher air temperatures.

Irrigation

In the two year analysis, the irrigation treatment was found to be significant for canopy temperature SUM. The value of the canopy temperature SUM within the irrigated treatment was -11.8, a value significantly lower than the SUM value within the dryland treatment, a value of -0.1 degrees C, although both values were negative. This would indicate a lack of sufficient moisture to transpire at a rate equivalent to plots which were irrigated. Ehler and van Bavel (3) found leaf temperatures to be strongly related to soil water availability. A measurement of leaf temperature of plants in dry soil was found to be greater than air temperature for the duration of the daylight hours with late afternoon leaf temperatures as much as five degrees above air temperature. These high leaf temperatures were attributed to a reduced rate of evaporative heat loss due to stomatal closure.

An irrigation by year interaction was significant for canopy temperature SUM. Values of SUM in 1980 in both irrigated and dryland treatments were negative and differed across treatments by approximately 23 degrees C. In 1981, however, values of SUM across irrigation treatments were positive and differed by less than 0.2 degrees C (Table 2.2). This response across years was attributed to the difference in environmental conditions experienced each year. Above average temperatures and below average rainfall were prevalent in 1980 causing a greater evaporative demand than was present in 1981 when temperatures were near or below normal and rainfall amounts were greater than average.

Table 2.2. Mean canopy temperature sum of 20 soybean genotypes separated into irrigated and non-irrigated treatments within a year.

	Canopy Temperature Sum	
Irrigation Treatment	1980	1981
Irrigated	-33.4	9.8
Non-irrigated	- 9.9	9.7
Average	-21.7	9.8

Varieties

Significant varietal differences for T_d were seen on six of the fourteen days in 1980 when canopy temperatures were measured and on four of the nine days in 1981. Due to the lack of detecting significant genotypic differences and the variability in the magnitude of canopy temperature from one reading day to the next (Appendix Figures A1a-A1h) the SUM value (Total of T_d's across sampling days) for a given genotype was used as the most reliable means of measuring genetic variation. Based on this temperature SUM, varieties were found to be significantly different in the two year analysis (Table 2.3). A variety by year interaction for canopy temperature SUM was also found to be significant (Table 2.3). All genotypes had a significantly higher SUM in 1981 as compared to that of 1980. When SUM values are ranked from coolest to hottest, the greatest change from 1980 to 1981 in rank was seen for Elf, Pixie, C1573, K1048 and Forrest.

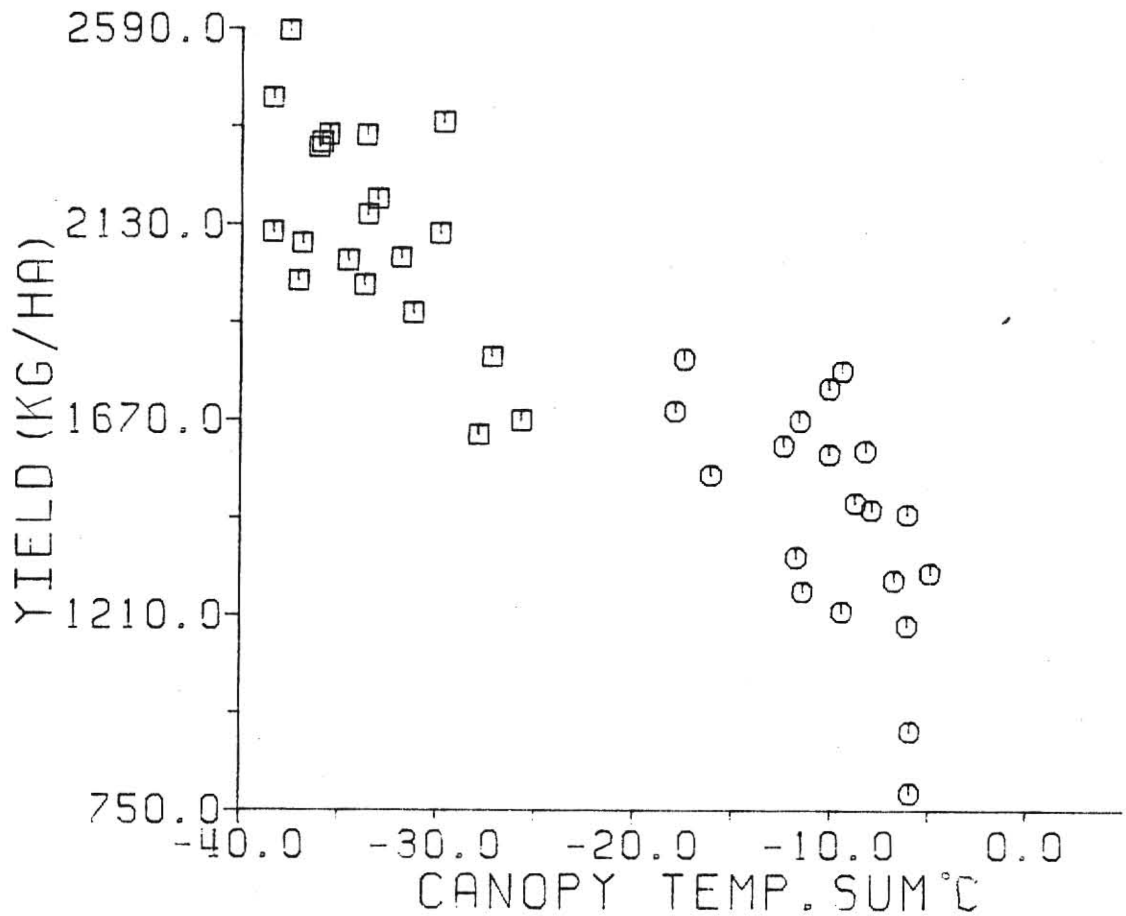
Correlations

The association between canopy temperature SUM and seed yield was determined using correlation analyses. When irrigated treatments were separated into dryland and irrigated plots, in 1980, a significant negative correlation existed (Figure 2.2) between SUM and seed yield. These correlations did not exist in 1981 with plots in either the irrigated or dryland treatments (Figure 2.3). Due to cloudy conditions in 1981, only nine canopy temperature readings were made on each plot, or just over half the total number of readings made in 1980. Although few observations were made in 1981, precision of the data collected was maintained. Nonsignificant correlations of canopy temperature SUM and

Table 2.3. Canopy temperature sum and yield averaged over irrigation treatments and row widths.

	Two-Year Average				1980				1981			
	Sum	Rank	Yield	Rank	Sum	Rank	Yield	Rank	Sum	Rank	Yield	Rank
DeSoto	-9.5	1	2730	3	-27.9	1	2119	2	9.0	7	3342	7
Cutler 71	-9.4	2	2434	13	-27.5	2	1843	8	8.8	6	3025	15
Crawford	-9.1	3	2290	17	-27.3	3	1826	10	9.1	8	2754	17
Douglas	-7.5	4	2808	2	-22.6	7	1910	6	7.5	3	3705	1
K1048	-7.3	5	2374	15	-21.3	11	1806	12	6.8	2	2942	16
K1049	-7.2	6	2468	12	-24.2	4	1675	16	9.8	10	3261	9
Cumberland	-7.1	7	2916	1	-23.5	5	2184	1	9.3	9	3648	2
Williams 79	-6.7	8	2662	5	-21.9	9	2041	3	8.5	4	3285	8
Forrest	-6.1	9	2197	18	-20.8	13	1727	14	8.6	5	2669	18
C1573	-6.0	10	2561	9	-18.7	16	1703	15	6.7	1	3419	4
V76-398	-5.7	11	2345	16	-21.6	10	1602	17	10.2	12	3088	14
Elf	-5.5	12	2593	7	-23.5	6	1927	5	12.4	20	3259	10
Calland	-5.3	13	2523	10	-20.1	14	1823	11	9.9	11	3223	12
Hobbit	-5.2	14	2521	11	-21.1	12	1879	7	10.7	15	3164	13
Pixie	-4.8	15	2725	4	-21.9	8	1968	4	12.3	19	3482	3
V76-482	-4.0	16	2400	14	-18.7	17	1554	18	10.6	14	3248	11
K74-108	-4.0	17	2586	8	-20.2	15	1763	13	12.2	18	3409	5
Dare	-3.1	18	1968	19	-16.9	19	1286	19	10.7	16	2652	19
Essex	-2.8	19	2595	6	-17.3	18	1839	9	11.7	17	3351	6
Bedford	-2.7	20	1823	20	-15.8	20	1228	20	10.4	13	2418	20
LSD (.05)	3.5		106		6.3		138		2.7		166	
CV (%)	102.4		12.2		36.6		15.5		34.8		10.5	

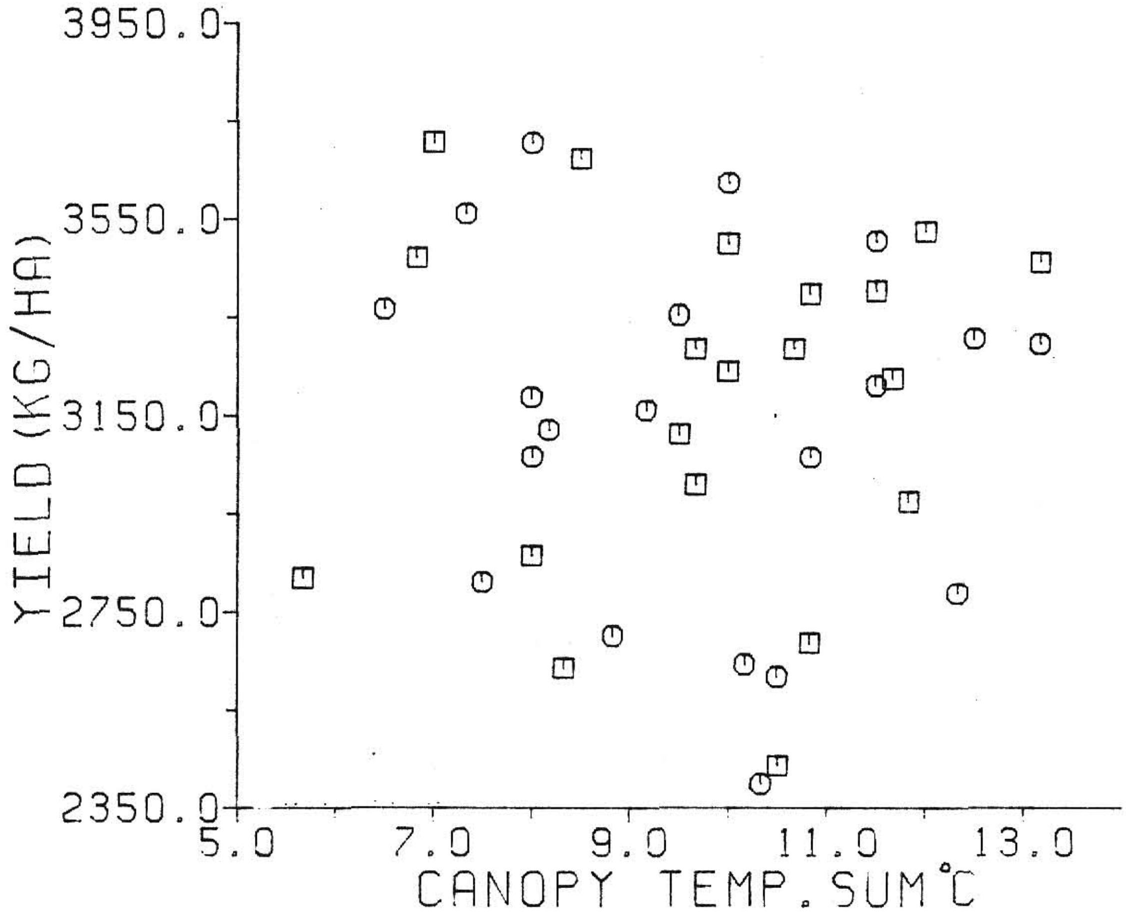
Figure 2.2. Relationship of seed yield and canopy temperature sum for 20 soybean genotypes in 1980, separated into irrigated and dryland treatments.



□ Irr r = -.688**

○ Dry r = -.611**

Figure 2.3. Relationship of seed yield and canopy temperature sum for 20 soybean genotypes in 1981, separated into irrigated and dryland treatments.



□ Irr r = .077NS

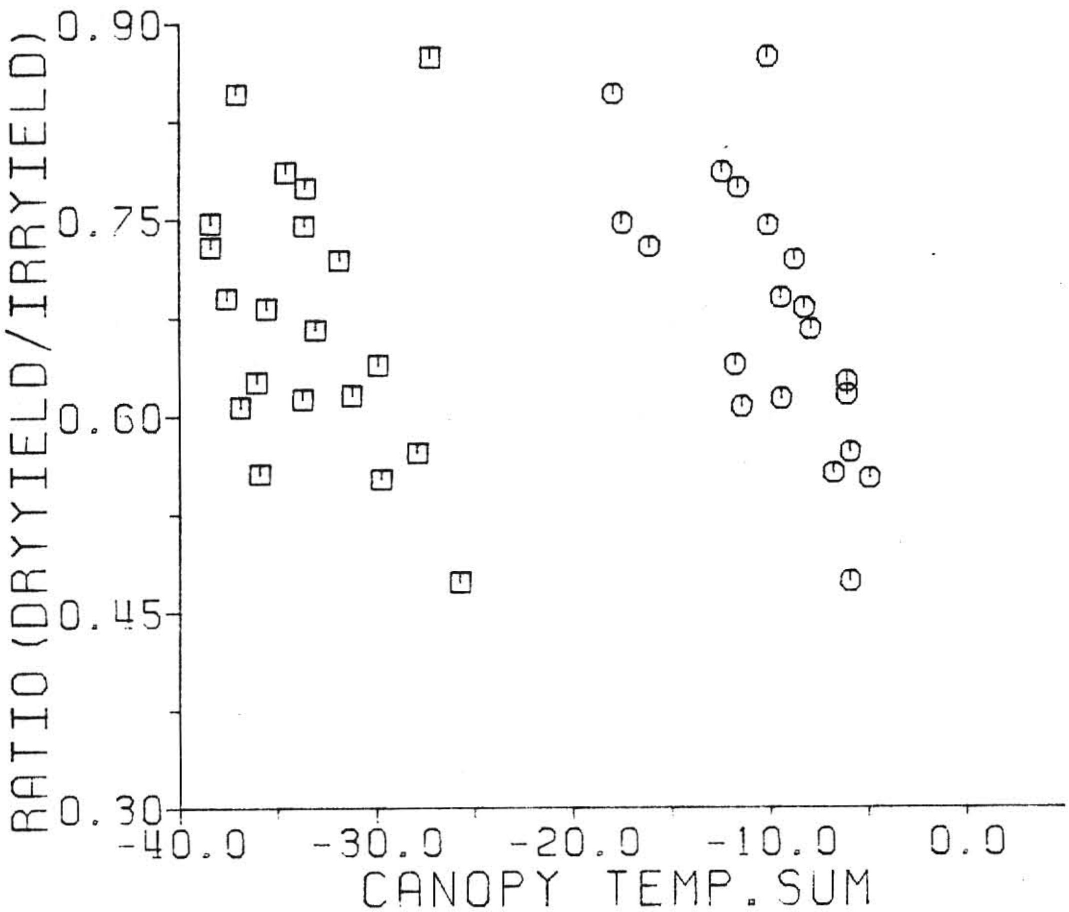
○ Dry r = -.134NS

yield are believed to be related to the fact that water was not limiting and that air temperatures were relatively low.

In order to examine the association of canopy temperature SUM and stress tolerance, a measurement of yield stability had to be made. This measurement was made by dividing the yield of an irrigated plot by the yield of its corresponding dryland plot and defined as the yield ratio. The irrigated and dryland values of canopy temperature SUM were separated and plotted against yield ratio. Correlations of SUM and yield ratio were made within irrigation treatments. In 1980, under dryland conditions, SUM and yield ratio were found to be significantly correlated (Figure 2.4). Under irrigation in 1980 and in both irrigation treatments in 1981, SUM and yield ratio were not significantly correlated (Figure 2.5). It should be noted, however, that yields across treatments in 1981 differed little and yield ratio for some genotypes was greater than one.

Seed yield in 1980 was linearly associated with seed yield in 1981 with a correlation coefficient of .57, significant at the 0.01 probability level. This, however, was not the case for canopy temperature SUM values in 1980 and 1981 which had a nonsignificant correlation coefficient of .26.

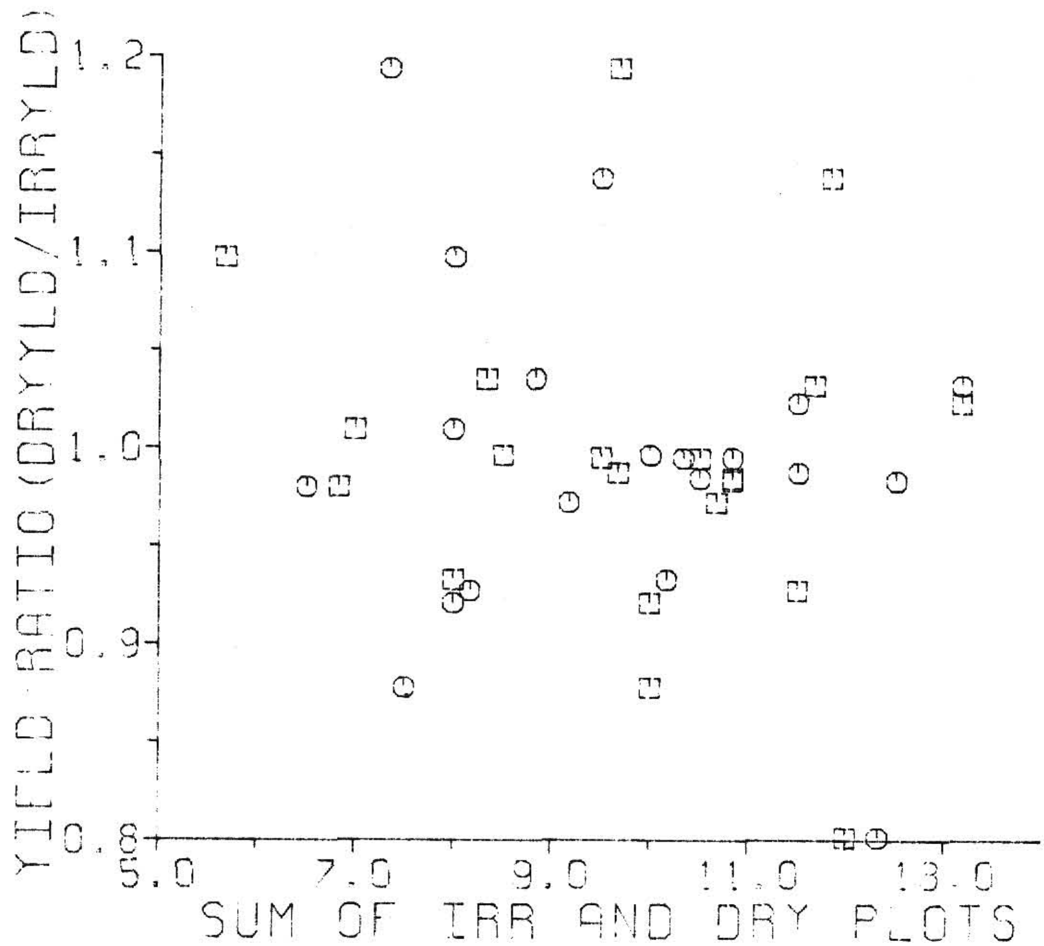
Figure 2.4. Relationship of yield stability vs. canopy temperature sum for 20 soybean genotypes in 1980, separated into irrigated and dryland treatments.



□ Irr r = -.315NS

○ Dry r = .688**

Figure 2.5. Relationship of yield stability vs. canopy temperature sum for 20 soybean genotypes in 1981, separated into irrigated and dryland treatments.



□ Irr r = -.178NS

○ Dry r = .194NS

Conclusions

In looking at the data collected in each of the two years, with high evaporative demand and the existence of moisture stress in 1980, a linear association between canopy temperature SUM and yield and canopy temperature SUM and yield ratio occurred. In 1981, coupled with the lack of a moisture stress treatment was the insufficient number of days on which readings could be made due to cloudy or overcast conditions. Therefore, in 1981, canopy temperature SUM was found not to be linearly associated with yield or with yield ratio. Based on these data, few conclusions about the use of the infrared thermometer as a tool for screening for drought tolerance can be made without the collection of more data in years with both stressed and non-stressed conditions. As other researchers have found, measurements made with the infrared thermometer are highly dependent upon climatic factors as well as the actual water status of the plant. When evaporative demands are relatively high, canopy temperature sum tends to be more linearly associated with seed yield than when evaporative demands are relatively low. Due to this result, use of the infrared thermometer in a breeding program may be limited to use in those years when evaporative demands are high and a moderate water stress treatment can be imposed.

LITERATURE CITED

1. Carlson, R. E., N. Y. Douglas, and R. H. Shaw. 1972. Environmental influences on the leaf temperatures of two soybean varieties grown under controlled irrigation. Agron. J. 64: 224-229.

2. Clark, R. N. and E. A. Hiler. 1973. Plant measurements as indicators of crop water deficit. Crop Sci. 13; 466-469.

3. Ehler, W. L. and C. H. M. van Bavel. 1967. Sorghum foliar responses to changes in soil water content. Agron. J. 59: 243-246.

4. Ehler, W. L., S. B. Idso, R. D. Jackson, and R. J. Reginato, 1978. Diurnal changes in plant water potential and canopy temperature of wheat as affected by drought. Agron J. 70: 999-1004.

5. Findlay, K. W., and G. N. Wilkinson. 1963. The analysis of adaptation in a plant-breeding programme. Aust. J. Agric. Res. 14: 742-754.

6. Idso, S. B., R. D. Jackson, and R. J. Reginato. 1977. Remote-sensing of crop yields. Science 196, 19-25.

7. Idso, S. B., R. D. Jackson, P. J. Pinter, Jr., R. J. Reginato and J. L. Hatfield. 1981a. Normalizing the stress-degree-day parameter for environmental variability. Agric. Meteorol. 24: 45-55.

8. Idso, S. B., R. J. Reginato, R. D. Jackson, and P. J. Pinter, Jr., 1981b. Foliage and air temperatures: evidence for a dynamic "equivalence point." Agric. Meterol. 24: 223-226.

9. Idso, S. B., R. J. Reginato, D. C. Reicosky, and J. L. Hatfield. 1981c. Determining soil-induced plant water potential depressions in alfalfa by means of infrared thermometry. Agron. J. 73: 826-830.

10. Stalfelt, M. G. 1962. The effect of temperature on opening of the stomatal cells. Physiol. Plant. 15: 772-779.

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

CHAPTER III

EFFECTS OF PRODUCTION PRACTICES ON GENOTYPIC COMPONENTS OF YIELD AND THE ASSOCIATION OF YIELD COMPONENTS WITH YIELD WITHIN EACH PRODUCTION SYSTEM EXAMINED

INTRODUCTION

Where differences in genotypic yield response across a set of environments occur, changes in the components of yield of each genotype becomes important. Carter and Boerma (2) compared plant trait correlations with seed yield across planting date and row spacing environments and found seed size to be consistently unrelated to seed yield in all environments. In this same study, a greater number of plant traits were found to be associated with yield at the late planting date than at the early planting date. These differences across planting dates were attributed to the fact that the late planted material suffered environmental limitations in establishing large enough plants for maximum seed production. In a study conducted in a high yield environment only, Johnson et al. (4), found seed weight to be significantly correlated with yield, however, number of seeds per plant, pods per plant, and nodes per plant were not consistently correlated with yield. From these observations it was concluded that per plant characteristics have limited practical usefulness as indicators of high yield. In a similar study, Anand and Torrie (1) found conflicting results when number of pods per plant and number of seeds per pod were more closely associated phenotypically with high seed yield than was seed weight. These researchers concluded that differences in their study and that of Johnson et al., were probably due in part to differences in environments under which the studies were conducted.

Water stress applied at various developmental stages of soybeans in studies by Shaw and Laing (5) and by Doss et al.(3) demonstrate the importance of sufficient moisture at critical periods in the development of a soybean plant. The amount of yield reduction was seen to be dependent upon the time and duration of the moisture stress period.

This study was designed to observe yield components of specific genotypes as well as overall yield component response to planting dates, row spacings and irrigations. The association of these yield components with yield in all possible environments, was also examined.

MATERIALS AND METHODS

The experiment was conducted at the Ashland Agronomy Research Farm in Manhattan, Kansas in 1980 and 1981. In 1980, the soybean plots were planted in a Muir silt loam soil classified as a Pachic Haplustoll, fine-silty, mixed, mesic. No fertilizer was applied. In early May, prior to planting, approximately 2.47 liters/ha of Trifluralin (α,α,α-trifluoro-2, 6-dinitro-N, N dipropyl-p-toluidine) were applied and at planting 3.36 Kg/ha of Chloramben (3-amino-2, 5-dichloro-benzoic acid) were applied. In 1981, the study was planted in an Eudora silt loam soil classified as a Fluventic Hapludoll, coarse-silty, mixed, mesic. Approximately 111 kg/ha of 18-46-0 fertilizer were applied late in April. At mid-April 2.47 liters/ha of Trifluralin were applied and at planting 3.36 kg/ha of Chloramben were applied. Total and average monthly rainfall from May to September in 1980 was below normal for each month. In 1981, however, monthly rainfall averages were well above normal in May, June, and July, one cm below normal in August and 6.6 cm below normal in September. Average monthly and average minimum and maximum temperatures were above normal from June to September in 1980. Average temperatures in 1981, for the same period, were near or below normal temperatures (Appendix Table A-1.)

The experimental design of this study was a split-split-plot with irrigation and dates as whole plots, row widths as sub-plots and genotypes as sub-sub-plots. There were two planting dates (1980: May 25 and June 30, 1981; May 21 and July 1) and two irrigation treatments (an irrigated treatment and a dryland treatment). There were two row widths, wide rows (76 cm) and narrow rows (25 cm). Twenty genotypes consisting of fourteen cultivars and six experimental lines were chosen to represent both determinate and indeterminate growth habits from maturity groups III, IV and V, (Chapter I, Table 1). Maturity group IV was further divided into early maturity group IV's (IV-E) and late maturity group IV's (IV-L) for analysis. Analysis of yield components was made for genotypes in maturity group III and IV-E only. This was due to the occurrence of frost prior to the completion of physiological development of several of the genotypes in maturity group IV-L and V, when planting date was delayed.

The narrow row plots consisted of ten rows 5.8 meters long with plant populations of 60,362 plants/hectare with the center six rows machine harvested for seed yield. The wide row plots consisted of four rows of each genotype, 5.8 meters long with plant populations of 50,331 plants/hectare and the two center rows machine harvested for seed yield. Harvest row length was 4.3 meters in both 76 and 25 cm spacings. Agronomic data were recorded per unit area. Total number of plants, nodes, pods and seeds in a .24 m^2 area were recorded as was seed weight for each plot.

The data were analyzed by maturity group in a combined analysis over years using an analysis of variance procedure. Number of plants, nodes, pods, seeds, and seed weight were used as dependent variables and genotypes, row widths, irrigation, and planting date and their interactions as independent variables.

RESULTS AND DISCUSSION

Year, Planting Date, Irrigation

Significant differences across years, planting dates, and irrigation treatments were seen for numbers of pods and seeds in both maturity groups III and IV-E (Table 3.1). Significant differences across years and planting dates were seen for number of nodes in both maturity groups, with no difference due to irrigation treatment (Table 3.1). When planting date was delayed, reductions in number of nodes, pods, seeds and reduced seed weight occurred in all maturity groups. This same trend existed for yield. The number of nodes did not differ significantly across irrigation treatments in either of the maturity divisions. Numbers of pods and seeds as well as seed weight decreased significantly under dryland conditions. Seed weight and number of nodes, pods, and seeds increased significantly in 1981 when air temperatures were cooler and moisture more abundant than existed in 1980.

Variety x Date

A variety by date interaction was significant for genotypes in maturity group III for all yield components (Table 3.2). Although the number of plants across planting dates did not differ significantly for any of the genotypes, Elf was the only genotype which had the highest plant population in the second date. With this higher population the number of nodes, pods and seeds did not differ significantly when planting was delayed, as did the yield components of the other genotypes. Seed weight of Elf decreased by the greatest amount when planting was delayed. It is also interesting to note that seed weight

Table 3.1. Yield component responses to planting, irrigation treatment and years, with means averaged over genotypes within a maturity group.

Yield Component	Early	Late	Irrigated	DryLand	1980	1981
	Maturity Group III					
Nodes (no.)	191a+	123b	158a	156a	135a	179b
Pods (no.)	305a	192b	261a	236b	194a	303b
Seeds (no.)	678a	432b	596a	514b	436a	675b
Seed Wt.(g/100)	16.9a	15.1b	16.7a	15.3b	15.3a	16.8b
	Maturity Group IV-E					
Nodes (no.)	183a	121b	157a	147a	141a	163b
Pods (no.)	289a	191b	268a	211b	206a	274b
Seeds (no.)	633a	430b	609a	455b	467a	597b
Seed wt.(g/100)	16.7a	14.8b	16.6a	14.9b	14.7a	16.8b

+ Means for a given yield component, across planting dates, irrigation treatments, or years, within a maturity group, followed by the same letter, are not significantly different at the 0.05 level of probability.

Table 3.2. Means represent a genotype by planting date interaction significant for various yield components.

Genotype	Maturity Group	No. of Plants Early	No. of Plants Late	No. of Nodes Early	No. of Nodes Late	No. of Pods Early	No. of Pods Late	No. of Seeds Early	No. of Seeds Late	Seed Weight Early	Seed Weight Late
Cumberland	III	8	6	204	111*	334	179*	754	399*	17.9	16.5*
Calland	III	8	7	220	128*	259	158*	597	363*	16.5	15.8
Williams 79	III	8	6	167	102*	295	146*	725	360*	17.0	16.3
Hobbit	III	8	6	198	123*	326	211*	701	460*	16.9	13.9*
K74-108	III	9	7	195	131*	330	212	690	473*	15.6	13.5*
Elf	III	8	8	163	141	286	246	602	540	17.4	14.9*
LSD (.05) within columns		1		26		41		93		0.8	
LSD (.05) within columns		2		42		63		142		1.2	
Cutler 71	IV-E	7	7	179	120*	268	183*	623	435*	16.6	15.5
DeSoto	IV-E	7	7	208	116*	329	168*	788	386*	16.5	15.5*
Pixie	IV-E	8	7	157	109*	254	188*	520	425	17.6	15.4*
K1049	IV-E	8	8	186	141*	305	224*	603	476	15.9	12.9*
LSD (.05) within columns		1		21		37		94		0.7	
LSD (.05) within columns		2		35		35		134		1.1	

* Means of a given yield component, across planting dates, for a particular genotype, are significant at the 0.05 level of probability.

of the determinate genotypes, Hobbit, K74-108, and Elf all decreased significantly in the late planting. Seed weight of Cumberland, an indeterminate genotype also decreased significantly in seed weight when planting was delayed, but maintained the highest seed weight at both planting dates. Yields of these genotypes were reduced significantly when planting was delayed (Table 3.3), with the exception of Hobbit. In maturity group IV-E, the genotype DeSoto had the greatest reduction in number of nodes, pods and seeds as compared with the other genotypes when planting was delayed. Pixie and K1049, the determinate genotypes in this maturity group had seed numbers which did not differ significantly across planting dates. Seed weight decreased significantly at the late date for DeSoto, Pixie and K1049, but not for Cutler 71. Yields for all genotypes in maturity group IV-E were reduced significantly when planting was delayed (Table 3.3). Pixie and K1049, the two genotypes with no significant reduction in seed number at the late planting date, were the highest yielding genotypes at this late planting date. These yields, however, were not significantly higher than the yield of DeSoto.

Variety x Irrigation

A genotype by irrigation interaction was significant for seed weight in maturity group III (Table 3.4).

The seed weight of the determinate genotypes, Hobbit, K74-108, and Elf, decreased significantly under dryland conditions and had the lowest seed weights of the six genotypes under these conditions.

Table 3.3 Mean yields of genotypes across planting dates.

YIELD

Maturity Group III			Maturity Group IV-E		
Genotype	Early	Late	Genotype	Early	Late
	— kg/ha —			— kg/ha —	
Cumberland	2917	2191 *	DeSoto	2730	2015 *
Calland	2520	1956 *	Cutler 71	2434	1919 *
Williams 79	2661	2056 *	Pixie	2725	2207 *
Hobbit	2520	2258	K1049	2468	2075 *
K74-108	2587	2023 *			
Elf	2594	2016 *			
LSD (.05) within columns		164		163	
LSD (.05) between columns		306		264	

* Means for a genotype, across planting dates, are significnatly different at the 0.05 level of probability.

Table 3.4 Means represent a genotype by irrigation interaction significant for seed weight and yield.

	Seed Weight		Yield	
Genotype	Irrigated	Non-Irrigated	Irrigated	Non-Irrigated
	— grams/100 —		—— kg/ha ——	
Cumberland	17.6	16.8	2830	2775
Calland	16.6	15.8	2514	1962
Williams 79	17.0	16.2	2494	2224
Hobbit	16.2	14.6 *	2675	2106
K74-108	15.3	13.8 *	2614	1993
Elf	17.5	14.8 *	2607	1999
LSD (.05) within columns	0.8		161	
LSD (.05) between columns	1.2		NS	

* Means for a genotype across irrigation treatments are significant at the 0.05 level of probability.

Correlations

Correlations of seed yield with each of the five yield components, was determined within each of the environments. The environments were divided by planting date, irrigation treatment and row width, with correlations based on sixty observations (Table 3.5). At the early planting date, under irrigated conditions, number of pods and seeds were significantly correlated with yield in both the wide and narrow row spacings. The number of nodes was significantly correlated with yield only at the narrow row spacings. At the early planting date, under dryland conditions, number of nodes, seeds and seed weight were significantly correlated at both row spacings and number of plants significantly correlated at the narrow row spacing only. At the late planting date, under irrigation, seed weight was significantly correlated with yield at both row spacings. Under dryland conditions, number of pods, seeds and seed weight were significantly correlated with seed yield at both row spacings. Number of nodes was significantly correlated with seed yield at the wide row spacings only. It appears from these date that under dryland conditions, with reduced vegetative growth, a larger number of yield components tend to be significantly correlated with seed yield. When comparing correlations across dates under irrigated conditions, the correlations of yield exist with seed number and pod number at the early planting date and with seed weight alone at the late date. This could be due, in part, to the fact that plant size is reduced and therefore number of nodes reduced when planting is delayed (Table 3.6). The result from reduced plant size would be reduced seed number (Table 3.6) and changes in yield would be related to changes in seed weight, with adequate moisture available. When comparing correlations across irrigaton treatments, within a date,

Table 3.5. Correlation between yield components and seed yield within each planting date, irrigation, and row spacing environment averaged over two years and twenty soybean genotypes.

	EARLY PLANTING DATE			
	Irrigated		Non-irrigated	
Yield Component	Wide	Narrow	Wide	Narrow
Plants (no.)	-.24+NS	-.05NS	-.16NS	.30*
Nodes (no.)	.10NS	.33*	.50**	.67**
Pods (no.)	.41**	.48**	.73**	.77**
Seeds (no.)	.43**	.36**	.77**	.77**
Seed weight (g/100)	.25NS	.24NS	.47**	.44**

	LATE PLANTING DATE			
	Irrigated		Non-irrigated	
Yield Component	Wide	Narrow	Wide	Narrow
Plants (no.)	-.16NS	-.12NS	-.06NS	.25NS
Nodes (no.)	-.09NS	-.18NS	.36**	.13NS
Pods (no.)	-.10NS	-.20NS	.55**	.48**
Seeds (no.)	-.02NS	-.13NS	.63**	.48**
Seed weight (g/100)	.47**	.66**	.40**	.54**

*,** Correlation values are significant at the 0.05 and 0.01 levels of probability, respecively.

+ Correlations based on 60 observations.

a larger number of components are significantly correlated with yield under non-irrigated conditions than when plants were irrigated. With moisture limiting, maximization to the potential number of nodes, pods, and seeds and seed weight is less likely to occur (Table 3.6). In a study by Shaw and Laing (5) when water deficits occurred during flowering, flower and pod abortion occurred. When stress occurs during the grain filling period, number of pods was reduced some but number of beans per pod and seed size were greatly reduced. In an irrigation timing study on soybeans Doss et al. (3) found lowest yields when water was applied only at full flower and two weeks later at early pod fill. This yield reduction was attributed to reduced plant size and severe moisture stress during late pod-fill. These studies demonstrate the effect of limited moisture at a particular developmental stage in reducing each of these yield components and therefore reducing the yield potential. With reduced yield potential due to insufficient moisture, each of these yield components would become an important factor in final yield and thus could become linearly associated with yield.

Table 3.6. Mean yield component values, averaged over genotypes, across planting dates and irrigation treatments.

	EARLY		LATE	
Yield Component	Irrigated	Non-Irrigated	Irrigated	Non-Irrigated
	Maturity Group III			
Node Number	192	190	123	122
Pod Number	316	294	207	177
Seed Number	725	631*	467	397
Seed Weight	17.4	16.4*	16.0	14.3*
	Maturity Group IV-E			
Node Number	187	179	128	114
Pod Number	317	261 *	219	162 *
Seed Number	719	548 *	499	362 *
Seed Weight	17.3	16.1 *	15.9	13.8 *

* Means across irrigation treatments, within a planting date are significantly different at the 0.05 level of probability.

CONCLUSIONS

In general, reductions in number of nodes, pods, and seeds and seed weight occurred when planting was delayed and when plants were grown under dryland conditions. Yield components in 1980 were significantly lower than in 1981 due to temperature and moisture stress prevalent in that year.

Genotypic differences in yield component response across planting dates occurred in both maturity group III and IV-E. The difference in response in maturity group III was due primarily to the fact that Elf had the highest plant population in the second date. Therefore, number of nodes, pods and seeds did not differ significantly when planting was delayed as did the yield components of the other genotypes. In maturity group IV-E, the two determinate genotypes, Pixie and K1049, had lower relative reductions in number of seeds when planting was delayed. These two genotypes were the highest ranking genotypes in terms of yield in the second planting date. In comparing responses of yield components of genotypes across planting dates (Table 3.2) the compensatory nature of these components is observed, with means averaged over irrigation treatments.

The correlations revealed differences across irrigation treatments and date of planting treatments, under irrigation. When comparing the correlations within planting dates, under irrigation, the association of seed and pod numbers with yield exists. At the late planting date, with plant size reduced, seed weight becomes the yield component linearly associated with yield. In this case seed weight can compensate as moisture is not limiting. At both dates of planting, with moisture insufficient no one particular yield component is maximized and all components are linearly associated with yield.

From these observations, several inferences can be made. As yield potential changes across environments such as planting date and irrigation, components of yield change in the degree of association they maintain with yield. With sufficient moisture available, compensation of one component with the reduction of another component is still possible. As moisture becomes limiting this compensation is no longer possible and all components become more closely associated with yield.

LITERATURE CITED

1. Anand, S.C. and J.H. Torrie. 1963. Heritability of yield and other traits in the F_3 and F_4 generations of three soybean crosses. Crop Sci. 3:508-511.

2. Carter, T.E. and H.R. Boerma. 1979. Implications of genotype x planting date and row spacing interactions in double-cropped soybean cultivar development. Crop Sci. 19 :607-610.

3. Doss, B.D., R.W. Pearson, and H.T. Rogers. 1974. Effect of soil water stress at various growth stages on soybean yield. Agron. J. 66:297-299.

4. Johnson, H.W., H.F. Robinson, and R.E. Comstock. 1955. Genotypic and phenotypic correlations in soybeans and their implications in selection. Agron. J. 47:477-483.

5. Shaw, R.H. and D.R. Laing. 1966. Moisture stress and plant response, p. 73-94. In W.H. Pierre, Don Kirkham, John Pesek, and Robert Shaw (eds.) Plant environment and efficient water use. Amer. Soc. Agron., Madison, Wisconsin.

APPENDIX

Table A-1. Average monthly maximum and minimum temperatures, average monthly temperature and rainfall for 1980, 1981 and the normal.[+][§]

	MAY	JUNE	JULY	AUG	SEPT
1980					
Maximum	25.2[‡]	32.4	38.6	35.8	29.2
Minimum	11.1	19.1	23.4	21.8	15.7
Average	18.2	25.8	31.0	28.8	22.5
Rainfall (cm)	4.6	7.1	3.0	7.4	6.4
1981					
Maximum	22.8	30.2	31.2	29.6	27.7
Minimum	11.1	18.7	21.5	18.2	14.5
Average	16.9	24.4	26.4	23.9	21.1
Rainfall (cm)	17.9	16.6	14.2	7.1	3.6
NORMAL					
Maximum	25.2	30.1	33.2	32.4	27.6
Minimum	11.9	17.3	20.0	19.1	13.8
Average	18.6	23.7	26.6	25.8	20.7
Rainfall (cm)	11.4	13.5	10.2	8.1	10.2

[+] Averaged from temperature data from 1951 to 1980

[‡] Temperatured in degree Celsius.

[§] Information received from the Weather Data Library, Kansas State University Agricultural Experiment Station, Manhattan, Kansas.

Table A-2. Two year analysis of variance significance levels for soybeans yields, 1980 and 1981.

	MGIII	MGIV-E	MGIV-L	MGV
Year (Y)	**	**	**	**
Date (D)	**	**	**	**
Irrigation (I)	**	**	**	**
Row Width (R)	NS	NS	NS	NS
Variety (V)	**	**	**	**
Y x I	**	**	*	**
Y x D	**	*	***	*
Y x R	NS	*	NS	NS
Y x V	NS	***	**	**
D x V	**	***	*	**
V x R	NS	NS	NS	NS
V x I	*	NS	NS	NS
D x V x R	NS	NS	NS	*
Y x D x V	NS	**	**	NS
Y x V x R	NS	NS	NS	NS
Y x V x I	NS	*	NS	NS
Y x D x V x R	NS	NS	NS	NS
D x V x I	NS	NS	NS	NS
D x V x I x Y	NS	NS	**	NS

***, *, ** Significant at the 0.10, 0.05, and 0.01 levels of probablity, respectively.

Table A-3. Two year analysis of variance significance levels for soybean maturity dates, 1980 and 1981.

	MGIII	MGIV
Year (Y)	**	**
Date (D)	**	**
Irrigation (I)	**	**
Row Width (R)	NS	NS
Variety (V)	**	**
Y x I	**	**
Y x D	**	**
Y x R	**	NS
Y x V	**	**
D x V	**	**
V x R	NS	NS
V x I	**	*
D x V x R	*	NS
Y x D x V	**	*
Y x V x R	NS	NS
Y x V x I	**	**
Y x D x V x R	NS	NS
D x V x I	**	*
D x V x I x Y	**	NS

***, *, ** Significant at the 0.10, 0.05, and 0.01 levels of probability, respectively.

Table A-4. Two year analysis of variance significance levels for soybean lodging scores, 1980 and 1981.

	MGIII	MGIV-E	MGIV-L	MGV
Year (Y)	**	*	**	**
Date (D)	**	***	**	**
Irrigation (I)	*	NS	**	**
Row Width (R)	NS	NS	NS	NS
Variety (V)	**	**	**	**
Y x I	**	*	**	**
Y x D	NS	NS	*	*
Y x R	**	*	NS	NS
Y x V	**	NS	**	**
D x V	**	**	**	NS
V x R	NS	*	NS	NS
V x I	NS	NS	**	NS
D x V x R	NS	NS	NS	NS
Y x D x V	*	*	NS	**
Y x V x R	*	NS	NS	NS
Y x V x I	**	*	*	NS
Y x D x V x R	NS	NS	NS	NS
D x V x I	**	***	NS	*
D x V x I x Y	NS	NS	NS	NS

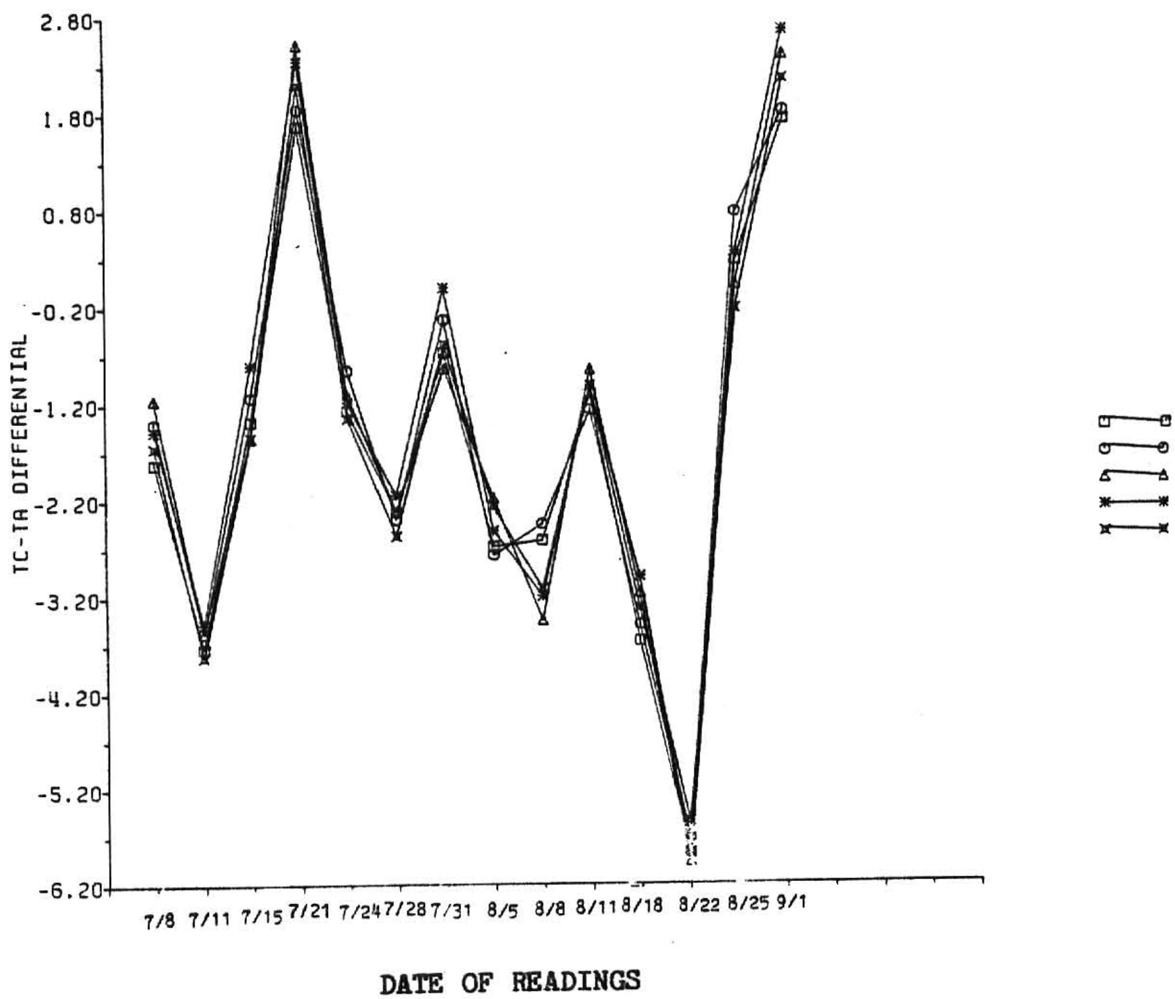
***, *, ** Significant at the 0.10, 0.05, and 0.01 levels of probablity, respectively.

Table A-5. Two year analysis of variance significance levels for soybean plant height, 1980 and 1981.

	MGIII	MGIV-E	MGIV-L	MGV
Year (Y)	NS	NS	*	NS
Date (D)	**	**	**	**
Irrigation (I)	*	*	**	*
Row Width (R)	NS	NS	NS	NS
Variety (V)	**	**	**	**
Y x I	*	NS	NS	NS
Y x D	**	*	**	**
Y x R	NS	NS	NS	NS
Y x V	NS	**	**	**
D x V	**	**	**	**
V x R	NS	NS	NS	NS
V x I	**	**	NS	**
D x V x R	NS	**	NS	NS
Y x D x V	**	**	***	*
Y x V x R	NS	NS	NS	NS
Y x V x I	**	**	NS	NS
Y x D x V x R	NS	NS	NS	NS
D x V x I	NS	NS	NS	NS
D x V x I x Y	NS	NS	NS	NS

***, *, ** Significant at the 0.10, 0.05, and 0.01 levels of probablity, respectively.

Figure A1a. Daily canopy minus air temperature differentials, by genotype in 1980.



Cumberland
Calland
Hobbit
K74-108
Elf

Figure A1b. Daily canopy minus air temperature differentials, by genotype in 1980.

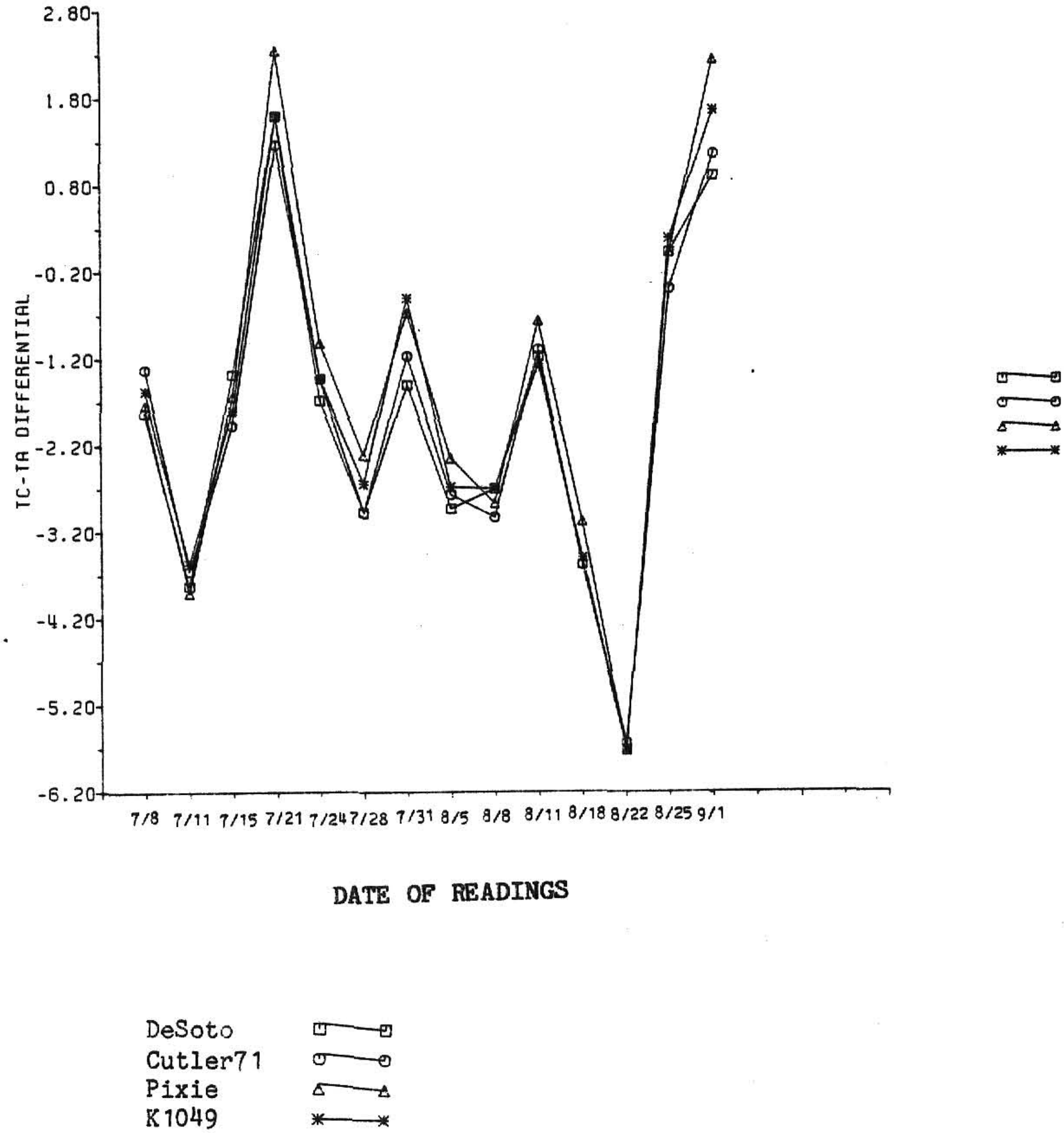
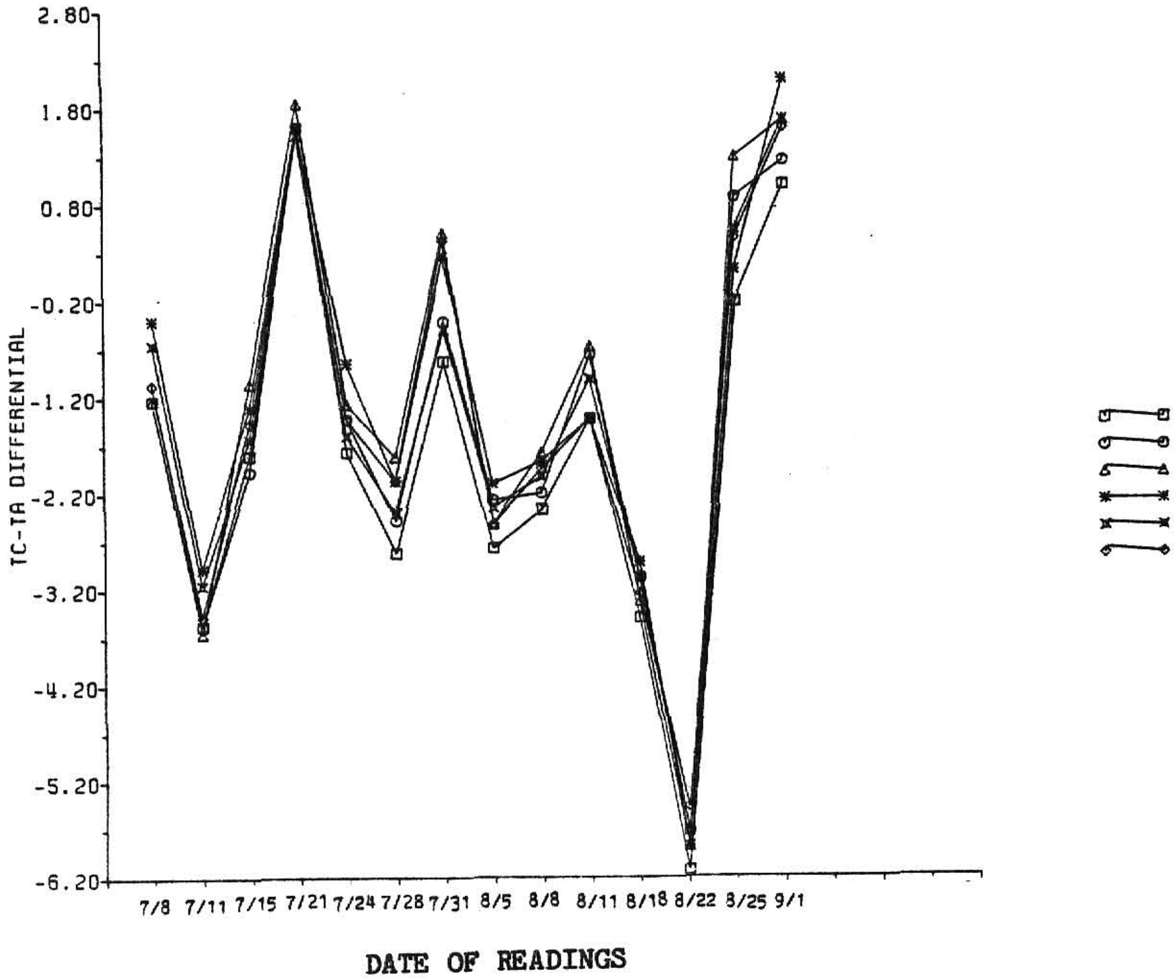
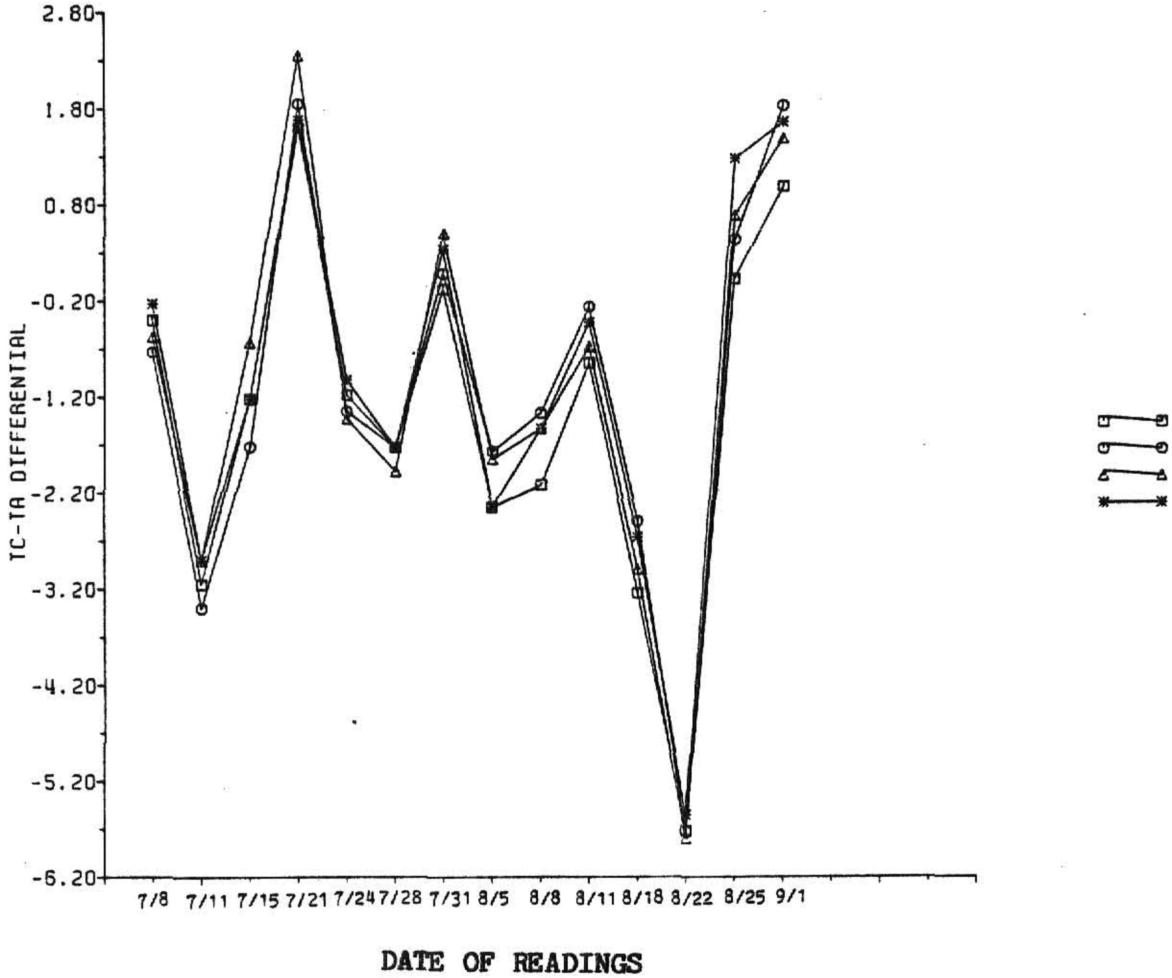


Figure A1c. Daily canopy minus air temperature differentials, by genotype in 1980.



Crawford
Douglas
C1573
V76-482
V76-398
K1048

Figure A1d. Daily canopy minus air temperature differentials, by genotype in 1980.



Essex
Forrest
Dare
Bedford

Figure A1e. Daily canopy minus air temperature differentials, by genotype in 1981.

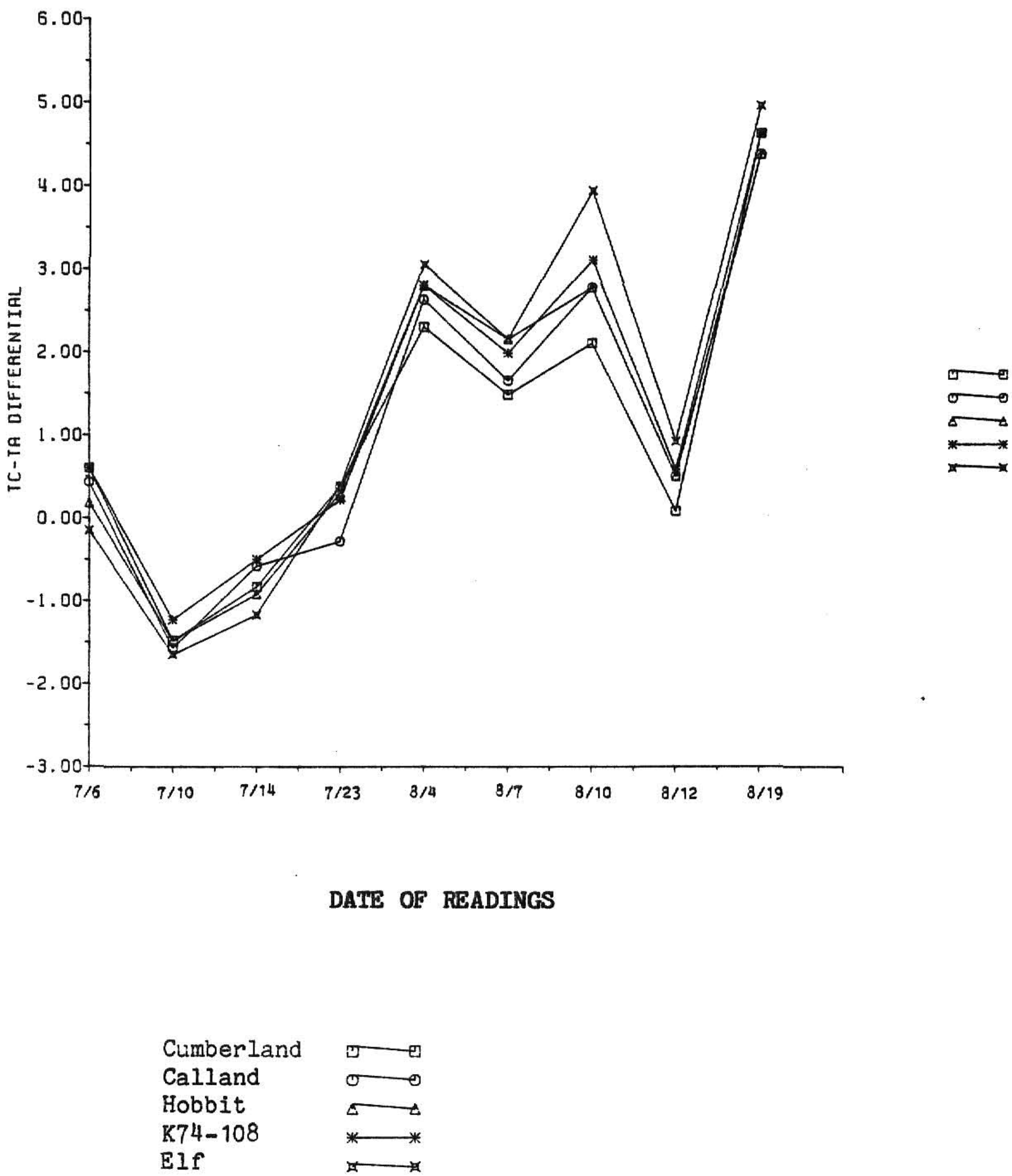


Figure A1f. Daily canopy minus air temperature differentials, by genotype in 1981.

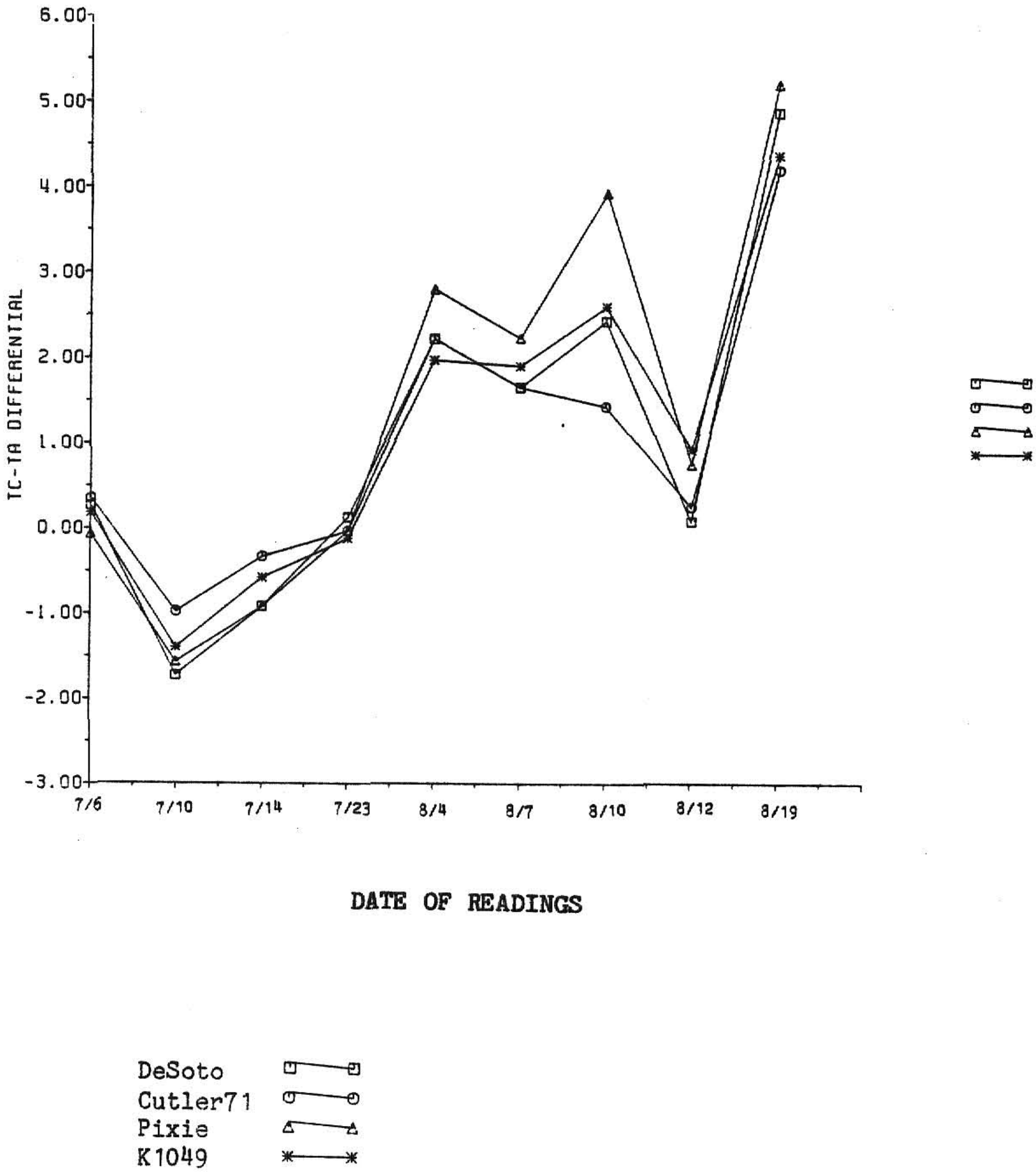


Figure A1g. Daily canopy minus air temperature differentials, by genotype in 1981.

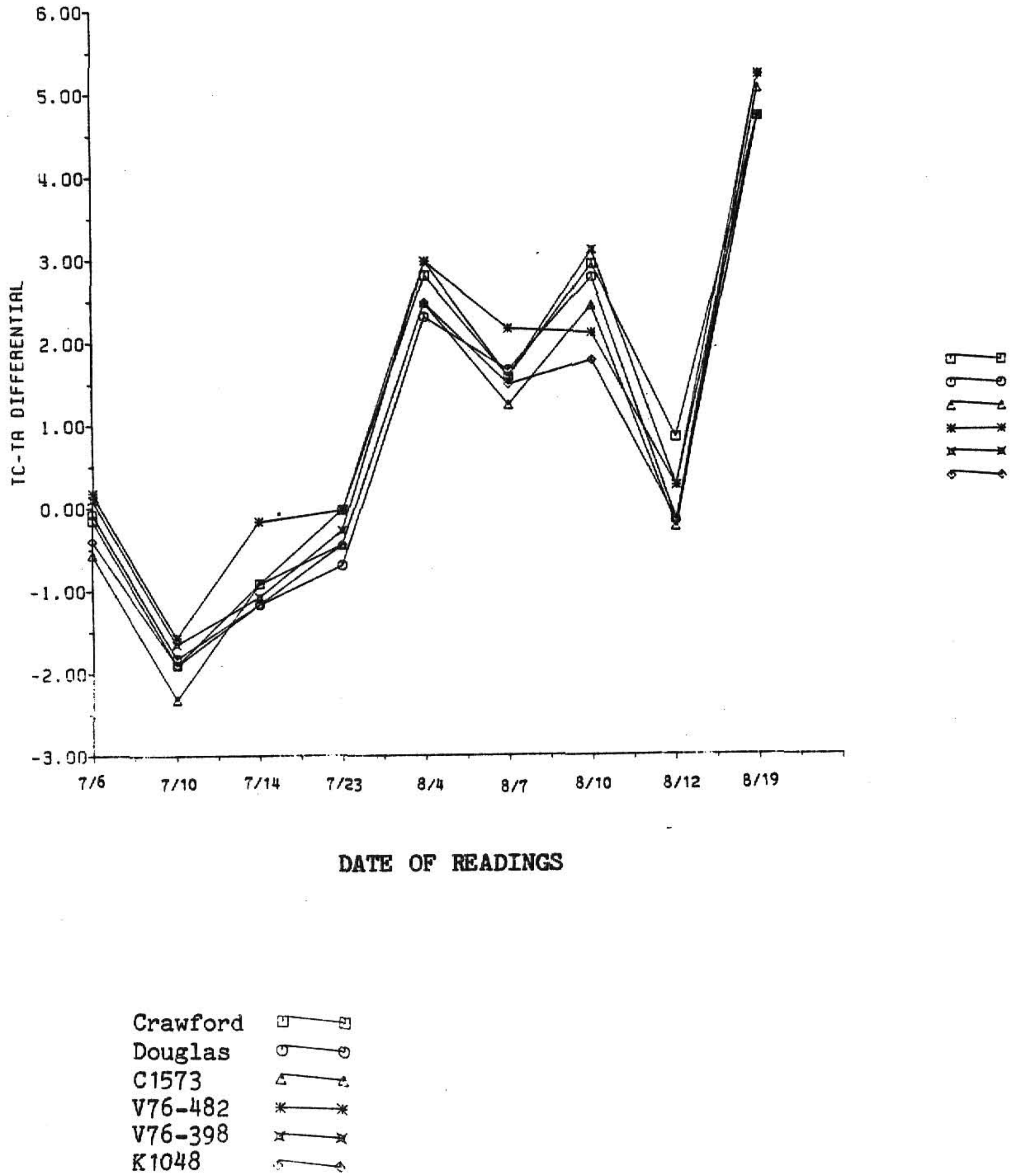
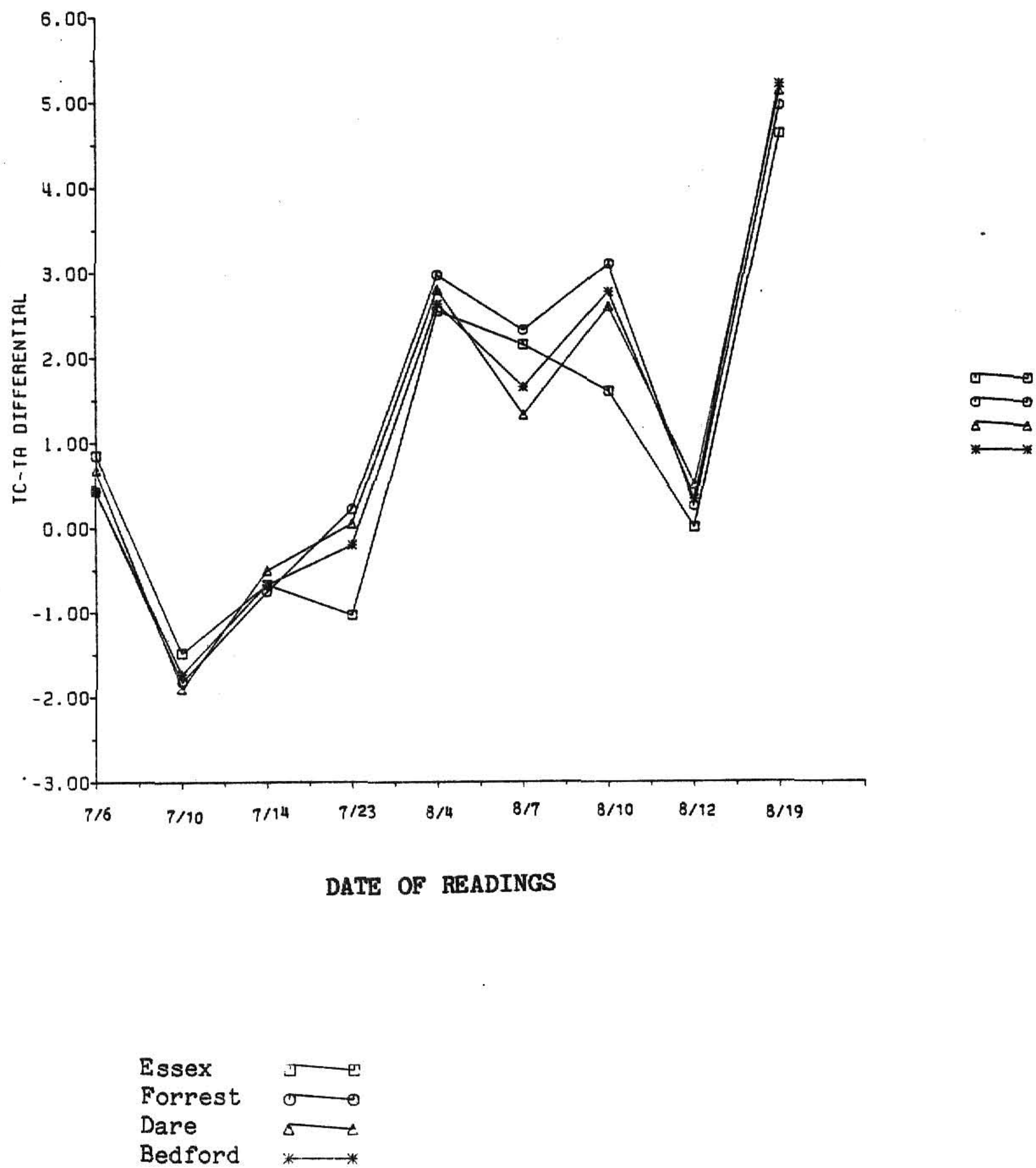


Figure A1h. Daily canopy minus air temperature differentials, by genotype in 1981.



THE INFLUENCE OF PRODUCTION PRACTICES ON AGRONOMIC PERFORMANCE AND COMPONENTS OF YIELD AND EXAMINATION OF GENETIC DIVERSITY FOR LEAF CANOPY TEMPERATURE IN SOYBEANS

by

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ABSTRACT

Soybeans are grown in several different production systems including production as a full season crop or as a double crop, at either narrow or wide-row spacings, and with or without supplemental irrigation. Genotypic performance across different environments may be diverse, in which case development of varieties specifically suited for one of these production systems could be accomplished with modified selection procedures.

In the first study, twenty soybean genotypes from maturity groups III, IV, and V, representing both determinate and indeterminate growth habits, were grown in several different environments. These environments included both 25 and 76 cm row spacings, both irrigated and non-irrigated conditions at both an early or conventional planting date and a delayed planting simulating a double-crop situation. Genotype by environment interactions existed for seed yield due to differences in response of genotypes to planting dates. In this interaction, however, high yielding genotypes were effected little by planting dates, remaining among the highest ranking genotypes at both dates. Interactions were due mainly to the genotypes with the lower yields at the conventional planting date moving up in yield rank when planting was delayed.

Genotype by environment interactions were significant for maturity date, lodging score and plant height across both irrigation treatments and planting dates. The interactions here were due mainly to differences in response of the determinate and indeterminate genotypes.

From this study, the results suggest that differences in response of yield, maturity, lodging and height due to row width, date of

planting and irrigated versus dryland treatments are not sufficient to warrant changes in a breeding program for development of soybeans for different production systems. Selection for high-yielding genotypes made from soybeans grown under irrigation, in wide rows and planted at the conventional time proved to be adequate for all environments tested.

The change in components of yield across treatments was the topic of the third study. Measurements of seed weight and number of plants, nodes, pods, and seeds were made on a .24 m^2 area in each plot. In general, reductions in seed weight and number of nodes, pods, and seeds occurred when planting was delayed and when plants were grown under dryland conditions. Yield components in 1980 were significantly lower than in 1981 due to temperature and moisture stresses prevalent in that year. Correlations were made between yield and each of the yield components for genotypes within a maturity group, within all possible combinations of planting date, irrigation and row width treatments. Similar correlation coefficients were seen across row widths with the greatest number of significant correlations occurring in the dryland treatments of each planting date.

Another area of interest in soybean varietal development is drought tolerance, with limitation of soybean production primarily to areas where rainfall or irrigation is sufficient for their growth. In the second study, a hand-held infrared thermometer was used to measure the leaf canopy temperature of twenty soybean genotypes under both irrigated and non-irrigated conditions. In 1980, fourteen canopy temperature measurements were made and nine made in 1981. Canopy temperature differentials (T_d = canopy temperature - air temperature) were consistently higher under dryland conditions. Values of T_d were totaled, within a year, to derive the canopy temperature Sum value.

Canopy temperature Sum was found to be negatively correlated with yield in both irrigation treatments in 1980 and not significantly correlated with yield in either irrigation treatment in 1981. In order to use leaf canopy temperature as a measurement of stress tolerance, a measurement of yield stability had to be made. Yield ratio (dryland yield/irrigated yield) was used as this measurement of yield stability. Correlation of yield ratio and canopy temperature Sum was significant in 1980 in the dryland treatment only. Yield ratio and Sum were not significantly correlated in the irrigated treatment in 1980 or in either irrigation treatment in 1981.

In 1980, evaporative demand was great with air temperatures abnormally high and moisture was limiting with rainfall well below normal. A reversal in environmental conditions occurred in 1981 with air temperatures at or below normal and rainfall above normal. In both years, genotypic differences for canopy temperature Sum existed, but genotypic response was not the same across years. The lack of association of canopy temperature Sum with yield and with yield ratio in 1981 seems to be due to the lack of moisture stress and the relatively low evaporative demand which existed in this year.