1846

EFFECTS OF MOISTURE STRESS ON YIELD, COMPONENTS OF YIELD, VEGETATIVE GROWTH COMPONENTS AND THEIR INTERRELATIONSHIPS IN CORN (*Zea mays* L.).

by

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B.A., Tabor College, 1969

A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Agronomy

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1978

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INTRODUCTION

Current American crop production emphasizes minimization of environmental stress on plant growth. Varietal selection in corn is, therefore, usually based on responses to optimized environments including available soil moisture. Environmental optimization for water consumes large amounts of energy and resources. Economic and ecological considerations increasingly require that limitations be put on water input. These limitations will become more critical in semi-arid corn production areas of Kansas in the near future. Varietal selection in corn based on response to suboptimal conditions has, therefore, great potential value.

This study investigated the effects of moisture stress on yield, components of yield, some vegetative growth components and their interrelationships for several corn varieties and inbreds. First, we looked at water deficit stress effects on several agronomic traits. We tried to determine the potential of these traits as selection criteria for high grain yield under moisture stress environments. Second, we analyzed the relationships of yield components to grain yield. The purpose was to determine the stability or plasticity of such relationships under various environments.

REVIEW OF LITERATURE

Plants growing on land send roots into a soil environment and shoots into the atmosphere. Water deficits in either environment induce stress on plant growth. Levitt (24) summarized that the shoot environment stress and the root environment stress did not contribute equally in their effect on plant growth. Richard and Fitzgerald (29) defined "agricultural drought" as water deficit solely in the root environment. Idso (18) demonstrated that water potential of even shoot tissue chloroplasts depends largely on soil moisture status. The moderating role of transpiration rate into the shoot environment modifies the soil water status effect. But, because it can be so quickly removed from the soil and supplied to shoot tissue, available soil water determines, for the most part, the degree of drought stress on the plant (24).

Effects of moisture stress on plant growth vary and are largely explained by the interaction between stress and stage of plant growth. Robins and Domingo (30) used any reduction field test yield as indicator or stress effect. Stress to wilting for one to two days at tasseling reduced yields 22% from non-stress yields. A six- to eight- day stress period at tasseling reduced yields 50%. Near physiological maturity, yields were no longer affected by stress. Denmead and Shaw (12) partitioned plant growth into vegetative, silking and ear development stages. Growth of vegetative components, such as leaf area and plant height, was reduced most by vegetative stress and least by ear-fill stress. Yield was restricted most by stress at silking stage. Further studies also substantiate that the plant organ under rapid development at the time of stress imposition will be most restricted (3).

The physiological basis for this growth restriction was partially explained by Kramer (21). He showed that cell turgidity is necessary for cell enlargement. Boyer (7) revealed that leaf enlargement was restricted by plant water deficit sooner and more severely than either photosynthesis or respiration. Acevedo et al. (1) reported that moderate soil moisture stress restricted leaf enlargement but growth following rewatering may for a short transitory phase exceed non-stress growth. This regrowth surge utilizes photosynthate accumulated when stress inhibited cell growth more than assimilation. Meristematic and meiotic cell division also decrease with increased water deficits and this influences vegetative growth as well as the formation of the pollen and ovule primordia (24).

Classen and Shaw (10) investigated the effects of non-repetitive four day stress treatments at various stages of growth. Short duration stress did not restrict leaf area development as was reported for longer stress periods during vegetative development (13). In Classen and Shaw's study, early shoot growth stress decreased cob size but enhanced stalk and leaf sheath dry matter accumulation. This divsersion of assimilate indicates that moisture stress can have qualitative as well as quantitative effects on plant growth. Silking is delayed by moisture stress at pollination (13,30). Barnes and Woolley (4) indicated that silking delay did not reduce fertilization of ears or reduce grain yield as much for a prolific variety as for a single-eared variety.

Vegetative components interact with yield components as determinants of final yield. Assimilatory leaf area produces photosynthate to fill grain. Stress during grain-fill reduces photosynthesis (8). Vegetative stress reduces leaf area development (4,7) and consequently photosynthetic potential. Kernel number per ear is affected by stress during shoot initiation and gamete formation. Decreasing kernel number limits the "sink" capacity to hold assimilates. This results in increased accumulation of photosynthate in the stalk (11).

Levitt (24) described plant genetic differences which modify the stress effect on growth and grain production. Early maturity varieties may avoid severe stress at critical stages of plant growth. This drought evasion mechanism still requires that normal amounts of water be available at critical growth stages. Levitt explained that earliness may be associated with decreased cell size which increases rate of development. True drought resistance implies plant survival without injury when exposed to normally injurous or killing low water potential. Two mechanisms, avoidance and tolerance, combine to determine the degree of resistance in higher plants. Avoiding plants maintain high water potential when exposed to external water stress. Some avoiders conserve through decreased transpiration by stomatal closure, vascular resistance, and increased cell osmotic potential. Other avoiding plants do not decrease transpiration but through expanded root systems and decreased root osmotic potential, take up sufficient water to avoid low internal water pressure without large decreases in transpiration rate. Tolerant plants survive low internal water potentials. Crop species are not tolerant of severe dehydration attesting to the importance of avoidance in crop drought resistance. How-ever, certain protoplasmic properties of some crop crop genotypes permit de-hydration avoidance at low internal water potential (5,32). Adaptations favorable to drought resistance and concurrent crop productivity include cellular hydration (5,32) and open stomata (33,34,36).

Increasing plant density places stress on yield per plant, vegetative growth, and yield components. Buren et al. (9) demonstrated that density stress reduced prolificacy and yield, increased barreness and the pollen-shed silking interval. Prior and Russel (28) tested prolific and non-prolific hybrids over a wide range of densities. Prolific types were superior at low density due to increased sink potential and at high density due to decreased barreness. Elsahookie (14) reported decreases in yield per plant and leaf area per plant with increased density pressure. Buren et al. (9) suggested that the ratio of grain yield to unit leaf area (Yield efficiency) would be a suitable trait in selection for density tolerance. Density pressure has been found to reduce yield efficiency (14).

The yield efficiency response to moisture stress is dependent upon the interplay of stress effects on yield and stress effects on leaf area.

Stress at early vegetative stages, with decreased leaf development and little effect on yield, increases yield efficiency (13). Stress during ear-fill or silking combined with full leaf development would greatly decrease yield efficiency.

Intense stress following pollination can reduce yields through elimination of already developed organs. Leaf stress to wilting speeds aging and decreases the leaf area duration through increased senescence of lower leaves (10). The potential sink size (number of ovules fertilized at pollination) can be reduced when stress causes embryos to abort. Classen and Shaw (11) observed that stress at early ear development reduced yields by aborting kernel development though a small increase in kernel weight often partially compensated for sink size reduction.

The multiplicative relationship of yield components to grain yield has enticed plant breeders seeking selection criteria for yield for some time. Grafius (16) suggested that favorable non-additive genetic variation could be selected for on the basis of highly correlated additive yield component effects. Efforts to capitalize on such additive component variation has not been encouraging. Johnson (19) indicated that in one case, estimates of additive genetic component variation were not highly correlated with grain yield. Robinson et al. (31) demonstrated, in a study of prolific corn lines, that ear number per plant had the highest positive genetic correlation with grain yield. In the same study, other yield components and vegetative components had non significant or negative correlations with each other. Nickell and Grafius (26) explained a negative response to selection for yield in barley on the basis of an inadvertant component selection. Due to winterkill, plants which tillered most were selected. In a more optimal season, such selections failed to do as well due to the negative correlation of other components to tillering and to the low correlation of tillering to yield. Hatfield et al. (17), working with corn, found the same variation of component with yield correlations due to diverse environmental conditions. A component undergoing rapid growth and development at the time of an environmental stress is most susceptible to that stress (3). Ensueing component development tends to compensate for modification of a prior component expression (2). The expressions of plant traits are recognized as being highly dependent upon environmental factors. Bonaparte and Brawn (6) showed that the relative plasticity or stability of any trait expression is under genetic control.

MATERIALS AND METHODS

These experiments were conducted in 1976.

Experimental design: A split-split plot design with three replications within each of two locations was used. Three water regimes provided the main-plot effect. Two population densities and two vigor group blockings were randomly cross-classified within the main plots. Five genotypes (nested within each of the two vigor groups) gave the split-split plot effects.

Locations: Test sites were the Kansas River Valley Experiment Field at Rossville, Kansas and the Ashland Agronomy Farm, Manhattan, Kansas, both on Eudora silt loam soils.

Moisture Regimes: Three moisture regimes were used. Weekly irrigation (Water Regime 1) was intended to minimize moisture stress at all stages of plant growth and development. The intermediate irrigation schedule (Water Regime 2) plots received water (saturation of furrow ridge) just prior to (Rossville) and during (Ashland) flowering. A second application followed at early grain-fill. Dryland plots (Water Regime 3) received only rainfall. Arid conditions prevailed at both locations during the water treatment period. Rainfall differences between Rossville and Ashland were expressed as location effect but also result in a modification of the water treatment. Figures 1 and 2 compare timing of rainfall, water regimes and flowering dates at the two locations.

Population Densities: Densities of 41,340 (Density 1) and 54,362 (Density 2) plants per hectare were employed.

Genotypes: Five genotypes from each of two vigor groups, (1) high vigor heterozygous lines, and (2) inbred lines, were selected on the basis of previous performance in stress environments. In the high vigor group, two commercial yellow hybrids, Frontier SX255 and Funk G4737 were thought to be stress resistant. Two open pollinated populations, Pride of Saline and Amarillo Bajio (A_o) were selected for susceptibility to moisture stress. K-7 selection of the Kansas Drought Synthetic (KDS) was included as a moisture stress resistant line. Pride of Saline is a white land variety. Amarillo Bajio is a CIMMYT-developed population incorporating some temperate and some Caribbean germplasm. The KDS synthetic population was developed at Kansas State University by intercrossing inbred lines selected for drought resistance. The low vigor group inbreds were chosen on the basis of previous yield and combining ability tests carried out under moisture stress. K731 and K724 were susceptible inbred line selections. H28, K55 and K41 were considered stress resistant.

Cultural Operations: All plots were hand planted at Ashland on May 8 and Rossville on May 10 at two seeds per hill and thinned to the experimental density three to four weeks after germination. Due to limited seed supplies for several genotypes and limited plot space, sub-sub plots were single rows (0.76 m). Vigor group blocking and planting an inbred composite border for the low vigor block helped alleviate variable competitive effects and poor seed set. Three border rows and

Figure 1. Time graph representing crop growth, irrigation scheduling and rainfall for Ashland.

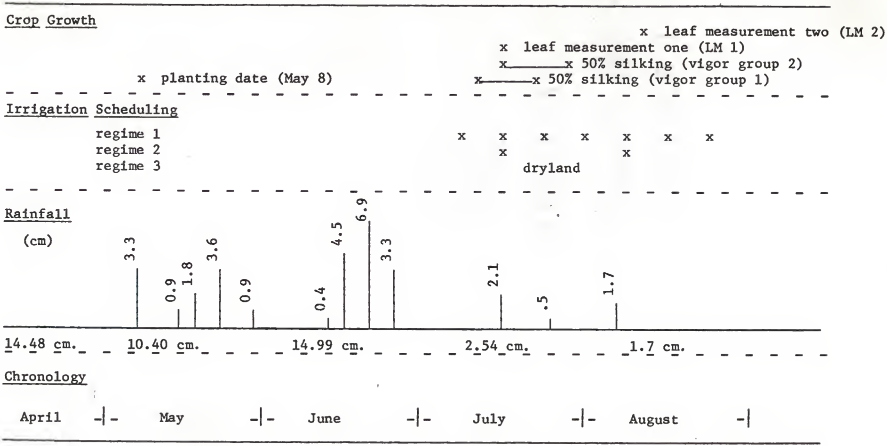
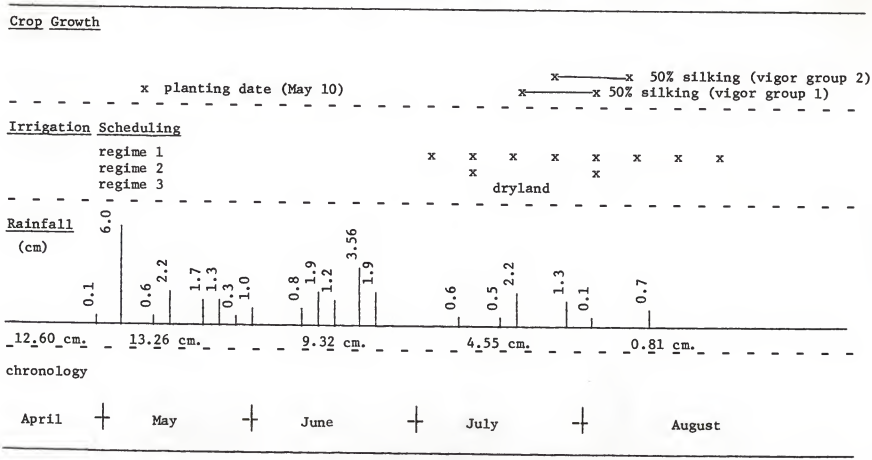


Figure 2. Time graph representing crop growth. irrigation scheduling and rainfall for Rossville.



a fortified irrigation furrow separated water treatment main plots. Two border rows separated vigor and density sub-plots. Weeds were controlled by a preplant application of atrazine followed by post germination machine cultivation and hand weeding. Twenty competitive plants from each sub-sub plot were selected and marked as test plants at flowering.

Measurements: All yield data were adjusted to 0% moisture. Yield and yield component data were computed as follows. Yield per plant (PLY) = plot yield adjusted for moisture/number plants harvested. Grain yield = PLY x plant density per hectare (Kg/ grain/ha). Resistance to barreness rating (RB) = 1 - (number barren plants/total test plants). Prolificacy rating (PROLIF) = total number ears harvested/(total test plants - barren plants). When RB = 0, then PROLIF was set to 1. Average ear number per plant (ERN) = total ears/total test plants. ERN is also equal to the product of RB and PROLIF. Average kernel weight (KW) = average of two 100 kernel weight counts/100. Average kernel number per ear (KN) = PLY/(ERN x KW). PLY is then equal to RB x PROLIF x KN x KW.

Vegetative component measurements were made at two stages of growth. Two randomly selected plants from each Ashland plot were measured for functional leaf area per plant (LAP), green leaf number per plant (GRLN) and dead leaf number per plant (DLN) 68-70 days after planting. First stage measurements, designated leaf measurement on (LM1), generally coincide with vegetative development at early flowering as evidenced by maturity data (Table 1). GRLN and DLN counts were made on ten plants of each Ashland plot 96-100 days after planting (LM2). LAP measurements were made, as well, for all ten plants of first replication plots. Second and third replication LAP estimates were made by multiplying the ear leaf area for all ten plants by its average ratio to total LAP in the corresponding treatment combination plot of the first replication as described

Table 1. 50% silking date for genotypes at Ashland location.

Genotype	Days after planting
Funk G4737	63-66
Frontier SX255	64-68
Pride of Saline	68-71
KDS	69-72
Amarillo Bajio	70-73
K55	66-67
K41	69-73
K724	69-73
K731	71-74
H28	74-76
LM1	69-73
LM2	96-100

No differences due to Density or Water regime treatments.
50% silking at Rossville followed the same genotype pattern but was delayed approximately 8-10 days.

by Francis et al. (13). Other leaf related computations were made as follows. Leaf area index values (LAI) = average plot LAP/m^2 soil area per plant. Yield efficiency (YE) = PLY/LAP (gms/m^2). LM2 leaf measurements, made at the Rossville location were discarded because extreme stress precipitated excessive leaf senescence and in many cases total plant desiccation.

In additions, lodging percentage, shelling percentage and an ear-fill coefficient (% ears in plot with at least two-thirds of cob filled with grain) were recorded.

RESULTS AND DISCUSSION

Treatments affecting the expression of any trait measured can be partitioned into environmental effects of location, density, water regime, and their interactions, genetic effects of vigor grouping and genotype; and genetic effect by environmental effect interactions.

GRAIN YIELD

The analysis of variance and treatment interaction means for grain yield are given in appendix tables 1 and 10. Overall, Water Regime 2 (intermediate) significantly reduced grain yield from Water Regime 1 level by 33% (Table 2). Regime 3 (dryland) production showed a highly significant reduction of grain yield of 59%. Comparison with results from other moisture stress by plant growth experiments is difficult. Magnitude of stress was not precisely imposed and was modified by varying natural climatic conditions. In addition, timing of stress varied due to variable maturity, particularily between vigor groups and between locations (Figure 1). Nonetheless, Regime 2 scheduling corresponds largely, by design and by result, to post silking stress with yield reductions reported of 50% (11), 21% (10) and 31% (23). Regime 3 (dryland) treatment combined stress and non-stress periods for several growth stages with greatest stress late and little stress during early vegetative growth. Robins and Domingo (23) reported a yield reduction of 52% due to combined tasseling and seed-fill period stresses.

Location effect and water regime x location interaction were highly significant influences on grain yield (Table 2). Soil fertility and atmospheric condition differences were not tested but may have contributed to location and regime effects. From the significant regime x location interaction, it is evident that moisture treatment effect varied considerably between locations. This is because rainfall, soil moisture retention, maturity differences and possible irrigation differences between locations are apparently included as additive effects within location mean effect but also seem to confound, differentially, with moisture treatment between locations. The Ashland location gave average grain yields 120% greater than the Rossville location. At the lower stress Ashland location, Water Regime 3

Table 2. Grain yield (Kg/ha) for genotypes as affected by locations, water regimes and location x regime.

	Locations		Water Regimes			Location x Regime						Means
Genotypes	1	2	1	2	3	1x1	1x2	1x3	2x1	2x2	2x3	
Frontier SX255	7823	4404	8402	5707	4231	9315	7719	6434	7489	3695	2029	6113
Funk G4737	6266	3733	7540	5037	2422	8447	6629	3722	6633	3445	1122	5000
Pride of Saline	6060	3227	6602	4629	2700	7953	6373	3854	5251	2885	1547	4644
Amarillo Bajio	5044	2003	5187	3197	2185	6386	5089	3655	3988	1306	715	3523
KDS	6224	2931	6103	4490	3140	7411	6294	4967	4795	2687	1312	4578
K724	1133	372	1158	655	445	1363	1191	845	953	118	44	752
K55	1752	384	1732	920	551	2442	1713	1100	1022	126	3	1068
H28	1866	379	1529	1201	637	2269	2074	1255	788	329	19	1123
K41	1358	236	1541	713	138	2461	1358	621	256	68	20	797
K731	3179	837	2899	1918	1208	3756	3480	2300	2041	355	68	2008
LSD .05	396		485			686						280
LSD .01	520		637			901						368
Vigor Group 1	6283	3260	6767	4612	2936	7902	6421	4521	5631	2803	1345	4772
Vigor Group 2	1858	442	1772	1081	596	2458	1063	1151	1085	199	41	1150
LSD .05	255		313			442						181
LSD .01	343		419			539						242
Means	4070	1851	4269	2847	1766	5180	3742	2839	3358	1501	693	2961
LSD .05	186		227			321						
LSD .01	270		330			467						

LSD valid for vertical comparisons.

reduced grain yield levels 45% and Regime 2 19% below Regime 1. At the higher stress Rossville location, Regime 3 reduced grain yields 79% and Regime 2 55% from Regime 1.

Density effect on grain yield was significant only through its interactions with water regime (Figure 3) and location. Under Water Regime 1, the high density was most productive (Table 3). Under Regime 3, low density was most productive. The compensation point of low density for moisture stress occured at stress above the Regime 2 schedule at Ashland and at stress between Regime 1 and 2 levels at Rossville. The significant density x location interaction indicated some differential component of location important to density effect: probably rainfall differences between locations.

Vigor group was highly significant as a direct effect on grain yield and through its interaction with several environmental effects (Tables 2 and 3). Predictably, the heterozygous lines outyielded inbred lines 315%. Vigor groups responded differentially to location, water regime, location x regime and location x density effects. Inbred lines were notably more susceptible (highly significant) to moisture regime stress. Regimes 3 and 2 reduced grain yields 57% and 32%, respectively, for the high vigor group and 66% and 39% for the inbred group. It was not possible, in this study, to separate susceptibility differences from differences due to later maturity of inbred group interacting with increasing stress late in the growing season.

Higher inbred susceptibility to moisture stress accounts for greater percentage yield reduction for inbreds at the stress location (Rossville) and moisture Regime 3 (dryland) within the stress location. Vigor groups responded similarly to the density x water regime interaction effect. Due to severe moisture stress at the stress location, inbred lines did not

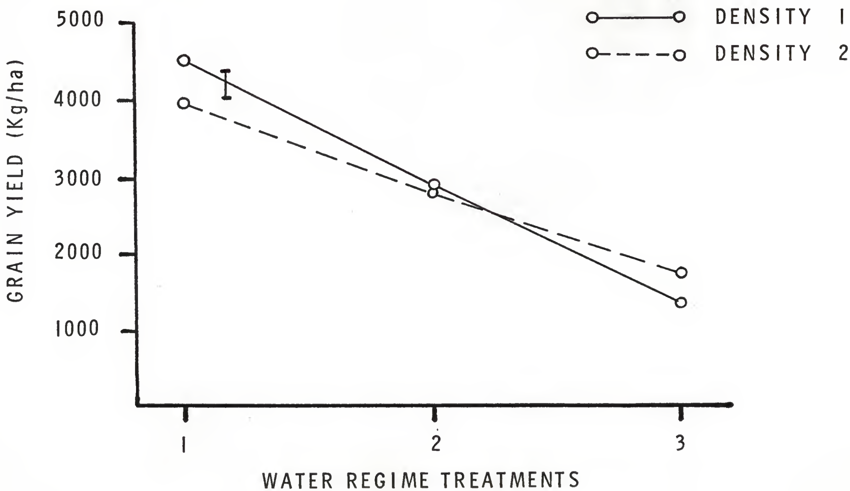


Figure 3. Water regime x density interaction for grain yield. The vertical bar indicates the significant range at 0.05 level.

Table 3. Grain yield (Kg/ha) as affected by density x location, density x water regime and density x location x vigor group.

	Locations		Water Regimes			Location x Vigor Group			
Densities	1	2	1	2	3	1x1	1x2	2x1	2x2
1	4237	1817	4560	2876	1645	6551	1923	3133	501
2	3904	1884	3978	2817	1887	6015	1792	3386	382
LSD .05	255		313			361			
LSD .01	343		419			484			

LSD valid for vertical comparisons.

show any significant response to density. This resulted in a significant location x density x vigor group interaction.

Differences of grain yields among genotypes within vigor groups were highly significant (Table 2). Frontier SX255 and K731 gave highest high-vigor and inbred yields, respectively. Genotype x water regime, genotype x location and genotype x regime x location interactions were highly significant indicating a differential genotype response for grain yield to increasing moisture stress (Table 2). All genotypes interacted similarly to density and more importantly to the density x water regime interaction. Increasing the number of density levels and degrees of freedom for observations per genotype by density-water regime combination, should show significant differences among genotypes for optimal density at different water regimes. Within each location x density x water regime x vigor group block, genotypes were given a relative response value for grain yield (Table 4). Relative response value relates genotype mean to an environmental index (vigor group mean) and to the total amount of genetic variability within the environment. Among genotypes, Frontier SX255 and inbred K731 had stable high yield rankings. KDS (K7) and H28 increased rank with increasing moisture stress. Funk G4737 and K41 decreased in rank with increasing moisture stress. Amarillo Bajio (A_o) and K724 inbred displayed relatively stable low yield rankings. Pride of Saline and K55 responses were not easily catagorized.

Field measurement ratios of non-stress to stress grain yields give some indication of resistance to drought stress, e.g. drought avoidance (17). Table 5 gives such yield stability ratios. A high drought resistance rating does not imply highest grain yield under stress conditions. This suggests that moisture stress adaptation selection should be based on grain yield under stress and not on a comparison with the genotype potential.

Table 4. Grain yield relative responses for genotypes within vigor group x environmental treatment combination blocks.

	Ashland					
	Water Regime x Density					
Genotype	1x1	2x1	3x1	1x2	2x2	3x2
Frontier SX255	+1.03	+1.16	+1.26	+1.14	+1.29	+1.51
Funk G4737	+0.65	+0.81	-0.48	+0.27	-0.38	-0.70
Pride of Saline	+0.29	-0.29	-0.62	-0.12	+0.19	-0.30
Amarillo Bajio	-1.37	-1.23	-0.49	-1.05	-1.29	-0.81
KDS	-0.60	-0.45	+0.33	-0.24	+0.19	+0.30
K724	-0.95	-0.65	-0.39	-1.48	-1.04	-0.40
K55	-0.14	-0.50	-0.34	+0.16	-0.08	+0.23
H28	-0.21	+0.34	+0.30	-0.19	-0.07	-0.05
K41	-0.21	-0.86	-1.12	+0.38	-0.51	-1.18
K731	+1.57	+1.67	+1.55	+1.14	+1.70	+1.40

	Rossville					
	Water Regime x Density					
Genotype	1x1	2x1	3x1	1x2	2x2	3x2
Frontier SX255	+1.08	+0.93	+0.95	+1.39	+0.45	+0.75
Funk G4737	+0.79	+0.73	-0.40	+0.57	+0.25	-0.14
Pride of Saline	-0.33	+0.10	+0.42	-0.19	+0.03	+0.05
Amarillo Bajio	-1.12	-1.33	-0.81	-1.08	-1.02	-0.77
KDS	-0.42	-0.42	-0.16	-0.68	+0.29	+0.11
K724	-0.33	-0.06	-	-0.10	-0.73	-
K55	-0.04	-0.73	-	-0.14	+0.03	-
H28	-0.39	+0.57	-	-0.49	+0.69	-
K41	-0.90	-0.68	-	-0.55	-0.59	-
K731	+1.66	+0.91	-	+1.28	+0.59	-

Table 5. Drought resistance ratios (measured as moisture stress yield divided by non moisture stress yield at same location x density x genotype level).

	Location x Density							
	1x1		1x2		2x1		2x2	
Genotype	R1/R2	R1/R3	R1/R2	R1/R3	R1/R2	R1/R3	R1/R2	R1/R3
Frontier SX255	.88	.79	.79	.61	.63	.36	.38	.19
Funk G4737	.87	.48	.70	.41	.63	.20	.42	.14
Pride of Saline	.77	.47	.83	.49	.65	.41	.46	.19
Amarillo Bajio	.83	.66	.77	.51	.33	.24	.33	.12
KDS	.85	.76	.85	.59	.52	.31	.60	.23
K724	1.01	.72	.76	.54	.28	.10	.04	.02
K55	.66	.44	.74	.46	.06	.00	.17	.01
H28	1.02	.71	.83	.42	.49	.06	.36	.01
K41	.55	.16	.55	.07	.17	.11	.08	.00
K731	.81	.62	1.06	.60	.22	.10	.14	.02

R1 = Water Regime 1, R2 = Water Regime 2, R3 = Water Regime 3

Tatum (27) suggested that selecting for a high degree of drought resistance may also eliminate adaptation to conditions favoring high production. Among the genotypes tested, stability of yield under stress and non-stress environments can be combined without sacrificing high yield under favorable conditions.

These grain yield rankings for genotypes (particularly under stress treatments) do not totally correspond to the basis for their selection. Funk G4737, K41 and K731 yields were decidedly inconsistent with expected responses. Funk G4737 and K41 may not have been evaluated previously at such severe moisture stress levels. The K731 response was so vigorous that the homozygosity of the line possibly is suspect. However, the plant type was totally consistent with K731 inbred characteristics under non-moisture stress conditions. In this experiment, we did not wish to evaluate drought resistance of genotypes but rather to evaluate traits associated with resistance. All further discussion is based on results of this test alone.

YIELD PER PLANT

The analysis of variance and treatment interaction means for yield per plant (PLY) are given in appendix tables 1 and 11. Environmental effects of location and water regime were highly significant determinants of PLY (Table 6). Increased plant density competition was highly significant in reducing PLY. There was no interaction between density and water regime, density and location or density x location x regime. If both location and water regime effects are construed as moisture effect determinants, then parallel moisture stress and density stress effects on PLY would be indicated.

Genetic effects of vigor group and genotype within vigor group were highly significant (Table 6). Genetic effect interactions with moisture

Table 6. Yield per plant (gms/plant) for genotypes as affected by locations, water regimes, densities and location x regime.

	Locations		Water Regimes			Densities		Location x Regime						Means
Genotypes	1	2	1	2	3	1	2	1x1	1x2	1x3	2x1	2x2	2x3	
Frontier SX255	165	94	177	122	91	145	114	196	163	137	158	81	45	130
Funk G4737	133	80	160	109	52	124	90	178	142	80	141	75	24	107
Pride of Saline	128	69	140	98	58	110	87	168	134	81	111	62	34	99
Amarillo Bajio	107	43	110	68	47	83	66	135	108	78	85	28	16	75
KDS	131	63	129	95	67	106	88	156	132	106	102	57	29	97
K724	24	8	24	14	10	18	14	29	26	18	20	3	1	16
K55	37	8	36	19	12	22	23	51	36	23	21	3	0	22
H28	40	8	32	26	14	27	21	48	44	27	16	7	1	24
K41	28	5	32	15	3	16	17	51	28	6	12	2	1	17
K731	68	18	62	41	26	49	37	81	73	50	43	8	3	43
LSD .05	9		11			9		15						6
LSD .01	11		14			11		20						8
Vigor Group 1	133	70	143	98	63	114	89	167	136	97	119	60	30	101
Vigor Group 2	39	9	37	23	13	26	22	52	41	25	22	4	1	24
LSD .05	6		7			6		10						4
LSD .01	8		9			8		13						6
Means	86	40	90	61	38	70	56	109	89	61	71	32	15	63
LSD .05	5		5			4		8						
LSD .01	6		8			6		11						

LSD valid for vertical comparisons.

stress and with density effects indicate differential responses to these stresses from which stress adapted lines could be selected. Since there was no significant genetic effect x moisture determinant x density interaction, these data suggest a genotype interaction with density would nearly equal its interaction with moisture stress. Genotypes selected for high PLY at population densities should also respond well to high moisture stress. This interpretation of the analysis of variance for PLY is not valid in the case where non-stress density level ranking of genotypes is significantly different from non-stress moisture level ranking.

LODGING

The analysis of variance and treatment interaction means for lodging % are given in appendix tables 4 and 12. Test yields were not adjusted for plants lodged. In field production, however, lodging may cause yield loss when mechanical harvesters fail to pick up prostrate plants.

Test for homogenity of variance between the two locations indicated a higher error variance associated with the larger % plants lodged mean at Rossville. Location effect on lodging was notable with stress location effect (Rossville) increasing the % plants lodged (location effect significcance could not be tested). Lodged plant counts were made at harvest which was one week later at Rossville than at Ashland. Delay of count added to moisture stress effect of Rossville location in increasing % plants lodged. Water regime stress significantly increased % plants lodged at both locations (Table 7). High density stress significantly increased lodging only at Ashland (Table 7). Density effect was apparently masked by the higher moisture stress at Rossville.

Genetic effects on lodging were highly significant at both locations (Table 7). The short statured inbred vigor block showed greater resistance

Table 7. Lodging percentage for genotypes as affected by water regime and density within Ashland and Rossville locations.

	Ashland						Rossville			
	Water Regimes			Densities		Means	Water Regimes			Means
Genotype	1	2	3	1	2		1	2	3	
Frontier SX255	1.7	3.3	3.3	1.1	4.4	2.8				14.6
Funk G4737	5.0	11.7	18.4	6.7	15.6	11.7				17.9
Pride of Saline	5.0	11.4	20.0	10.0	14.3	12.1				34.3
Amarillo Bajio	0.0	1.7	3.3	2.2	1.1	1.7				19.9
KDS	3.3	5.0	1.7	2.3	4.3	3.3				29.1
K724	1.7	1.4	12.5	7.0	3.3	5.2				8.8
K55	1.5	0.0	0.0	1.0	0.0	0.5				2.5
H28	0.0	3.3	3.3	1.1	3.3	2.2				11.6
K41	0.0	3.3	21.6	2.2	14.4	8.3				23.2
K731	1.7	0.0	10.0	3.3	4.4	3.9				10.7
LSD .05	7.6			6.2		4.4	n.s.			11.9
LSD .01	10.1			n.s.		5.8				15.7
Vigor Group 1						6.3	12.6	18.7	38.2	23.1
Vigor Group 2						4.0	7.2	17.4	9.6	11.4
LSD .05	n.s.			n.s.		2.3	11.9			6.9
LSD .01						n.s.	16.2			9.4
Means	2.0	4.1	9.4	3.8	6.5	5.2	9.9	18.0	23.9	17.2
LSD .05	5.0			2.2			5.3			
LSD .01	n.s.			n.s.			n.s.			

LSD valid for vertical comparisons.

overall to lodging (7.7% lodged) than the taller high vigor block (14.7% lodged). Genotype within vigor group plant heights generally correspond to % lodging at both locations. Pride of Saline, the tallest high vigor genotype lodged 23.3%. K55, the shortest inbred, lodged 1.5%. However, the moderately tall Funk G4737 hybrid lodged significantly more (14.8%) than the taller Amarillo Bajio synthetic (10.8%). An extensive 1948 study of plant trait relationships for 145 American inbreds (15) reported a non-significant +.081 simple correlation of plant height to % lodging.

The same study reported non-significant correlations of -.060 between % root lodging and grain yield and -.059 between % stalk lodging and grain yield. The present study found non-significant correlations between total % lodging and PLY; $r_{(PLY \cdot \%LODGE)} = -.076$ for high vigor group and $r_{(PLY \cdot \%LODGE)} = -.047$ for the inbred block. Due to mean yield and mean % lodging differences of vigor groups, overall $r_{(PLY \cdot \%LODGE)} = +.124$. This indicates susceptibilities to stress for yield and for lodging are not related.

EARS PER PLANT

Average number ears per plant (ERN) is divided into two components, % plants producing ears - termed resistance to barreness (RB) - and average number ears per productive plant or prolificacy rating (PROLIF). The product of RB and PROLIF equals ERN. Therefore PROLIF never has a value of less than one.

The analysis of variance and treatment interaction means for ERN, RB and PROLIF are given in appendix tables 2 and 13, 2 and 14, and 2 and 15, respectively.

Following are comparisons of environmental and genetic effects on ERN with corresponding effects on ERN components (Tables 8, 9 and 10).

Table 8. Average number ears per plant for genotypes as affected by locations, water regimes, densities and location x regime.

	Locations		Water Regimes			Densities		Location x Regime						Means
Genotypes	1	2	1	2	3	1	2	1x1	1x2	1x3	2x1	2x2	2x3	
Frontier SX255	1.00	0.93	1.01	0.99	0.88	0.99	0.94	1.00	1.00	1.00	1.02	0.99	0.77	0.96
Funk G4737	1.06	0.89	1.06	1.06	0.81	1.01	0.94	1.08	1.10	1.00	1.03	1.02	0.61	0.97
Pride of Saline	1.03	0.80	1.04	0.92	0.78	0.96	0.88	1.10	1.03	0.95	0.98	0.81	0.62	0.92
Amarillo Bajio	1.15	0.70	1.13	0.86	0.79	0.98	0.88	1.28	1.07	1.10	0.98	0.65	0.47	0.93
KDS	1.07	0.85	1.04	1.02	0.82	1.01	0.91	1.05	1.10	1.07	1.03	0.95	0.58	0.96
K724	0.95	0.55	1.00	0.71	0.53	0.84	0.66	1.04	0.89	0.92	0.97	0.53	0.15	0.75
K55	0.97	0.46	0.98	0.68	0.48	0.71	0.72	0.97	1.00	0.95	0.98	0.37	0.92	0.71
H28	1.24	0.56	1.18	0.96	0.56	0.92	0.89	1.53	1.18	1.00	0.83	0.73	0.13	0.90
K41	0.75	0.29	0.87	0.54	0.15	0.55	0.49	1.12	0.87	0.25	0.61	0.21	0.05	0.52
K731	1.53	0165	1.40	1.23	0.79	1.29	0.99	1.64	1.56	1.40	1.17	0.90	0.18	1.14
LSD .05	0.10		0.13			0.10		0.18						0.07
LSD .01	0.14		0.16			0.14		0.23						0.10
Vigor Group 1	1.06	0.84	1.06	0.97	0.82									0.95
Vigor Group 2	1.09	0.52	1.09	0.82	0.51									0.81
LSD .05	0.10		0.12			n.s.		n.s.						0.06
LSD .01	0.11		0.13											0.08
Means	1.08	0.68	1.07	0.90	0.66	0.92	0.83	1.18	1.08	0.96	0.96	0.72	0.36	0.88
LSD .05	0.08		0.10			0.06		0.13						
LSD .01	0.11		0.14			0.08		0.19						

LSD valid for vertical comparisons.

Table 9. Resistance to barreness rating for genotypes as affected by locations, water regimes, densities and location x regime.

	Locations		Water Regimes			Densities		Location x Regime						Means
Genotypes	1	2	1	2	3	1	2	1x1	1x2	1x3	2x1	2x2	2x3	
Frontier SX255	1.00	0.90	1.00	0.97	0.88	0.97	0.94	1.00	1.00	1.00	1.00	0.95	0.77	0.95
Funk G4737	1.00	0.86	1.00	0.98	0.81	0.95	0.91	1.00	1.00	1.00	1.00	0.97	0.61	0.93
Pride of Saline	0.96	0.79	0.98	0.88	0.77	0.90	0.85	1.00	0.98	0.90	0.97	0.78	0.63	0.88
Amarillo Bajio	0.98	0.67	0.96	0.79	0.73	0.85	0.80	1.00	0.97	0.98	0.92	0.62	0.47	0.83
KDS	1.00	0.82	1.00	0.94	0.79	0.93	0.89	1.00	1.00	1.00	1.00	0.88	0.58	0.91
K724	0.84	0.51	0.88	0.64	0.50	0.75	0.59	0.85	0.81	0.85	0.92	0.46	0.15	0.67
K55	0.93	0.46	0.97	0.66	0.46	0.68	0.71	0.95	0.94	0.90	0.98	0.37	0.02	0.69
H28	0.98	0.53	0.90	0.82	0.54	0.74	0.77	1.00	0.98	0.95	0.80	0.66	0.13	0.75
K41	0.69	0.28	0.79	0.51	0.15	0.50	0.46	0.97	0.85	0.25	0.61	0.17	0.05	0.48
K731	0.98	0.59	0.93	0.85	0.57	0.82	0.75	0.98	1.00	0.95	0.88	0.70	0.18	0.78
LSD .05	0.08		0.10			0.08		0.13						0.06
LSD .01	0.10		0.12			0.10		0.17						0.07
Vigor Group 1	0.99	0.81	0.99	0.91	0.79									0.90
Vigor Group 2	0.88	0.47	0.89	0.70	0.44									0.68
LSD .05	0.07		0.09			n.s.		n.s.						0.05
LSD .01	0.09		0.11											0.07
Means	0.94	0.64	0.94	0.81	0.62	0.76	0.81	0.98	0.95	0.88	0.91	0.66	0.36	0.79
LSD .05	0.07		0.08			0.05		0.12						
LSD .01	0.12		0.12			n.s.		0.17						

LSD valid for vertical comparisons.

Table 10. Prolificacy rating for genotypes as affected by locations, water regimes and location x regime.

Genotypes	Locations		Water Regimes			Location x Regime						Means
	1	2	1	2	3	1x1	1x2	1x3	2x1	2x2	2x3	
Frontier SX255												1.01
Funk G4737												1.05
Pride of Saline												1.05
Amarillo Bajio												1.11
KDS												1.05
K724												1.09
K55												1.02
H28												1.16
K41												1.07
K731												1.39
LSD .05	n.s.		n.s.			n.s.						.10
LSD .01												.13
Vigor Group 1	1.07	1.073	1.06	1.07	1.02							
Vigor Group 2	1.21	1.08	1.20	1.16	1.07							
LSD .05	.09		.11			n.s.						n.s.
LSD .01	.12		.13									
Means	1.14	1.05	1.13	1.12	1.04							1.10
LSD .05	.08		.10			n.s.						
LSD .01	n.s.		n.s.									

Water regime stress, stress location and water regime stress within stress location all significantly reduced ERN, RB and PROLIF. Higher density decreased ERN, RB and PROLIF although the PROLIF reduction was signigicant only at the .10 level. Vigor group x regime and vigor x location interactions were highly significant for ERN, RE and PROLIF. Inbred ear development proved more susceptible to moisture stress than that of high vigor lines. Overall, high vigor lines had significantly greater levels of ERN and RB. Vigor effect on PROLIF was not significant due to higher inbred prolificacy under non-moisture stress and greater high vigor prolificacy under stress. Genotype within vigor group effect was highly significant for ERN, RB and PROLIF. For PROLIF, all genotypes within vigor group interacted similarly with stress treatments. This indicates that selection for stable prolificacy under stress and non-stress would not be of value. ERN, on the other hand, displayed significant and highly significant differential genotype interactions with density and moisture stress levels. Among high vigor lines, Frontier SX255 produced 1.0 ERN under Water Regime 1 at Ashland location, 1.0 ERN under Regime 3 at the same location and still 0.77 ERN under Regime 3 at Rossville location. A more susceptible Amarillo Bajio produced 1.28, 1.10 and 0.47 ERN under the same set of environments. Among inbreds, K731 produced 1.64 and 1.40 ERN under Regime 1 and Regime 3 at Ashland whereas the susceptible K41 produced 1.12 and 0.25 ERN.

The significance of the various genotype by environmental component interactions for ERN must be largely explained by RB variation. All genotypes within vigor group interacted similarly to stress for PROLIF. Genotype interactions with environment were highly significant for RB. Correlation analysis for ERN, RB and PROLIF gives a $r_{(PROLIF \cdot ERN)}=+.625$ and a $r_{(RB \cdot ERN)}=+.751$. However, with increasing stress, the contribution of RB to ERN increases and the contribution of PROLIF decreases.

Correlations from data of the two test locations demonstrate this. At the non-stress location, $r_{(PROLIF \cdot ERN)} = +0.889^{**}$ and $r_{(RB \cdot ERN)} = +0.450^{**}$. At the stress location, $r_{(PROLIF \cdot ERN)} = +0.428^{**}$ and $r_{(RB \cdot ERN)} = +0.969^{**}$. All ERN correlations were adjusted for vigor group means. Selection for RB can increase RN under stress conditions. Since RB is only fully expressed under stress environments and due to the significant genotype x stress interactions for RB, this selection must be made under stress environments. A non-stress indicator of high RB under stress for genotypes would be useful. As has been suggested for density stress (7), non-stress PROLIF appears the most useful criterion. For inbreds, $r_{(PROLIF\text{-}Regime\ 1 \cdot RB\text{-}Regime\ 3)} = +0.626^{**}$. For high vigor lines, $r_{(PROLIF\text{-}Regime\ 1 \cdot RB\text{-}Regime\ 3)} = +0.349^{**}$. The relationship seems to hold for inbreds tested, however the significance of the correlation for high vigor lines may well be due to coincident effects on PROLIF (Regime 1) and RB (Regime 3) from location and density treatments.

KERNELS PER EAR

The analysis of variance and treatment interaction means for average number kernels per ear (KN) are given in appendix tables 3 and 16. Among yield components, KN showed the highest correlation with grain yield ($r = +0.865^{**}$). Consequently, knowledge of environmental and genetic effects on KN would be useful in yield component selection to increase yield

Stress effects of Rossville location and Water Regime 3 were highly significant in reducing KN (Table 11). Water Regime 3 at Rossville reduced KN more than at Ashland resulting in a highly significant location x regime interaction. Density effect was highly significant (Table 11). Higher KN, together with higher ERN, at low density compensate for lower number plants per unit soil area. This KN compensation for plant density

Table 11. Average number kernels per ear for genotypes as affected by locations, water regimes, densities and location x regime.

	Locations		Water Regimes			Densities		Location x Regime						Means
Genotypes	1	2	1	2	3	1	2	1x1	1x2	1x3	2x1	2x2	2x3	
Frontier SX255	574	406	581	487	403			600	575	548	561	399	258	490
Funk G4737	485	369	539	422	299			545	500	410	533	385	189	427
Pride of Saline	434	355	453	431	300			495	463	344	411	398	256	394
Amarillo Bajio	343	211	329	284	217			345	387	297	313	182	138	277
KDS	456	309	471	364	313			519	444	406	176	283	220	382
K724	127	44	112	81	65			130	140	111	93	21	20	86
K55	163	50	152	104	63			194	173	123	110	36	3	106
H28	166	56	125	122	87			135	196	169	116	48	5	111
K41	178	42	144	104	83			195	184	156	93	24	9	110
K731	216	81	192	144	109			209	245	194	176	42	25	148
LSD .05	37		45			n.s.		64						26
LSD .01	49		59					84						35
Vigor Group 1			475	402	307	421	368							394
Vigor Group 1			145	111	81	114	111							112
LSD .05	n.s.		26			21		n.s.						15
LSD .01			35			28								20
Means	314	192	310	256	194	240	267	337	331	276	283	182	112	253
LSD .05	15		19			15		26						
LSD .01	22		27			20		84						

LSD valid for vertical comparisons.

was significant for the taller, highly competitive, high vigor lines (KN for high density = 368 and KN for low density = 421) but not for the less competitive inbreds (KN for high density = 111 and KN for low density = 114). Density x vigor interaction was therefore highly significant. Vigor group mean effect and genotype within vigor group effect were highly significant. Significant and highly significant genetic x environment interactions were vigor x water regime, genotype x water regime, genotype x location and genotype x location x regime. All genotype interactions were with some moisture stress factor. The data suggest that genotype selection for high KN under moisture stress must be performed under stress to be effective. Selection for high KN under high density stress could be made at either high or low density. A full range of density levels was not tested. Caution must, therefore, be give to this last proposition. Voldeng and Blackman (29,30) reported a highly significant genotype x density interaction for ear weight and shelling % when 15 population densities were involved. The product of ear weight by shelling % equals the product of KN by average kernel weight. The present study failed to show any significant genotype x density interaction effect for either KN or kernel weight. The significance of such density interaction may have been lost due to the relatively high variability for genotype response to water regime treatment at both density levels.

To interpret stress factors which reduce KN, two parameters of ear cob-seed proportion were measured. Shelling % (appendix tables 3 and 18) relates KN and average kernel weight to cob size. Moisture stress effects were highly significant in reducing shelling %. Genotype within vigor group effect and genotype interactions, though, were not significant for shelling %. For this reason, shelling % can not, in this case, be used to explain variable genotype response to stress for KN. Nonetheless, due to concomitant influence of moisture stress on shelling % and KN means, a highly significant correlation, $r_{(\text{Shelling } \% \cdot \text{KN})} = +0.690^{**}$ was obtained. A second parameter, ear-fill coefficient (ER-FILL COEF)(appendix tables 3 and 19) relates cob size and possibly pre-anthesis sink size potential to actual seed set. ER-FILL COEF was a visual classification value equal to % ears in the plot with at least two-thirds of cob filled with grain. Moisture stress effects reduced ER-FILL COEF means. In addition, genotype effect and genotype by moisture stress interactions were significant. In this study, ER-FILL COEF had a better predictive value for KN ($r_{(\text{ER-FILL COEF} \cdot \text{KN})} = +0.890^{**}$) than did shelling %. In light of the significance of ER-FILL COEF in predicting KN, it appears reduced KN was due to reduced effective fertilization at anthesis and not due to reduced sink size potential during ear formation (9,23). The rainfall data corroborate this timing of stress finding (Figures 1 and 2).

KN response was not linear to water regime treatment. Inbred lines and some high vigor lines had higher KN under Water Regime 2 than under Water Regime 1. Since a reduction of PROLIF due to less moisture might increase KN by eliminating many small second ears, KN was converted to kernel number per m^2 soil (KN/m^2) for comparisons of stress level effects on total sink capacity. Treatment interaction means for KN/m^2 are given in appendix table 17. Several lines, particularly prolific inbreds, continued to display insignificant decreases or even increases of KN/m^2 for Water Regime 2 at Ashland. This may indicate a soil moisture excess for Regime 1 plots at anthesis. Subsequent irrigation of these same plots significantly increased kernel weight above that of Water Regime 2. Resulting grain yields were higher for Regime 1 plots (with the exception of inbred K731) due to the kernel weight and ERN compensation for reduced KN.

Of interest are KN response comparisons for genotypes with similar maturity and vigor ratings. Earliest high vigor lines, Frontier and Funk hybrids, responded similarly for KN to non-stress treatment, but KN for the Frontier hybrid was significantly higher under moisture stress. Among high vigor populations, KDS and Pride of Saline (at Rossville location), were most stable for KN overall moisture regimes.

Non-stress PROLIF appeared significant among inbreds in predicting stable KN under stress and non-stress. This agrees with the suggestion that prolific genotypes are better fit than one-eared lines to develop the first ear when exposed to moisture stress (3). The correlations of $r_{(\text{PROLIF-Regime 1} \cdot \text{KN-Regime 3})} = +0.810^{**}$ and $r_{(\text{PROLIF-Regime 1} \cdot \text{KN-Regime 1})} = +0.660^{**}$ indicate prolificacy ratings generated under Water Regime 1 were better predictors for KN under Regime 3 than for KN of the irrigated conditions. The high vigor group did not include adapted prolific lines so that the PROLIF·KN correlation was both insignificant and meaningless. Positive and highly significant correlations were also obtained from the PROLIF-Regime 1 · KN/m^2-Regime 3 relationship.

KERNEL WEIGHT

The analysis of variance and treatment interaction means for average kernel weight (KW) are given in appendix tables 4 and 20. Due to greater moisture stress, Rossville had a lower KW mean than Ashland. However, heterogenous error variances between locations, for KW, correlate with KW mean and pre-empt location and overall treatment effect evaluation.

Significant treatment effects are indicated within each location (Table 12). Water regime effect was highly significant at both locations. Rainfall data (Figure 1) substantiate that grain-fill period moisture stress for stress treatments was very severe. High vigor lines produced larger kernels than inbreds at both locations and exhibited greater capacity to maintain high KW under water stress. Lower KW for high density stress plots was significant at Ashland but significant only at P greater than .90 level at Rossville.

Several high vigor lines produced higher KW on Water Regime 3 plots at Rossville than on Regime 2 plots. This is expressed in a highly significant regimex vigor group interaction effect at Rossville. Under these same stress conditions, KN and KN/m^2 were most severely reduced. Increases in KW under stress were partial compensation for decreased sink capacity but KW under Water Regime 3 always remained less than under Water Regime 1. Hastened maturity for stress plots, indicated by increased leaf senescence (see vegetative components), may have limited grain-fill compensation for KN (9,11).

Genotype within vigor group effect was highly significant at both locations. Genotype x regime interaction was also significant at each location. Selection for high KW under stress appears feasible. However, KW shows an erratic but sometimes negative correlation with KN and KN/m^2. When adjusted for treatment effect means other than genotype, $r_{(KW \cdot KN/m^2)} = -0.166$ for high vigor group and $r_{(KW \cdot KN/m^2)} = +0.300$ for inbreds. Furthermore, KW compensation for reduced KN due to stress is not sufficient to maintain high grain yield under stress. The correlation, $r_{(KW \cdot \text{Grain Yield})} = +0.316$, when adjusted for treatment effect means other than genotypes. Improved ranking of KDS, under stress, for grain yield may be attributable to KW, but Amarillo ajio and K724 were both poor yielders under moisture stress despite high KW.

Table 12. Average kernel weight (gms) for genotypes as affected by water regime and density within Ashland and Rossville locations.

	Ashland						Rossville			
	Water Regimes			Densities		Means	Water Regimes			Means
Genotype	1	2	3	1	2		1	2	3	
Frontier SX255	.3256	.2840	.2493	.3033	.2692	.2863	.2763	.1961	.2069	.2265
Funk G4737	.3035	.2581	.1936	.2616	.2418	.2517	.2539	.1910	.2032	.2160
Pride of Saline	.3133	.2807	.2431	.2833	.2747	.2790	.2764	.2165	.2054	.2327
Amarillo Bajio	.3098	.2640	.2390	.2705	.2714	.2709	.2753	.2345	.2289	.2462
KDS	.2874	.2711	.2447	.2690	.2664	.2677	.2331	.2150	.2170	.2217
K724	.2172	.2095	.1774	.1971	.2055	.2014	.2085	.1489	.0908	.1494
K55	.2727	.2111	.1928	.2205	.2162	.2265	.1978	.1551	.0259	.1263
H28	.2403	.1920	.1591	.2009	.1930	.1971	.1977	.1985	.0586	.1516
K41	.2353	.1798	.1572	.1861	.1955	.1908	.1902	.0691	.0281	.0958
K731	.2383	.1949	.1821	.2075	.2027	.2051	.2084	.1900	.0578	.1521
LSD .05	.0178			.0146		.0103	.0438			.0253
LSD .01	.0236			.0193		.0136	n.s.			.0335
Vigor Group 1						.2711	.2730	.2106	.2123	.2286
Vigor Group 2						.2040	.2005	.1523	.0522	.1350
LSD .05	n.s.			n.s.		.0068	.0370			.0214
LSD .01						.0092	.0506			.0293
Means	.2743	.2345	.2038	.2414	.2337	.2376	.2318	.1815	.1323	.1818
LSD .05	.0113			.0068			.0527			
LSD .01	.0186			.0092			.0873			

LSD valid for vertical comparisons.

LEAF AREA PER PLANT, GREEN LEAF NUMBER, DEAD LEAF NUMBER

Vegetative measurements (Ashland only) were from two stages of plant growth, LM1 and LM2 (Materials and Methods). Treatment interaction means at both LM1 and LM2 are given for leaf area per plant (LAP) in appendix table 21. Similar interaction means are given for LM2 only, for dead leaf number per plant (DLN) and green leaf number per plant (GRLN) in appendix tables 22 and 23. Analysis of variance tables for LAP, DLN and GRLN at both LM1 and LM2 are given in appendix tables 5, 6 and 7, respectively.

Effective LAP for total photosynthesis is a LAP by time function. Not enough LAP by time measurements were recorded to properly integrate LAP by time. However, comparison of LAP at LM1 and LAP at LM2 indicates treatment effect on both LAP and leaf area duration (Tables 13 and 14). At LM1, density stress significantly reduced LAP but moisture stress did not. Both density and water regime stresses significantly reduced LAP at LM2. Table 15 shows there was considerable leaf expansion between LM1 and LM2. Calculated as average area increase per leaf, no difference between water regime treatments was found for leaf expansion. Figure 5 compares LAP, DLN and GRLN for water regime treatments at LM1 and LM2. The water regime effect on LAP at LM2 appears due to increased leaf senescence under stress rather than inhibited leaf expansion. The larger for stress plots indicates hastened leaf senescence and shorter leaf duration under stress. Since water regime treatment had no apparent effect on 50% silking date (Table 1), moisture stress at Ashland shortened the grain-fill period.

The genotype x water regime interaction was highly significant for both DLN and GRLN at LM2 (Tables 16 and 17), but the implication for plant yield of high GRLN or low DLN under moisture stress was not clear. The concomitant influence of stress effects on both parameters caused correlations

Table 13. Average leaf area per plant (m^2/plant) for genotypes as affected by densities at LM 1.

	Water Regimes			Densities		Regime x Density						Means
Genotype	1	2	3	1	2	1x1	2x1	3x1	1x2	2x2	3x2	
Frontier SX255												.570
Funk 4737												.623
Pride of Saline												.638
Amarillo Bajio												.743
KDS												.576
K724												.552
K55												.383
H28												.478
K41												.394
K731												.619
LSD .05	n.s.			n.s.		n.s.						.033
LSD .01												.043
Vigor Group 1												.630
Vigor Group 2												.485
LSD .05	n.s.			n.s.		n.s.						.030
LSD .01												.041
Means				.612	.515							.558
LSD .05	n.s.			.030		n.s.						
LSD .01				.041								

LSD valid for vertical comparisons.

Table 14. Average leaf area per plant (m^2/plant) for genotypes as affected by water regimes, densities and regime x density at LM 2.

Genotype	Water Regimes 1	2	3	Densities 1	2	Regime x Density 1x1	2x1	3x1	1x2	2x2	3x2	Means
Frontier SX255	.715	.653	.596			.736	.676	.639	.694	.630	.552	.654
Funk G4737	.707	.696	.556			.729	.701	.628	.684	.691	.484	.653
Pride of Saline	.748	.737	.617			.767	.792	.667	.729	.682	.568	.701
Amarillo Bajio	1.007	.842	.759			1.147	.845	.852	.867	.840	.665	.869
KDS	.748	.719	.677			.784	.801	.782	.712	.638	.572	.715
K724	.647	.584	.541			.656	.603	.577	.638	.565	.505	.590
K55	.429	.427	.373			.434	.427	.368	.435	.427	.379	.410
H28	.513	.490	.484			.527	.495	.501	.498	.485	.467	.496
K41	.509	.457	.337			.527	.484	.386	.491	.430	.288	.434
K731	.722	.752	.557			.784	.755	.578	.660	.749	.536	.677
LSD .05	.212			n.s.		.300						.123
LSD .01	.281					.397						.162
Vigor Group 1						.833	.763	.714	.737	.606	.568	.719
Vigor Group 2						.585	.553	.482	.542	.531	.435	.521
LSD .05	n.s.			n.s.		.130						.053
LSD .01						.177						.073
Means	.674	.636	.550	.655	.585	.709	.658	.598	.640	.614	.502	.620
LSD .05	.135			.053		0.92						
LSD .01	.224			.073		.126						

LSD valid for vertical comparisons.

Table 15. Average leaf area (m^2) per green leaf at LM1 and LM2 across genotypes (within vigor group) within water regime x density combination block.

	Vigor Group 1					
	Regime x Density					
Leaf Measurement	1x1	2x1	3x1	1x2	2x2	3x2
LM 1	.0475(.0051)	0.395(.0051)	.0434(.0053)	.0362(.0028)	.0376(.0036)	.0381(.0061)
LM 2	.0579(.0087)	.0551(.0043)	.0662(.0083)	.0535(.0038)	.0515(.0044)	.0522(.0021)

	Vigor Group 2					
	Regime x Density					
Leaf Measurement	1x1	2x1	3x1	1x2	2x2	3x2
LM 1	.0345(.0071)	.0355(.0067)	.0335(.0058)	.0287(.0066)	.0305(.0074)	.0290(.0055)
LM 2	.0452(.0076)	.0433(.0068)	.0430(.0051)	.0409(.0056)	.0431(.0072)	.0426(.0073)

( ) denotes standard deviation for leaf area mean.

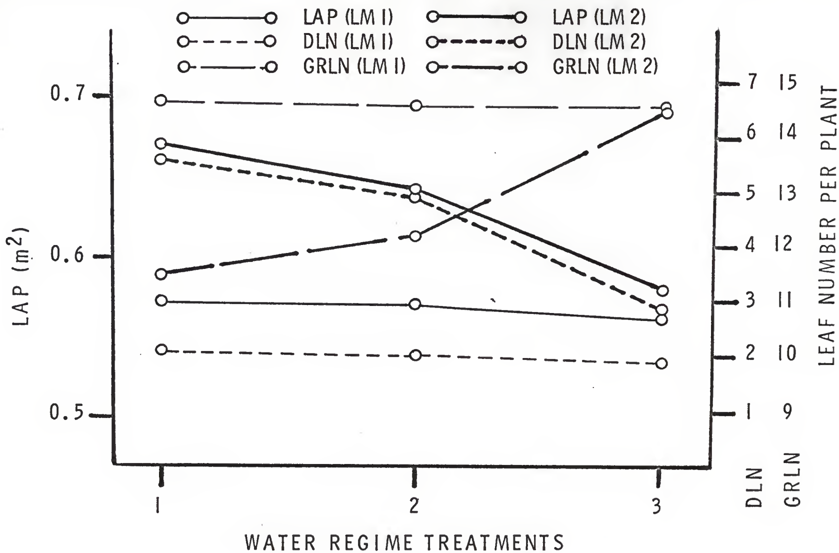


Figure 4. Leaf area per plant (LAP), dead leaf number per plant (DLN) and green leaf number per plant (GRLN) responses to water regime treatments at leaf measurement 1 (just prior to flowering) and at leaf measurement 2 (during grain-fill period).

16. Average dead leaf number per plant for genotypes as affected by water regimes and densities at LM 2.

	Water Regimes			Densities		Regime x Density						Means
Genotype	1	2	3	1	2	1x1	2x1	3x1	1x2	2x2	3x2	
Frontier SX255	2.78	3.59	5.67									4.01
Funk G4737	3.27	2.78	6.87									4.59
Pride of Saline	4.15	3.67	7.73									5.18
Amarillo Bajio	3.64	4.27	5.29									4.40
KDS	3.20	3.82	5.99									4.34
K724	3.59	4.15	6.79									4.84
K55	4.65	5.47	8.32									6.15
H28	3.23	3.70	5.39									4.11
K41	4.17	4.40	7.67									5.41
K731	3.45	4.02	5.78									4.42
LSD .05	0.86			n.s.		n.s.						0.50
LSD .01	1.13											0.66
Vigor Group 1												4.45
Vigor Group 2												4.99
LSD .05	n.s.			n.s.		n.s.						0.49
LSD .01												0.68
Means	3.62	3.99	6.55	4.38	5.05							4.72
LSD .05	0.55			0.49		n.s.						
LSD .01	0.91			0.68								

LSD valid for vertical comparisons.

Table 17. Average green leaf number per plant for genotypes as affected by water regimes and regime x density at LM 2.

Genotypes	Water Regimes 1	2	3	Densities 1	2	Regime x Density 1x1	2x1	3x1	1x2	2x2	3x2	Means
Frontier SX255	13.5	12.8	10.8									12.4
Funk G4737	13.9	14.1	9.7									12.6
Pride of Saline	13.7	13.3	9.4									12.2
Amarillo Bajio	15.2	14.3	12.3									14.3
KDS	13.9	13.8	11.4									13.0
K724	13.1	12.6	10.7									12.1
K55	12.5	11.6	10.3									11.4
H28	12.9	12.4	11.1									12.2
K41	12.1	11.7	8.9									10.9
K731	14.6	14.0	12.1									13.5
LSD .05	0.9			n.s.		n.s.						0.7
LSD .01	1.2											1.2
Vigor Group 1												12.9
Vigor Group 2												12.0
LSD .05	n.s.			n.s.		n.s.						0.6
LSD .01	n.s.			n.s.		n.s.						0.8
Means	13.5	13.1	10.8									12.5
LSD .05	1.0			n.s.		n.s.						
LSD .01	1.6											

of DLN and GRLN with PLY to be highly significant over all treatments (Table 18).

Table 18. Correlations of DLN and GRLN at LM2 with PLY and LAP at LM2.

d.f./cell = 88

correlation	Vigor Group 1	Vigor Group 2
$r_{(DLN \cdot PLY)} =$	-0.708**	-0.579**
$r_{(GRLN \cdot PLY)} =$	+0.501**	+0.719**
$r_{(GRLN \cdot LAP)} =$	+0.537**	+0.715**
$r_{(DLN \cdot LAP)} =$	-0.305**	-0.563**
$r_{(GRLN \cdot DLN)} =$	-0.854**	-0.821**

** Significant at the .01 level.

Under Water Regime 3, these correlations (adjusted for vigor group means) were not as significant but follow similar trends (Table 19).

Table 19. Correlations of DLN and GRLN at LM2 with PLY and LAP at LM2 under Water Regime 3.

d.f./cell = 58

correlation	r
$r_{(DLN \cdot PLY)} =$	-0.409*
$r_{(GRLN \cdot PLY)} =$	+0.287*
$r_{(GRLN \cdot LAP)} =$	+0.411*
$r_{(DLN \cdot LAP)} =$	-0.395*
$r_{(GRLN \cdot DLN)} =$	-0.825**

* Significant at the .05 level.

DLN and GRLN were stronger determinants of LAP under moisture stress than under Water Regime 1 conditions. Any importance given LAP for yield under stress would require consideration of GRLN and DLN, particularly for a grain-fill period stress of the type encountered in this test.

LEAF AREA INDEX

Analysis of variance for LM1 and LM2 and treatment interaction means for LM2 for leaf area index (LAI) in appendix tables 8 and 24.

Increased population density was highly significant in increasing LAI at both LM1 and LM2 in spite of a reduced LAP due to density stress. Genotype x density interaction was not significant. Significant mean comparisons for LAI at LM2 are given in Table 20. As for LAP, high density foliar cover proved more susceptible to water regime stress than low density foliar cover. Reduced LAI at LM2 was interpreted as shortened leaf area duration on the basis of leaf senescence data, average leaf area expansion and because water regime effect was not significant for LAI at LM1. The larger LAI of the high vigor group showed a greater percentage reduction due to water regime stress than did the smaller LAI of the inbred group. This response maybe attributed to the earlier maturity of high vigor lines and the accompanying earlier leaf senescence. The genotype within vigor group response appears more related to the non-stress LAI dimension than to maturity. The correlation between non-stress LAI and the slope of the LAI response to increasing moisture stress equaled -0.853** for high vigor lines and -0.546** for inbred lines. This indicates large LAI under non-stress moisture levels was detrimental to the duration of that leaf area. The most stable genotypes for LAI over moisture stress represented both earlier and later maturities (e.g. H28, K55, KDS and Frontier SX255) but all these possesed relatively small LAI.

Table 20. Leaf area index (m^2 leaf area/m^2 soil area) for genotypes as affected by water regimes, densities and regime x density at LM 2.

Genotype	Water Regimes			Densities		Regime x Density						Means
	1	2	3	1	2	1x1	2x1	3x1	1x2	2x2	3x2	
Frontier SX255	3.36	3.06	2.80			3.04	2.79	2.64	3.77	3.42	3.00	3.07
Funk G4737	3.32	3.27	2.61			3.01	2.90	2.60	3.72	3.76	2.63	3.07
Pride of Saline	3.51	3.46	2.90			3.17	3.27	2.76	3.96	3.71	3.09	3.29
Amarillo Bajio	4.73	3.96	3.56			4.74	3.49	3.52	4.72	4.57	3.61	4.08
KDS	3.51	3.38	3.18			3.24	3.31	3.23	3.87	3.47	3.11	3.36
K724	3.04	2.74	2.54			2.71	2.49	2.38	3.47	3.07	2.75	2.77
K55	2.02	2.01	1.75			1.79	1.77	1.52	2.31	2.32	2.06	1.92
H28	2.41	2.30	2.27			2.18	2.05	2.07	2.71	2.64	2.54	2.33
K41	2.39	2.15	1.58			2.18	2.00	1.60	2.67	2.34	1.57	2.04
K731	3.39	3.53	2.62			3.24	3.12	2.39	3.59	4.07	2.91	3.18
LSD .05	.05			n.s.		.07						.03
LSD .01	.07					.09						.04
Vigor Group 1												3.37
Vigor Group 2												2.45
LSD .05	n.s.			n.s.		n.s.						.02
LSD .01												.03
Means	3.17	2.99	2.58	2.71	3.18	2.93	2.72	2.47	3.48	3.34	2.73	2.91
LSD .05	.03			.02		.03						
LSD .01	.05			.03		.05						

LSD valid for vertical comparisons.

The relationships of grain yield to variation in LAI for each genotype across environments are shown in Table 21.

Table 21. Correlations of LAI at LM2 to grain yield, KN/m^2 and KW for genotypes across environments.

d.f./cell = 16

Genotype	LAI · Yield	LAI · KN/m^2	LAI · KW
Frontier SX255	+0.850**	+0.950**	+0.216
Funk G4737	+0.682**	+0.818**	+0.512*
Pride of Saline	+0.812**	+0.844**	+0.573*
Amarillo Bajio	+0.844**	+0.681**	+0.910**
KDS	+0.892**	+0.871**	+0.668*
K724	+0.481*	+0.274	+0.685**
K55	+0.684**	+0.875**	+0.030
H28	+0.125	+0.028	+0.102
K41	+0.968**	+0.988**	+0.837**
K731	+0.704**	+0.775**	+0.388

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

The water regime x genotype interaction effect was highly significant for LAI at LM2. This interaction effect on LAI did not parallel the water regime x genotype interaction effect on grain yield. The inbred K731 showed a sharp reduction in LAI due to stress but maintained a stable grain yield. K55 was stable for LAI and vulnerable to stress for grain yield. It has also been observed that certain moisture stress patterns (e.g. early vegetative stress) can reduce foliar development without critically affecting yield (4). The relationship, under the type of stress found in this experiment, appears to be insignificant for high vigor lines and highly positive for inbreds when considered across genotypes within a single moisture stress environment. For high vigor lines, this LAI ·

Yield correlation is highly negative and for inbreds insignificant within the non-stress environmental blocks (Table 22).

Table 22. Correlations of LAI at LM2 to grain yield across genotypes (within vigor groups) within water regime x density combination blocks at Ashland.

d.f./~~cell~~ = 13

	Regime x Density					
Vigor	1x1	2x1	3x1	1x2	2x2	3x2
Vigor Group 1	-0.851**	-0.996**	-0.223	-0.811**	-0.888**	-0.171
Vigor Group 2	+0.328	+0.759**	+0.654**	-0.095	+0.721**	+0.709**

** Significant at the .01 level.

The negative correlation between LAI and grain yield for high vigor lines is probably due to the inclusion of populations with large LAI and relatively low sink capacity. In all cases, large LAI appeared most benefical to grain production under moisture stress (least detrimental in the case of high vigor group). Grain yield is most probably related to leaf area duration of which LAI at LM2 is partially a function.

Due to the high correlation between grain yield and KN/m^2, the correlation LAI · KN/m^2, was nearly analagous to that found between grain yield and LAI (Table 23). KW, primarily dependent upon photosynthesis

Table 23. Correlations of LAI at LM2 to KN/m^2 across genotypes (within vigor groups) within water regime x density combination blocks at Ashland.

d.f./cell = 13

	Regime x Density					
Vigor	1x1	2x1	3x1	1x2	2x2	3x2
Vigor Group 1	-0.985**	-0.923**	-0.310	-0.876**	-0.934**	-0.445
Vigor Group 2	+0.487	+0.774**	=0.676**	+0.141	+0.699**	+0.744**

** Significant at the .01 level.

during the grain-fill period, would be expected to have a high correlation with LAI at LM2 (4). This was mostly the case under moisture stress conditions (Table 24).

Table 24. Correlations of LAI at LM2 to KW across genotypes (within vigor groups) within water regime x density combination blocks at Ashland.

d.f./cell = 13

	Regime x Density					
Vigor	1x1	2x1	3x1	1x2	2x2	3x2
Vigor Group 1	+0.158	+0.297	+0.802**	+0.042	+0.306	+0.729**
Vigor Group 2	-0.407	-0.296	-0.007	-0.911**	+0.545*	+0.247

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

Not enough population density levels were tested to determine the optimal LAI for each genotype at each moisture level although a shift of optimal density with different water regimes is evident. All genotypes recorded higher yields at high density under Regime 1 and Regime 2 indicating optimal or suboptimal LAI. For Regime 3 plots, highest yields were recorded for low density suggesting high density LAI was above optimum.

YIELD EFFICIENCY

Yield efficiency (YE) is the ratio of grain yield produced to unit leaf area (gms/m^2). Analysis of variance and treatment interaction means for YE (calculated on the basis of LAP at LM1 and at LM2) are presented in appendix tables 9 and 25.

YE values depend simultaneously upon factors governing LAP variation and upon factors governing grain yield variation. At LM1, LAI increase due to high density was not yet fully expressed. Though density effect

Table 25. Yield efficiency (gms grain/m^2 leaf area) for genotypes as affected by water regimes and densities at LM 1.

Genotypes	Water Regimes 1	2	3	Densities 1	2	Regime x Density 1x1	2x1	3x1	1x2	2x2	3x2	Means
Frontier SX255	333	295	241	292	287							290
Funk G4737	271	230	132	224	198							211
Pride of Saline	254	215	131	196	203							200
Amarillo Bajio	175	151	115	150	143							147
KDS	259	218	180	215	222							219
K724	54	44	33	48	39							44
K55	143	91	60	87	109							98
H28	98	90	59	93	71							82
K41	141	70	15	62	88							75
K731	128	113	85	119	98							109
LSD .05	30			25		n.s.						18
LSD .01	40			n.s.								23
Vigor Group 1	258	222	160									213
Vigor Group 2	113	82	50									82
LSD .05	22			n.s.		n.s.						13
LSD .01	30											17
Means	186	152	105									148
LSD .05	24			n.s.		n.s.						
LSD .01	39											

LSD valid for vertical comparisons.

Table 26. Yield efficiency (gms grain/m^2 leaf area) for genotypes as affected by water regimes and densities at LM 2.

Genotype	Water Regimes 1	2	3	Densities 1	2	Regime x Density 1x1	2x1	3x1	1x2	2x2	3x2	Means
Frontier SX255	274	250	229	262	239							251
Funk G4737	253	204	143	218	182							200
Pride of Saline	225	183	132	183	176							180
Amarillo Bajio	135	128	103	124	120							122
KDS	208	186	157	179	188							184
K724	45	44	33	46	35							41
K55	119	84	62	88	88							88
H28	94	91	56	90	70							80
K41	101	63	17	56	64							60
K731	111	98	88	111	87							99
LSD .05	24			20		n.s.						14
LSD .01	32			n.s.								19
Vigor Group 1												187
Vigor Group 2												74
LSD .05	n.s.			n.s.		n.s.						10
LSD .01												14
Means	157	133	102	136	125							131
LSD .05	18			10		n.s.						
LSD .01	30			n.s.								

LSD valid for vertical comparisons.

was already significant for LAI at LM1, it more closely paralleled overall density effect on grain yield eliciting a stable YE ratio response to density treatments. It should be noted that the significance of density effect was related to interaction with moisture levels. Expected responses to density effect would be different for a single moisture regime. Significant mean comparisons for both YE of LM1 and YE of LM2 are given in Tables 25 and 26. Moisture stress and plant density stress significantly reduced YE calculated from LM2 leaf area. The density effect on YE is due to greater stress on yield than on leaf area at higher populations. This is particularly true when water is limiting.

YE has been proposed as a selection criterion for high yield under stress (9,14). Correlation coefficients for relationships of YE to graine yield in all water regime x density x vigor group block combinations are given in Table 27.

Table 27. Correlations of YE from both LM1 and LM2 to grain yield across genotypes (within vigor groups) within water regime x density combination blocks at Ashland.

d.f./cell = 13

	Regime x Density					
Vigor	1x1	2x1	3x1	1x2	2x2	3x2
Vigor Group 1						
LM 1	+0.935**	+0.953**	+0.966**	+0.941**	+0.964**	+0.976**
LM 2	+0.959**	+0.966**	+0.983**	+0.930**	+0.950**	+0.968**
Vigor Group 2						
LM 1	+0.901**	+0.890**	+0.789**	+0.942**	+0.688**	+0.910**
LM 2	+0.908**	+0.920**	+0.890**	+0.740**	+0.820**	+0.705**

** Significant at the .01 level.

Muleba defined two plant mechanisms for high yield. Either they develope large LAI to maximize light interception or they produce a large grain weight per unit leaf area ratio (YE). If plant yield deterioration at high density was due to mutual leaf shading (9,25), high YE would permit enlargement of the sink capacity without large risk of surpassing the critical LAI. The highly significant genetic effects of vigor group and genotype within vigor group disclose heritable variability for YE. Density x genotype interaction effect was significant for both LM1 and LM2. Nonetheless, low density YE (LM2) was significantly correlated to high density grain yield (Table 28). Elsahookie (14) reported a

Table 28. Relationship of low density YE to high density grain yield for genotypes (within vigor groups) within water regime levels.

d.f./cell = 13

	Water Regimes		
Vigor	1	2	3
Vigor Group 1	+0.908**	+0.694**	+0.946**
Vigor Group 2	+0.907**	+0.781**	+0.968**

** Significant at the .01 level.

significant genotype x density interaction for YE but also found that many genotypes were density tolerant for YE. Buren et al. (9) felt that selection for high YE under critical plant density could be made on the basis of YE at low plant densities.

Water regime x genotype effects were highly significant for YE at both LM1 and LM2. Correlations of Regime 1 YE to Regime 3 grain yield were +0.522* for high vigor lines and +0.320 for inbreds. No adjustment was made for density means at moisture stress levels in these correlations. Genotype x environment interaction significance for YE and the modest correlation of non-stress YE to stress yield argue against the practicability of non-stress YE selection for high stress yield. This proposition should be subjected to further testing.

Individual genotypes did demonstrate stability for YE across moisture levels. The Frontier and Funk hybrids exhibited similar LAI and YE at non-stress water regime, but the Frontier hybrid was far superior for YE and grain yield under stress. No discernable trait totally characterized YE stability across moisture levels. For inbreds, however, high non-stress YE was relatively stable for stress when associated with moderately high LAI at LM2 under non-stress moisture level. This merely eliminates from consideration, lines with high YE due to low LAI and accentuates the role of stress stable sink capacity for high yield under stress. Table 29 reveals the highly negative correlation between LAI and YE. However, the relationship tends to be less negative under moisture stress. The seemingly greater importance of higher LAI under stress for YE reflects the increasing value of leaf area duration for grain yield under stress.

Table 29. Relationship of LAI (LM2) to YE (LM2) for genotypes (within vigor groups) within water regime levels at Ashland.

d.f./cell = 28

	Water Regimes		
Vigor	1	2	3
Vigor Group 1	-0.842**	-0.806**	-0.530**
Vigor Group 2	-0.358	-0.103	+0.295

** Significant at the .01 level.

The selection potential of non-stress YE for predicting high YE or grain yield under stress conditions was not substantiated by this study. The significant genotype x density interaction for YE in even such a narrow density range and the highly significant genotype x water regime interaction for YE leave doubt as to the efficacy of such selections. On the basis of F-test values, the genotype effect for YE was of much greater significance than were the genotype x environment interactions. If these ten genotypes typify available genetic deversity for corn, numberous genotypes are relatively stable for YE under non-stress and stress conditions.

REGRESSION MODELS FOR YIELD SELECTION

The results of stepwise regression equation variable selections to predict grain yield per m^2 within each of density x water regime combination blocks on the basis of all plant variables examined, are presented in Tables 30 - 32. The equations provided a mode for selection within each environmental condition and were not suitable for non-stress environmental selection to obtain high grain yield under stress conditions.

Notable is the presence of LAI (LM2) and YE (LM2) in nearly every environmental model. YE (LM2) and YE (LM1) were nearly equally correlated (simple correlation) with grain yield in each environmental block. However, the YE (LM2) prediction of grain yield was best modified by positive selection for LAI (LM2) which denotes both genetic LAI level for that density and leaf area duration. LAI (LM1) only relates to genetic LAI level for that density. Weighting of these two variables (T-test values) in the model is rather consistently 2-2.5 YE to 1 LAI.

Conspicious is the absence of sink capacity (KN) from all models. The omission of KN, inspite its consistently high simple correlation with grain yield, is due to its effect being absorbed by the YE variable when selection for YE is adjusted to simultaneous positive selection for LAI.

Under Regime 3, the prediction models suggest selection against RB at low density and against ERN at high density. Such selection would not be

Table 30. Stepwise (Sigin = .05, Sigout = .10) regression models to predict grain yield per meter square soil within water regime x density combination blocks at Ashland.

Water Regime 1, Density 1

Analysis of Variance

source	d.f.	MS	F
regression	3	42493.275	1709.44
residual	26	24.858	
total	29		

R^2 = .99496
Intercept = -333.2396
Std err of Intercept = 37.529

Model Variables	B	T-test
LAI (LM2)	120.137	14.92
YE (LM2)	2.884	26.50
Vigor (forced)	3.110	0.29

Water Regime 1, Density 2

Analysis of Variance

source	d.f.	MS	F
regression	3	33926.055	1760.78
residual	26	19.268	
total	29		

R^2 = .99510
Intercept = -449.1895
Std err of Intercept = 58.659

Model Variables	B	T-test
LAI (LM2)	128.212	10.77
YE (LM2)	3.619	25.33
Vigor (forced)	-0.062	-0.01

Table 31. Stepwise (Sigin = .05, Sigout = .10) regression models to predict grain yield per meter square soil within water regime x density combination blocks at Ashland.

Water Regime 2, Density 1

Analysis of Variance

source	d.f.	MS	F
regression	3	23911.716	1822.17
residual	26	13.123	
total	29		

R^2 = .99658

Intercept = -189.1267

Std err of Intercept = 26.727

Model Variables	B	T-test
LAI (LM2)	97.181	13.96
YE (LM2)	2.318	30.39
Vigor (forced)	34.886	4.96

Water Regime 2, Density 2

Analysis of Variance

source	d.f.	MS	F
regression	3	21216.211	3749.59
residual	26	5.658	
total	29		

R^2 = .99769

Intercept = -245.8395

Std err of Intercept = 21.234

Model Variables	B	T-test
LAI (LM2)	86.308	18.63
YE (LM2)	3.138	41.72
Vigor (forced)	20.139	3.49

Table 32. Stepwise (Sigin = .05, Sigout = .10) regression models to predict grain yield per meter square soil within water regime x density combination blocks at Ashland.

Water Regime 3, Density 1

Analysis of Variance

source	d.f.	MS	F
regression	6	12536.164	1448.41
residual	23	8.655	
total	29		

R^2 = .99736

Intercept = -112.1837

Std err of Intercept = 16.084

Model Variables	B	T-test
GRLN	6.378	3.93
RB	-74.027	-4.82
LAI (LM1)	50.330	5.58
YE (LM1)	1.661	12.81
YE (LM2)	0.831	6.84
Vigor (forced)	22.950	3.97

Water Regime 3, Density 2

Analysis of Variance

source	d.f.	MS	F
regression	4	7705.638	1168.61
residual	25	6.594	
total	29		

R^2 = .99591

Intercept = -180.1579

Std err of Intercept = 38.695

Model Variables	B	T-test
LAI (LM2)	100.629	9.92
ERN	-118.069	-6.37
YE (LM2)	3.048	32.85
Vigor (forced)	-11.488	-1.69

realistic but the model suggests at least neutrality towards these components in selection schemes. After the YE (LM2) and LAI (LM2) prediction alignement is set, selection for large number ears (which tended to include many small ears whose contribution to grain yield was insignificant) works to the detriment of grain yield. The simple correlations of RB and ER to grain yield under moisture stress were +0.870** and +0.590** for high density and +0.810** and +0.708** for low density.

CORRELATIVE ANALYSIS OF YIELD AND YIELD COMPONENTS

Correlation coefficients for yield components and yield relationships within each vigor group x water regime x density combination are given in Tables 33 and 34. All coefficients are partials with replication mean effects removed. The resulting correlations is based on the genetic variance plus error term of each variable. An inspection of the analysis of variance tables for grain yield, KN, KW, ERN, RB and PROLIF, reveals that genotype effect is highly significant. However, in comparison, vigor group effect and environmental effects of density, water regime and location have generally much larger F-test values. Due to micro-environment variability and reduced degrees of freedom, within several of the treatment combination blocks, genotype effect for various component or yield variables is not significant.

ERN correlations with grain yield ranged from -0.55 to +0.94. Despite the variability, consistent trends were readily evident. ERN was more influential on inbred grain yield than on high vigor yield. In nearly all cases, the correlation went from negative or insignificant under Regime 1 to positive or positive under Regime 3. Stress location (Rossville), as for stress water regime, enhanced the importance of high ERN for grain yield. The relative contribution of RB and PROLIF to ERN shifts

Table 33. Correlation coefficients for yield and yield components among genotypes (within vigor group 1) within location x water regime x density combination block.

d.f./cell = 12

r greater than 0.53, significant at .05
r greater than 0.66, significant at .01

Correlation	Vigor Group 1 Location x Regime x Density											
	1x1x1	1x2x1	1x3x1	1x1x2	1x2x2	1x3x2	2x1x1	2x2x1	2x3x1	2x1x2	2x2x2	2x3x2
$r_{ERN} \cdot Y$	-0.22	+0.16	+0.20	-0.55	-0.37	+0.08	+0.07	+0.62	+0.76	+0.36	+0.49	+0.85
$r_{PROLIF} \cdot ERN$	+1.00	+0.92	+0.87	+1.00	+1.00	+0.48	+0.78	+0.25	---	+0.69	+0.44	+0.06
$r_{RB} \cdot ERN$	---	+0.23	+0.36	---	---	+0.77	+0.56	+0.86	---	+0.84	+0.95	+0.99
$r_{PROLIF} \cdot RB$	---	-0.17	-0.14	---	---	-0.19	-0.07	-0.25	---	+0.18	+0.16	-0.16
$r_{KN} \cdot Y$	+0.67	+0.66	+0.88	+0.89	+0.88	+0.84	+0.93	+0.87	+0.94	+0.88	+0.44	+0.84
$r_{ERN} \cdot KN$	-0.77	-0.49	-0.06	-0.84	-0.63	-0.19	-0.08	+0.39	+0.58	+0.10	-0.42	+0.49
$r_{PROLIF} \cdot KN$	-0.77	-0.59	-0.27	-0.84	-0.63	-0.56	-0.51	-0.31	---	-0.30	-0.17	-0.22
$r_{KW} \cdot Y$	+0.33	+0.60	+0.60	+0.38	+0.30	+0.35	+0.43	+0.28	-0.21	+0.26	+0.01	+0.03
$r_{ERN} \cdot KW$	-0.17	-0.05	-0.10	+0.14	+0.19	+0.07	-0.48	+0.10	-0.28	+0.17	-0.24	-0.14
$r_{KN} \cdot KW$	-0.04	+0.15	+0.28	-0.04	-0.15	-0.15	+0.23	-0.09	-0.36	-0.19	-0.36	+0.12

Table 34. Correlation coefficients for yield and yield components among genotypes (within vigor group 2) within location x water regime x density combination block.

d.f./cell = 12

r greater than 0.53, significant at .05
r greater than 0.66, significant at .01

Correlation	Vigor Group 2 — Location x Regime x Density											
	1x1x1	1x2x1	1x3x1	1x1x2	1x2x2	1x3x2	2x1x1	2x2x1	2x3x1	2x1x2	2x2x2	2x3x2
$r_{ERN \cdot Y}$	+0.64	+0.96	+0.94	+0.34	+0.79	+0.83	+0.79	+0.74	+0.93	+0.62	+0.84	+0.60
$r_{PROLIF \cdot ERN}$	+0.99	+0.95	+0.84	+0.90	+0.89	+0.51	+0.55	+0.24	---	+0.62	+0.46	---
$r_{RB \cdot ERN}$	+0.47	+0.59	+0.78	+0.56	+0.75	+0.92	+0.90	+0.93	+1.00	+0.77	+0.99	+1.00
$r_{PROLIF \cdot RB}$	+0.32	+0.32	+0.32	+0.14	+0.37	+0.13	+0.13	-0.04	---	-0.01	+0.32	---
$r_{KN \cdot Y}$	+0.77	+0.82	+0.52	+0.77	+0.74	+0.57	+0.56	+0.87	+0.94	+0.96	+0.64	+0.83
$r_{ERN \cdot KN}$	+0.03	+0.69	+0.23	-0.31	+0.22	+0.08	+0.15	+0.54	+0.94	+0.39	+0.45	+0.47
$r_{PROLIF \cdot KN}$	+0.01	+0.72	+0.34	-0.45	+0.12	+0.40	+0.41	+0.45	---	+0.46	+0.33	---
$r_{KW \cdot Y}$	+0.27	-0.12	+0.43	+0.12	+0.01	+0.29	+0.65	+0.52	+0.75	+0.23	+0.52	+0.55
$r_{ERN \cdot KW}$	-0.05	-0.11	+0.59	-0.28	-0.09	+0.27	+0.66	+0.65	+0.93	-0.02	+0.69	+0.92
$r_{KN \cdot KW}$	-0.12	-0.19	-0.23	-0.27	-0.54	-0.22	+0.18	+0.58	+0.61	+0.33	+0.43	+0.87

from highly positive correlations for PROLIF under non-stress water regime to highly positive correlations for RB within dryland plots. A similar shift is evident for non-stress and stress locations. The RB·PROLIF correlation is insignificant. A negative correlation was avoided because stress factors produced positive correlations to ERN for both RB and PROLIF despite their opposing non-stress to stress trends.

Of all components considered, KN manifested the most stable and highest positive correlation with grain yield. Leng (22) proved that yield increases defined as heterotic can be attributed to increased KN, but attempts to equate yield inheritance with phenotypic KN expression were not satisfactory (23). The stability of the KN · Yield correlation for all stress levels is nonetheless remarkable. Noteworthy are the relatively high F-test values, from the KN analysis of variance table (appendix table 16) for genotype effect compared to those for the genotype x environment interactions. The results suggest a strong genetic correlation between KN and grain yield but do not differentiate additive from non-additive genetic variance effects on KN. Selection would be effective only on the additive genetic variance.

ERN and PROLIF both demonstrated correlation trends from negative under non-stress to positive under stress with KN. Such a component compensation would have to be accounted for in a selection scheme (e.g. simultaneous selection for ERN and KN under optimum growing conditions). On the other hand, much of the negative correlation is due to small inconsequental ears under high moisture. To conclusively test this component compensation, adapted prolific high vigor lines should be studied.

KW was a highly variable contributer to grain yield prediction. It reached a significant level of importance (positive) for grain yield mostly under moisture stress treatments though no real trend was apparent.

Negative KW · Yield correlations are associated with a large error term and insignificant genetic effect for KW in many of the environmental blocks. KW must be an important determinant of grain yield, particularly when the grain-fill period is stressed, though this study does not bear that out. KW variation was secondary to that of KN and ERN (under stress) in predicting yield.

The ERN · KW and KN · KW compensations are insignificant with the exception of positive correlations for inbreds under moisture stress. There was no strong case for component compensation with KW in this experiment. Several insignificant negative correlations did appear but the high degree of error variability for KW prevented detection of any definite trend. A KW compensation for KN or ERN would be expected if the test had included an ear formation stress period followed by a non-stress grain-fill period.

Correlations of components and yield were drastically affected by the environment with the exception of KN · Yield. Under the conditions imposed in this test, the genetic yield potential of varieties can be ascertained through KN evaluation. The relationship of KW to grain yield was too unstable to be useful. ERN was beneficial in defining genetic yield potential through its high correlation with grain yield (Regime 3) and absence of competition with KN.

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APPENDIX

Table 1. Mean squares from analyses of variance on grain yield and yield per plant (PLY).

Source	d.f.	Grain yield	PLY
Location L	1	443,466,752**	196,148.56**
Rep (Loc)	4	1,674,262	725.06
Water Regime W	2	189,171,584**	81,946.44**
L x W	2	5,780,199**	2,459.45**
Error A	8	580,195	276.76
Density D	1	1,594,816	18,455.79**
Vigor group V	1	1,180,659,200**	534,929.19**
D x V	1	6,589	9,569.26
L x D	1	3,607,975*	422.98
L x V	1	58,123,888**	24,647.17**
L x D x V	1	3,392,476*	293.44
W x D	2	5,209,143**	87.63
W x V	2	53,062,608**	23,161.95**
W x D x V	2	1,088,953	35.10
L x W x D	2	465,490	94.56
L x W x V	2	2,920,468*	1,353.98*
L x W x D x V	2	34,158	69.65
Error B	36	710,618	331.50
Genotype (Vig) G	8	20,212,096**	9,224.22**
L x G	8	2,119,966**	959.34**
W x G	16	1,641,828**	745.83**
L x W x G	16	795,717**	359.76**
D x G	8	342,132	382.63**
L x D x G	8	268,312	110.10
W x D x G	16	152,344	192.50
L x W x D x G	16	198,430	93.98
Error C	192	366,519	166.30
Total	359		

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

Table 2. Mean squares from analyses of variance on ear number per plant (ERN), resistance to barreness (RB) and prolificacy (PROLIF).

Source	d.f.	ERN	RB	PROLIF
Location L	1	14.16575**	7.86988**	1.09698*
Rep (Loc)	4	0.11965	0.06647	0.25264
Water Regime W	2	5.10891**	3.14796**	0.83360*
L x W	2	1.14565**	1.53598**	0.71839*
Error A	8	0.09390	0.06886	0.10639
Density D	1	0.81436**	0.15770*	0.34621
Vigor group V	1	1.85399**	4.42018**	0.23243
D x V	1	0.02248	0.00013	0.03472
L x D	1	0.02165	0.00614	0.01214
L x V	1	2.50201**	1.20491**	3.28931**
L x D x V	1	0.12763	0.09445	0.00161
W x D	2	0.11400	0.12234	0.09462
W x V	2	0.87506**	0.49550**	1.53898**
W x D x V	2	0.06275	0.03639	0.04937
L x W x D	2	0.08546	0.07705	0.03856
L x W x V	2	0.03902	0.11405	0.90185**
L x W x D x V	2	0.06427	0.03530	0.04260
Error B	36	0.06024	0.04757	0.08585
Genotype (Vig) G	8	0.98832**	0.28985**	0.57657**
L x G	8	0.19603**	0.04496**	0.06378
W x G	16	0.05386**	0.04161**	0.03748
L x W x G	16	0.13579**	0.10073**	0.04152
D x G	8	0.07493**	0.02625*	0.07306
L x D x G	8	0.03020	0.01843	0.05210
W x D x G	16	0.02817	0.09944	0.04131
L x W x D x G	16	0.01779	0.00879	0.02622
Error C	192	0.02296	0.01296	0.03986
Total	359			

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

Table 3. Mean squares from analyses of variance on average kernel number per ear (KN), shelling percentage and ear-fill coefficient.

Source	d.f.	KN	Shelling percentage	Ear-fill coefficient
Location L	1	1,340,399.21**	19,798.69**	34,900.49**
Rep (Loc)	4	9,017.26	879.37	180.78
Water Regime W	2	402,624.92**	7,442.51**	9,276.57**
L x W	2	106,094.67**	6,784.20**	3,766.47**
Error A	8	3,762.12	307.52	397.49
Density D	1	68,601.47**	18.02	165.67
Vigor group V	1	7,144,289.08**	60,036.20**	256,363.63**
D x V	1	57,019,16**	212.30	475.61
L x D	1	815.72	62.93	403.35
L x V	1	3,894.89	16,016.33**	6,191,50**
L x D x V	1	3,434.39	28.74	512,73
W x D	2	5,183.20	99.13	408.69
W x V	2	83,594.39**	3,488.91**	766.07
W x D x V	2	417.63	122.68	142.05
L x W x D	2	3,390.43	108.64	50.45
L x W x V	2	7,989.98	4,363.86**	614.45
L x W x D x V	2	21.77	91.38	62.57
Error B	36	4,695.22	291.85	379.42
Genotype (Vig) G	8	118,195.81**	480.84	5,793.49**
L x G	8	7,329.89*	263.32	1,984.59**
W x G	16	6,109.94*	213.25	445.59
L x W x G	16	6,265.02*	226.54	490.12
D x G	8	2,966.32	360.64	227.30
L x D x G	8	3,042.81	240.63	182.30
W x D x G	16	4,261.11	312.18	227.43
L x W x D x G	16	3,614.94	222.50	384.70
Error C	192	3,146.62	248.90	271.11
Total	359			

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

Table 4. Mean squares from analyses of variance on lodging percentage and kernel weight (KW) at Ashland and Rossville locations.

Source	d.f.	Lodging % Ashland	Lodging % Rossville	KW Ashland	KW Rossville
Replication	2	0.015337	0.049290	0.000050	0.022644
Water Regime W	2	0.087779*	0.294460*	0.075003**	0.148507**
Error A	4	0.009674	0.110911	0.000489	0.010774
Density D	1	0.033155*	0.135307	0.002706**	0.006526
Vigor group V	1	0.023439*	0.623300**	0.202923**	0.394410**
D x V	1	0.001403	0.008010	0.001177	0.001280
W x D	2	0.008192	0.111960	0.000534	0.001217
W x V	2	0.009874	0.323603**	0.000721	0.049725**
W x D x V	2	0.022417**	0.025915	0.000093	0.000831
Error B	18	0.004610	0.047326	0.000458	0.004636
Genotype (Vig) G	8	0.031717**	0.111905**	0.003089**	0.006583**
W x G	16	0.011461**	0.033140	0.000921**	0.002984*
D x G	8	0.010537*	0.024097	0.000767**	0.001153
W x D x G	16	0.007633*	0.011888	0.000255	0.001251
Error C	96	0.004365	0.031904	0.000241	0.001464
Total	179				

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

Table 5. Mean squares from analyses of variance on leaf area per plant at leaf measurement one (LAP at LM1) and at leaf measurement two (LAP at LM2) for Ashland location.

Source	d.f.	LAP (LM1)	LAP (LM2)
Replication	2	0.004998	0.011198
Water Regime W	2	0.022093	0.220263**
Error A	4	0.004697	0.002772
Density D	1	0.427537**	0.215579**
Vigor group V	1	0.791131**	1.759728**
D x V	1	0.026848	0.054119**
W x D	2	0.008223	0.012408*
W x V	2	0.009711	0.002779
W x D x V	2	0.007016	0.004373
Error B	18	0.008988	0.003020
Genotype (Vig) G	8	0.123713**	0.183470**
W x G	16	0.003020	0.013834**
D x G	8	0.001323	0.005230**
W x D x G	16	0.002592	0.007090**
Error C	96	0.002385	0.001589
Total	179		

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

Table 6. Mean squares from analyses of variance on dead leaf number per plant at leaf measurement one(DLN at LM1) and at leaf measurement two (DLN at LM2) for Ashland location.

Source	d.f.	DLN (LM1)	DLN (LM2)
Replication	2	2.254164	4.14.960
Water Regime W	2	1.129168	157.927979**
Error A	4	1.339581	1.152662
Density D	1	0.200000	16.866684*
Vigor group V	1	9.799976*	16.866684*
D x V	1	0.138890	2.112426
W x D	2	0.912497	1.314903
W x V	2	0.454169	0.181561
W x D x V	2	0.476389	3.532683
Error B	18	0.611108	2.438957
Genotype (Vig) G	8	2.594440**	6.609840**
W x G	16	0.355902	2.015588**
D x G	8	0.426388	1.072939
W x D x G	16	0.248263	0.449813
Error C	96	0.379861	0.551176
Total	179		

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

Table 7. Mean squares from analyses of variance on green leaf number per plant at leaf measurement one (GRLN at LM1) and at leaf measurement two (GRLN at LM2) for Ashland location.

Source	d.f.	GRLN (LM1)	GRLN (LM2)
Replication	2	1.016725	8.511658
Water Regime W	2	0.963398	131.222900**
Error A	4	1.387948	3.260745
Density D	1	7.646709*	4.801976
Vigor group V	1	21.286819**	31.584305**
D x V	1	14.506536**	0.056890
W x D	2	0.005056	0.601169
W x V	2	1.348361	3.645366
W x D x V	2	0.470049	3.128431
Error B	18	1.730494	2.962829
Genotype (Vig) G	8	11.218500**	15.175388**
W x G	16	0.754135	1.999411**
D x G	8	0.432973	0.460696
W x D x G	16	0.909417	0.900610
Error C	96	0.984785	0.564208
Total	179		

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

Table 8. Mean squares from analyses of variance on leaf area index at leaf measurement one (LAI at LM1) and at leaf measurement two (LAI at LM2) for Ashland location.

Source	d.f.	LAI (LM1)	LAI (LM2)
Replication	2	0.171317	0.237650
Water Regime W	2	0.589703	5.305960**
Error A	4	0.123607	0.070905
Density D	1	63.047028**	10.142660**
Vigor group V	1	19.034164**	38.392776**
D x V	1	1.858214**	0.062234
W x D	2	0.277997	0.634744**
W x V	2	0.417758	0.085893
W x D x V	2	0.334575	0.121720*
Error B	18	0.217452	0.028302
Genotype (Vig) G	8	2.842388**	4.072071**
W x G	16	0.077291	0.288332**
D x G	8	0.091885	0.066407
W x D x G	16	0.105213	0.136782**
Error C	96	0.060592	0.034086
Total	179		

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

Table 9. Mean squares from analyses of variance on yield efficiency at leaf measurement one (YE at LM1) and at leaf measurement two (YE at LM2) for Ashland location.

Source	d.f.	YE (LM1)	YE (LM2)
Replication	2	41.14	4,517.89
Water Regime W	2	105,806.31**	48,213.78**
Error A	4	2,132.18	1,201.87
Density D	1	89.20	5,680.41*
Vigor group V	1	859,399.44**	586,736.31**
D x V	1	38.47	64.40
W x D	2	5,475.73	242.11
W x V	2	13,690.46**	2,792.19
W x D x V	2	1,431.41	184.01
Error B	18	1,565.29	997.94
Genotype (Vig) G	8	28,257.63**	24,452.80**
W x G	16	2,563.08**	1,577.40**
D x G	8	1.483.52*	918.36*
W x D x G	16	576.58	582.02
Error C	96	679.35	438.24
Total	179		

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

Table 10. Location x water regime x density x genotype interaction means for grain yield (Kg/ha).

	Location x Regime x Density											
Genotype	1x1x1	1x2x1	1x3x1	1x1x2	1x2x2	1x3x2	2x1x1	2x2x1	2x3x1	2x1x2	2x2x2	2x3x2
Frontier SX255	8371	7330	6586	10259	8108	6282	6904	4342	2503	8073	3048	1556
Funk G4737	7978	6980	3823	8915	6279	3622	6503	4065	1311	6763	2825	932
Pride of Saline	7605	5849	3602	8301	6896	4106	4965	3211	2031	5536	2559	1062
Amarillo Bajio	5900	4893	3817	6872	5285	3493	3873	1268	944	4103	1343	486
KDS	6695	5691	5108	8127	6896	4826	4842	2508	1522	4749	3865	1102
K724	1281	1289	917	1445	1093	773	691	191	69	1214	46	19
K55	2153	1414	957	2731	2012	1243	856	52	0	1187	200	5
H28	2083	2122	1475	2455	2026	1035	653	323	37	924	334	2
K41	2016	1111	317	2906	1605	194	368	61	39	874	74	0
K731	4011	3246	2489	3502	3715	2111	1815	394	183	2267	315	50

Table 11. Location x water regime x density x genotype interaction means for yield per plant (gms/plant).

	Location x Regime x Density											
Genotype	1x1x1	1x2x1	1x3x1	1x1x2	1x2x2	1x3x2	2x1x1	2x2x1	2x3x1	2x1x2	2x2x2	2x3x2
Frontier SX255	202.5	177.3	159.3	188.7	149.1	115.6	167.0	105.0	60.5	148.5	56.1	28.6
Funk G4737	193.0	168.8	92.5	164.0	115.5	66.6	157.3	98.3	31.7	124.4	52.0	17.1
Pride of Saline	184.0	141.5	87.1	152.7	126.9	75.5	120.1	77.7	49.1	101.8	47.1	19.5
Amarillo Bajio	142.7	118.4	92.3	126.4	97.2	64.3	93.7	30.7	22.8	75.5	24.7	8.9
KDS	161.9	137.7	123.6	149.5	126.9	88.8	117.1	60.7	36.8	87.4	52.7	20.3
K724	31.0	31.2	22.2	26.6	20.1	14.2	16.7	4.6	1.7	22.3	0.8	0.3
K55	52.1	34.2	23.1	50.2	37.0	22.9	20.7	1.3	0.0	21.8	3.7	0.1
H28	50.4	51.3	35.7	45.2	27.2	19.0	15.8	7.8	0.9	17.0	6.2	0.1
K41	48.8	26.9	7.7	53.5	29.5	3.6	8.9	1.5	0.9	16.1	1.4	0.0
K731	97.0	78.5	60.2	64.4	68.3	38.8	43.9	9.5	4.4	41.7	5.8	0.9

Table 12. Location x water regime x density x genotype interaction means for lodging percentage.

	Location x Regime x Density											
Genotype	1x1x1	1x2x1	1x3x1	1x1x2	1x2x2	1x3x2	2x1x1	2x2x1	2x3x1	2x1x2	2x2x2	2x3x2
Frontier SX255	0.0	0.0	3.3	3.3	6.7	3.3	3.3	6.7	26.7	0.0	14.2	36.7
Funk G4737	3.3	3.3	16.7	6.7	20.0	20.0	3.3	13.3	34.1	3.3	6.4	46.7
Pride of Saline	3.3	6.7	20.0	6.7	16.1	20.0	33.3	21.1	20.0	36.7	40.0	54.8
Amarillo Bajio	0.0	0.0	6.7	0.0	3.3	0.0	13.3	16.7	23.3	6.4	19.1	40.4
KDS	3.3	3.3	0.0	3.3	6.4	3.3	6.7	24.1	50.0	20.0	24.8	48.8
K724	3.3	2.8	15.0	0.0	0.0	10.0	10.0	6.7	3.3	3.0	16.7	13.3
K55	3.0	0.0	0.0	0.0	0.0	0.0	8.3	6.7	0.0	0.0	0.0	0.0
H28	0.0	0.0	3.3	0.0	6.7	3.3	20.0	11.1	3.3	3.0	19.7	12.5
K41	0.0	3.3	3.3	0.0	3.3	39.8	13.3	32.5	0.0	6.7	53.3	33.3
K731	3.3	0.0	6.7	0.0	0.0	13.3	7.4	3.3	13.3	0.0	23.3	16.7

Table 13. Location x water regime x density x genotype interaction means for ear number per plant.

	Location x Regime x Density											
Genotype	1x1x1	1x2x1	1x3x1	1x1x2	1x2x2	1x3x2	2x1x1	2x2x1	2x3x1	2x1x2	2x2x2	2x3x2
Frontier SX255	1.000	1.000	1.000	1.000	1.000	1.000	1.033	1.067	0.833	1.000	0.924	0.700
Funk G4737	1.167	1.167	1.000	1.000	1.033	1.000	1.033	0.967	0.726	1.033	1.067	0.500
Pride of Saline	1.100	1.067	1.000	1.100	1.000	0.900	0.933	0.917	0.712	1.033	0.707	0.518
Amarillo Bajio	1.324	1.067	1.133	1.233	1.067	1.067	1.033	0.667	0.633	0.936	0.642	0.315
KDS	1.067	1.133	1.133	1.033	1.067	1.000	1.067	0.963	0.700	1.000	0.933	0.452
K724	1.138	1.006	0.933	0.933	0.767	0.900	1.000	0.800	0.167	0.936	0.258	0.133
K55	0.970	1.033	1.000	0.975	0.967	0.900	0.958	0.295	0.000	1.000	0.442	0.033
H28	1.567	1.233	1.033	1.500	1.133	0.967	0.633	0.856	0.167	1.036	0.603	0.083
K41	1.179	0.933	0.358	1.067	0.800	0.149	0.452	0.250	0.100	0.767	0.167	0.000
K731	1.809	1.693	1.667	1.467	1.433	1.133	1.204	1.110	0.267	1.133	0.700	0.100

Table 14. Location x water regime x density x genotype interaction means for resistance to barreness rating.

	Location x Regime x Density											
Genotype	1x1x1	1x2x1	1x3x1	1x1x2	1x2x2	1x3x2	2x1x1	2x2x1	2x3x1	2x1x2	2x2x2	2x3x2
Frontier SX255	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.967	0.833	1.000	0.925	0.700
Funk G4737	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.967	0.726	1.000	0.967	0.500
Pride of Saline	1.000	0.967	0.933	1.000	1.000	0.867	0.933	0.845	0.712	1.000	0.707	0.548
Amarillo Bajio	1.000	0.933	1.000	1.000	1.000	0.967	0.933	0.600	0.633	0.903	0.642	0.315
KDS	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.896	0.700	1.000	0.867	0.452
K724	0.933	0.833	0.933	0.767	0.733	0.767	0.933	0.667	0.167	0.903	0.258	0.133
K55	0.970	0.930	0.933	0.933	0.967	0.867	0.958	0.295	0.000	1.000	0.442	0.033
H28	1.000	0.967	0.933	1.000	1.000	0.967	0.633	0.748	0.167	0.967	0.573	0.083
K41	0.974	0.933	0.358	0.958	0.767	0.149	0.452	0.208	0.100	0.767	0.133	0.000
K731	1.000	1.000	1.000	0.967	1.000	0.900	0.856	0.767	0.267	0.909	0.633	0.100

Table 15. Location x water regime x density x genotype interaction means for prolificacy rating.

	Location x Regime x Density											
Genotype	1x1x1	1x2x1	1x3x1	1x1x2	1x2x2	1x3x2	2x1x1	2x2x1	2x3x1	2x1x2	2x2x2	2x3x2
Frontier SX255	1.000	1.000	1.000	1.000	1.000	1.000	1.033	1.111	1.000	1.000	1.000	1.000
Funk G4737	1.167	1.167	1.000	1.000	1.033	1.000	1.033	1.000	1.000	1.033	1.104	1.000
Pride of Saline	1.100	1.104	1.075	1.100	1.000	1.037	1.000	1.100	1.000	1.033	1.000	1.000
Amarillo Bajio	1.324	1.144	1.133	1.233	1.067	1.104	1.107	1.111	1.000	1.033	1.000	1.000
KDS	1.067	1.133	1.133	1.033	1.067	1.000	1.067	1.067	1.000	1.000	1.083	1.000
K724	1.213	1.141	1.000	1.217	1.037	1.185	1.067	1.222	1.000	1.033	1.000	1.000
K55	1.000	1.116	1.083	1.042	1.000	1.033	1.000	1.000	1.000	1.000	1.000	1.000
H28	1.567	1.274	1.111	1.500	1.133	1.000	1.000	1.200	1.000	1.070	1.037	1.000
K41	1.211	1.000	1.000	1.114	1.042	1.000	1.000	1.333	1.000	1.000	1.083	1.000
K731	1.809	1.693	1.667	1.530	1.433	1.282	1.426	1.443	1.000	1.258	1.095	1.000

Table 16. Location x water regime x density x genotype interaction means for average kernel number per ear.

	Location x Regime x Density											
Genotype	1x1x1	1x2x1	1x3x1	1x1x2	1x2x2	1x3x2	2x1x1	2x2x1	2x3x1	2x1x2	2x2x2	2x3x2
Frontier SX255	604.6	587.4	584.2	595.6	562.5	512.4	564.8	449.0	333.9	557.4	349.6	182.4
Funk G4737	536.9	535.0	465.1	553.8	464.6	354.5	570.8	487.2	196.9	494.6	282.0	181.1
Pride of Saline	549.4	448.0	342.3	440.2	478.0	344.0	458.2	360.7	332.9	363.7	435.7	179.2
Amarillo Bajio	347.9	440.7	339.2	341.8	333.3	254.5	327.8	204.2	134.2	298.4	159.1	140.8
KDS	540.1	437.7	445.7	497.3	450.7	366.1	453.5	303.7	234.0	392.1	262.5	204.6
K724	134.0	147.6	136.4	126.5	132.5	85.4	76.0	27.5	16.9	109.7	14.3	22.2
K55	192.7	144.1	118.6	194.8	201.5	127.4	110.7	11.8	0.0	108.9	60.3	6.1
H28	141.9	211.4	207.2	127.6	179.8	130.0	150.3	46.4	9.0	80.8	50.3	1.0
K41	179.3	167.0	158.9	210.7	200.8	153.6	77.5	27.2	18.8	108.2	21.7	0.0
K731	216.0	239.2	200.2	201.2	251.8	187.0	169.4	42.1	31.2	181.6	42.7	18.1

Table 17. Location x water regime x density x genotype interaction means for average kernel number per meter square soil surface.

	Location x Regime x Density											
Genotype	1x1x1	1x2x1	1x3x1	1x1x2	1x2x2	1x3x2	2x1x1	2x2x1	2x3x1	2x1x2	2x2x2	2x3x2
Frontier SX255	2501	2429	2416	3214	3035	2765	2414	1981	1151	3008	1745	689
Funk G4737	2591	2582	1924	2988	2591	1913	2439	1948	591	2758	1623	488
Pride of Saline	2500	1977	1416	2612	2580	1675	1769	1368	980	2027	1274	530
Amarillo Bajio	1905	1944	1590	2275	1919	1465	1401	563	352	1508	552	239
KDS	2383	2052	2089	2773	2594	1976	2001	1210	680	2116	1322	499
K724	631	614	527	638	548	415	314	91	-	554	30	-
K55	773	616	491	1025	1051	619	439	22	-	588	144	-
H28	919	1078	886	1033	1099	679	394	164	-	452	164	-
K41	874	645	235	1213	867	124	145	42	-	448	59	-
K731	1616	1675	1380	1593	1947	1143	843	193	-	1110	161	-

Table 18. Location x water regime x density x genotype interaction means for shelling percentage.

	Location x Regime x Density											
Genotype	1x1x1	1x2x1	1x3x1	1x1x2	1x2x2	1x3x2	2x1x1	2x2x1	2x3x1	2x1x2	2x2x2	2x3x2
Frontier SX255	86.1	85.6	83.8	87.0	85.6	85.0	86.4	83.6	80.1	85.4	79.6	69.7
Funk G4737	81.8	84.3	83.1	86.7	83.2	82.9	73.8	83.0	72.8	85.3	79.2	72.2
Pride of Saline	81.9	78.6	78.2	80.8	79.2	77.9	81.1	82.8	80.5	81.9	77.5	68.3
Amarillo Bajio	79.9	78.0	79.0	82.2	80.8	74.4	81.7	78.4	70.9	79.2	78.3	70.8
KDS	78.1	80.5	79.4	82.2	78.5	80.7	77.6	76.8	70.8	80.0	76.0	78.0
K724	64.0	69.3	71.1	56.4	60.0	60.0	62.8	33.4	18.0	68.3	22.6	17.5
K55	66.1	57.6	59.0	73.1	68.5	65.7	66.6	29.1	0.0	66.6	52.8	25.0
H28	77.6	78.5	75.2	71.2	71.9	76.8	75.5	49.8	12.1	52.5	60.4	2.4
K41	68.5	68.0	72.9	67.9	66.0	74.7	63.6	49.6	22.2	71.0	23.9	0.0
K731	77.1	73.6	72.6	72.2	74.8	71.8	69.2	47.3	19.7	70.9	47.8	24.8

Table 19. Location x water regime x density x genotype interaction means for ear-fill coefficient (%).

	Location x Regime x Density											
Genotype	1x1x1	1x2x1	1x3x1	1x1x2	1x2x2	1x3x2	2x1x1	2x2x1	2x3x1	2x1x2	2x2x2	2x3x2
Frontier SX255	100.0	100.0	100.0	100.0	100.0	100.0	96.7	86.1	90.5	96.7	95.2	43.3
Funk G4737	84.1	87.4	100.0	100.0	90.9	83.3	97.0	100.0	42.9	97.0	75.1	52.8
Pride of Saline	96.7	81.2	72.2	94.2	93.3	88.8	92.6	85.9	60.8	83.9	79.3	87.8
Amarillo Bajio	66.5	63.6	59.3	61.1	75.2	53.6	60.6	58.3	48.1	51.0	61.1	58.3
KDS	91.4	82.6	76.2	93.9	93.9	86.3	88.9	73.6	75.8	96.7	64.6	33.3
K724	23.4	35.0	23.1	43.6	22.5	17.4	15.2	3.3	13.3	39.5	0.0	0.0
K55	44.6	9.8	24.2	49.0	30.7	22.7	26.0	0.0	0.0	26.7	0.0	0.0
H28	25.1	55.4	25.2	24.4	33.3	27.4	17.8	4.2	0.0	10.0	20.0	0.0
K41	59.2	71.3	75.6	91.7	79.0	83.3	50.0	6.7	0.0	68.3	13.3	0.0
K731	44.8	30.6	39.0	32.3	42.8	36.9	23.3	2.8	0.0	39.9	3.7	0.0

Table 20. Location x water regime x density x genotype interaction means for average kernel weight (gms).

	Location x Regime x Density											
Genotype	1x1x1	1x2x1	1x3x1	1x1x2	1x2x2	1x3x2	2x1x1	2x2x1	2x3x1	2x1x2	2x2x2	2x3x2
Frontier SX255	.3349	.3023	.2727	.3162	.2656	.2259	.2855	.2217	.2155	.2671	.1706	.1983
Funk G4737	.3107	.2745	.1997	.2963	.2416	.1875	.2649	.2075	.2124	.2430	.1744	.1940
Pride of Saline	.3101	.2962	.2437	.3164	.2652	.2424	.2802	.2381	.1994	.2725	.1949	.2113
Amarillo Bajio	.3152	.2552	.2411	.3044	.2728	.2370	.2771	.2209	.2622	.2734	.2480	.1956
KDS	.2837	.2778	.2456	.2911	.2644	.2437	.2437	.2138	.2168	.2225	.2162	.2172
K724	.2086	.2118	.1710	.2257	.2072	.1837	.2043	.1654	.0662	.2127	.1323	.1153
K55	.2786	.2306	.1954	.2667	.1916	.1902	.1972	.1518	.0000	.1985	.1583	.0519
H28	.2402	.1976	.1650	.2405	.1864	.1521	.1994	.2146	.0660	.1960	.1823	.0513
K41	.2288	.1786	.1508	.2419	.1810	.1636	.1831	.0964	.0561	.1972	.0418	.0000
K731	.2487	.1931	.1807	.2279	.1967	.1835	.2195	.1964	.0591	.1974	.1836	.0564

Table 21. Water regime x density x genotype interaction means for leaf area (m^2) per plant at leaf measurement one (LAP at LM1) and at leaf measurement two (LAP at LM2) for Ashland location.

	LM1						LM2					
	Regime x Density						Regime x Density					
Genotype	1x1	2x1	3x1	1x2	2x2	3x2	1x1	2x1	3x1	1x2	2x2	3x2
Frontier SX255	.646	.573	.631	.536	.530	.505	.736	.676	.639	.694	.630	.552
Funk G4737	.709	.657	.645	.606	.567	.556	.729	.701	.628	.684	.691	.484
Pride of Saline	.779	.651	.645	.564	.599	.593	.767	.792	.667	.729	.682	.568
Amarillo Bajio	.867	.766	.833	.681	.664	.646	1.147	.845	.852	.867	.840	.665
KDS	.633	.560	.607	.538	.544	.572	.784	.801	.782	.712	.638	.572
K724	.579	.585	.598	.501	.568	.483	.656	.603	.577	.638	.565	.505
K55	.399	.447	.436	.326	.351	.342	.434	.427	.368	.425	.427	.379
H28	.483	.510	.481	.494	.470	.429	.527	.495	.501	.498	.485	.467
K41	.440	.498	.379	.314	.349	.384	.527	.484	.386	.491	.430	.288
K731	.681	.683	.609	.564	.621	.555	.784	.755	.578	.660	.749	.536

Table 22. Water regime x density x genotype interaction means for green leaf number per plant at leaf measurement two for Ashland location.

	Regime x Density					
Genotype	1x1	2x1	3x1	1x2	2x2	3x2
Frontier SX255	13.67	12.97	10.73	13.30	12.63	10.77
Funk G4737	13.83	14.27	10.40	14.03	14.00	8.93
Pride of Saline	14.10	13.63	8.40	13.33	13.03	10.43
Amarillo Bajio	15.63	14.37	13.73	14.67	14.30	12.80
KDS	14.23	14.00	11.27	13.50	13.50	11.60
K724	12.77	13.03	11.83	13.37	12.17	9.57
K55	12.30	12.00	10.40	12.60	11.10	10.17
H28	12.90	12.47	11.30	12.93	12.37	10.97
K41	11.80	11.67	9.43	12.47	11.63	8.40
K731	14.57	14.13	12.60	14.57	13.80	11.57

Table 23. Water regime x density x genotype interaction means for dead leaf number per plant at leaf measurement two for Ashland location.

	Regime x Density					
Genotype	1x1	2x1	3x1	1x2	2x2	3x2
Frontier SX255	2.33	3.10	5.60	3.23	4.07	5.73
Funk G4737	3.13	2.23	6.03	3.40	3.33	7.70
Pride of Saline	3.57	3.73	8.43	4.73	3.60	7.03
Amarillo Bajio	3.30	3.70	5.37	3.97	4.83	5.20
KDS	2.60	3.67	6.07	3.80	3.97	5.90
K724	3.60	3.70	5.77	3.57	4.60	7.80
K55	4.43	5.30	8.00	4.87	5.63	8.63
H28	2.93	3.47	4.57	3.53	3.93	6.20
K41	4.40	3.90	6.83	3.93	4.90	8.50
K731	3.43	3.43	4.73	3.47	4.60	6.83

Table 24. Water regime x density x genotype interaction means for leaf area index at leaf measurement two for Ashland location.

	Regime x Density					
Genotype	1x1	2x1	3x1	1x2	2x2	3x2
Frontier SX255	3.04	2.79	2.64	3.77	3.42	3.00
Funk G4737	3.01	2.90	2.60	3.72	3.76	2.63
Pride of Saline	3.17	3.27	2.76	3.96	3.71	3.09
Amarillo Bajio	4.74	3.49	3.52	4.72	4.57	3.61
KDS	3.24	3.31	3.23	3.87	3.47	3.11
K724	2.71	2.49	2.38	3.47	3.07	2.75
K55	1.79	1.77	1.52	2.31	2.32	2.06
H28	2.18	2.05	2.07	2.71	2.64	2.54
K41	2.18	2.00	1.60	2.67	2.34	1.57
K731	3.24	3.12	2.39	3.59	4.07	2.91

Table 25. Water regime x density x genotype interaction means for yield efficiency (gms/m^2 leaf area) at leaf measurement one (YE at LM1) and at leaf measurement two (YE at LM2) for Ashland location.

	LM1						LM2					
	Regime x Density						Regime x Density					
Genotype	1x1	2x1	3x1	1x2	2x2	3x2	1x1	2x1	3x1	1x2	2x2	3x2
Frontier SX255	314	309	253	352	281	229	275	262	249	272	237	209
Funk G4737	272	257	144	270	203	120	265	241	147	240	167	138
Pride of Saline	236	217	135	271	212	127	240	179	240	209	186	133
Amarillo Bajio	165	155	130	185	146	99	124	140	108	146	116	97
KDS	240	202	204	278	233	155	206	172	158	210	199	155
K724	54	53	37	53	35	29	47	52	38	42	36	28
K55	131	77	53	154	105	67	120	80	63	118	87	60
H28	104	101	74	91	79	44	96	104	71	91	77	41
K41	111	54	20	170	85	9	93	56	20	109	69	13
K731	142	115	99	114	110	70	124	104	104	98	91	72

EFFECTS OF MOISTURE STRESS ON YIELD, COMPONENTS OF YIELD, VEGETATIVE GROWTH COMPONENTS AND THEIR INTERRELATIONSHIPS IN CORN (*Zea mays* L.).

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B.A., Tabor College, 1969

AN ABSTRACT OF A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Agronomy

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1978

ABSTRACT

Ten selected corn genotypes were grown under three water regimes, two densities and at two locations to determine which plant traits could be used as basis for selection for high yield in a stress environment.

Grain yield (Kg/ha), yield per plant (gms/plant), averge number ears per plant, barreness rating, prolificacy rating, average kernel number per ear and average kernel weight all responded negatively to moisture stress. The highly positive correlation of average kernel number per ear to grain yield was found to be useful in predicting yield within an environmental situation. Average kernel weight showed a compensatory response to low average kernel number per ear but did not predict yield. Average number ears per plant, barreness rating and prolificacy rating were positively and highly correlated with yield under stress conditions. Prolifacacy rating, under non-stress showed some predictive potential for yield under stress. A parallel response for yield per plant, among all genotypes, to moisture stress and density stress indicates selection for stable performance at high density could serve as an effective selection scheme for moisture stress.

Vegetative growth components of leaf area per plant (m^2/plant), dead leaf number, functional green leaf number and yield efficiency (gms/m^2 leaf area) were measured prior to flowering and during the grain fill period. Dead leaf counts indicated that early leaf senescence (hastened physiological maturity) severely limited grain yield in the stress plots. Genotypes with large leaf areas were most susceptible to leaf senescence under stress environments. Yield efficiency, which incorporated average kernel number per ear trends and leaf area per plant, was positively and highly correlated with grain yield in all environments. Regression models

indicated that genotypes with high yield efficiency, when combined with average or large leaf area per plant, would produce the highest grain yield in both stress and non-stress environments.

Additional index words: Water stress, Grain yield, Yield components, Leaf senescence, Leaf area per plant, Yield efficiency