Experiment 1 : Screening of Maize Genotypes for Drought Tolerance

Objective

The objective of this study was to evaluate and compare maize genotypes for relative degrees of drought tolerance.

Materials and Methods

The experiment was conducted on sandy loam soil (Typic Plinthuults) at the farm of the Phitsanulok Field Crops Experiment Station, Phitsanulok, Thailand from November 1997 to March 1998. Soil samples were collected and analyzed for soil physical and chemical properties at each plot differing in soil depth prior to sowing as showed in Appendix Table 1.

Thirty-one maize genotypes (Table 1) were evaluated under three moisture regimes : wet (closest to the line source) , intermediate wet, and dry (farthest from the line source). A strip plot design with four replications was used. Three moisture regimes were arranged as the vertical factor and 31 maize genotypes as horizontal factor. Each plot (1.5 x 13.5 m) assigned to each genotype was subdivided into three subplots (1.5 x 4.5 m) representing three moisture regimes.

After harvesting lowland rice, the land was plowed, harrowed and fertilized with 62.5-62.5-62.5 N-P_2O_5-K_2O kg/ha. Maize seeds were planted with 0.75 x 0.25 meter spacing with 2 seeds/hill. To ensure uniform crop emergence, 30 mm. of irrigation water was uniformly applied by sprinkler to the experimental area immediately after sowing. One week after emergence, plants were thinned to 1 plant/hill. Weeds were controlled with metolachlor (2-chlor-6-ethyl-N-(2-methoxy-1-methylethy)-acet-o-toluidide) at 1.5 kg a.i./ha. applied immediately after sowing, followed by one handweeding at one month after sowing. Urea at 156 kg/ha was used as a top-dressing fertilizer after hand weeding. Carbosulfan and carbofuran were used for insect control.

Table 1. Thirty-one maize genotypes used in Experiment 1.

No. / Pedigree	Source*	No. / Pedigree	Source
1. NSX 9210	NS FCRC	17. PACIFIC 700	PACIFIC
2. NSX 9213	NS FCRC	18. G 5449	NOVARTIS
3. NSX 9601	NS FCRC	19. G 5445	NOVARTIS
4. NSX 9605	NS FCRC	20. G 5431	NOVARTIS
5. NSX 9607	NS FCRC	21. CARGILL 717	CARGILL
6. NSX 9608	NS FCRC	22. CARGILL 727	CARGILL
7. NTX 9701	NS FCRC	23. CARGILL 919	CARGILL
8. NTX 9702	NS FCRC	24. CARGILL 922	CARGILL
9. NTX 9703	NS FCRC	25. CARGILL 7118	CARGILL
10. SW 3601	SUWAN FARM	26. CARGILL 7122	CARGILL
11. CP 222	CP	27. CARGILL 7140	CARGILL
12. DK 888	CP	28. KK-DR C4S1	NS FCRC
13. PIONEER 3012	PIONEER	29. NST 89101	NS FCRC
14. PIONEER 3013	PIONEER	30. NS 1	NS FCRC
15. PACIFIC 300	PACIFIC	31. SW 1	SUWAN FARM
16. PACIFIC 328	PACIFIC		

* NS FCRC = Nakorn Sawan Field Crops Research Center ; CP = Chareon Pokaphan

Remarks : Thirty-one genotypes can be divided into 2 groups in terms of maize hybrids, developed by public namely entries no. 1-10 and private sectors namely entries no. 11-27, and open-pollinated varieties namely entries no. 28-31.

Experimental areas was irrigated uniformly until 2 weeks after emergence and a line source sprinkler irrigation system (Hanks *et al.*, 1976) was then installed in perpendicular to the rows until the crop reaches physiological maturity (Appendix Table 2). Catch cans for measuring the amount of water application was installed above the canopy at 4.75, 9.25 and 13.75 m from the line source. Weekly irrigation was scheduled. The amount of water applied (ET) for wet regime equals Kp x Ep , where Kp is pan coefficient for maize at different growth stage and Ep is sum of daily pan evaporation (US Class A-pan) in mm to replenish a week before water applied. Water applied by line source sprinkler system decreased with increasing distance from the line (Figure 1).

Yield data was collected from an area of 6.0 m^2 in each subplot. Yields was immediately determined in ear weights and moisture contents. Seeds were threshed, dried and measured in seed yield adjusted to a standard 15 % moisture content. A sub-sample of 10 plants in each plot was measured for analysis of yield components in terms of number of ears per plant, number of kernels per ear, the length and diameter of ear, and kernel weight. Crop drought susceptibility index (DSI) as described by Fischer and Wood (1979) and drought index (DI) as proposed by Fischer *et al.* (1983) were used to identify drought tolerant genotypes. A commonly observed phenomena under drought imposed at flowering was the lengthening of the anthesis - silking interval as proposed by Balaños and Edmeades(1996).

The change in soil moisture was determined at the soil depth of 0.2 m increments to 1.0 m one day before irrigation by volumetric method. The PVC pipe 7.62 cm in diameter was installed at two plots (wet and dry plots) in each replication for determining the soil water table.

The slopes from the regressed seed yield against reduction in water applied was used to represent drought potential. The relationship between seed yield potential (intercept) and drought susceptibility (slopes) was used to identify drought tolerant genotypes as proposed by Senthong *et al.* (1986). Correlation coefficients at the 1% level was also used to establish relationships between agronomic characteristics measured in this study.

Agro-meteorological data consisting of air temperature, rainfall, and solar radiation were obtained from weather station of the Phitsanulok Field Crops Experiment Station located approximately 50 m away. The weather in 1998 was quite favorable for screening of maize genotypes for drought tolerance (Figure 2).

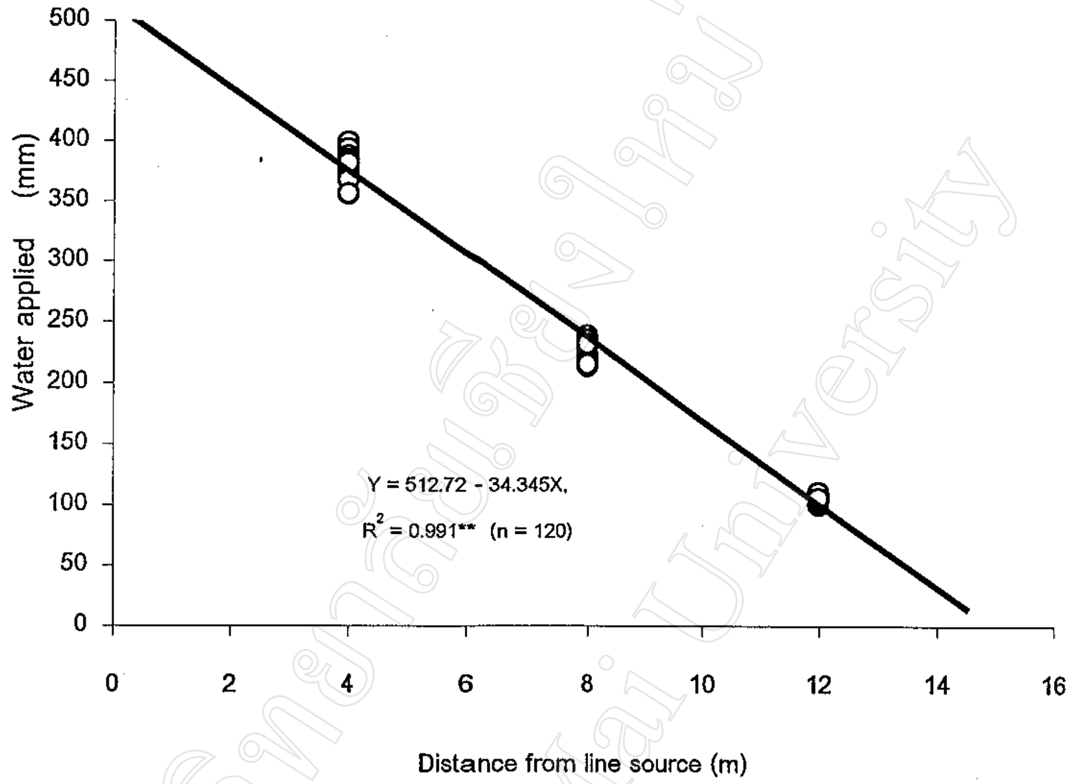

Figure 1. Relationship of water applied and distance from line source for thirty-one maize genotypes in 1998.

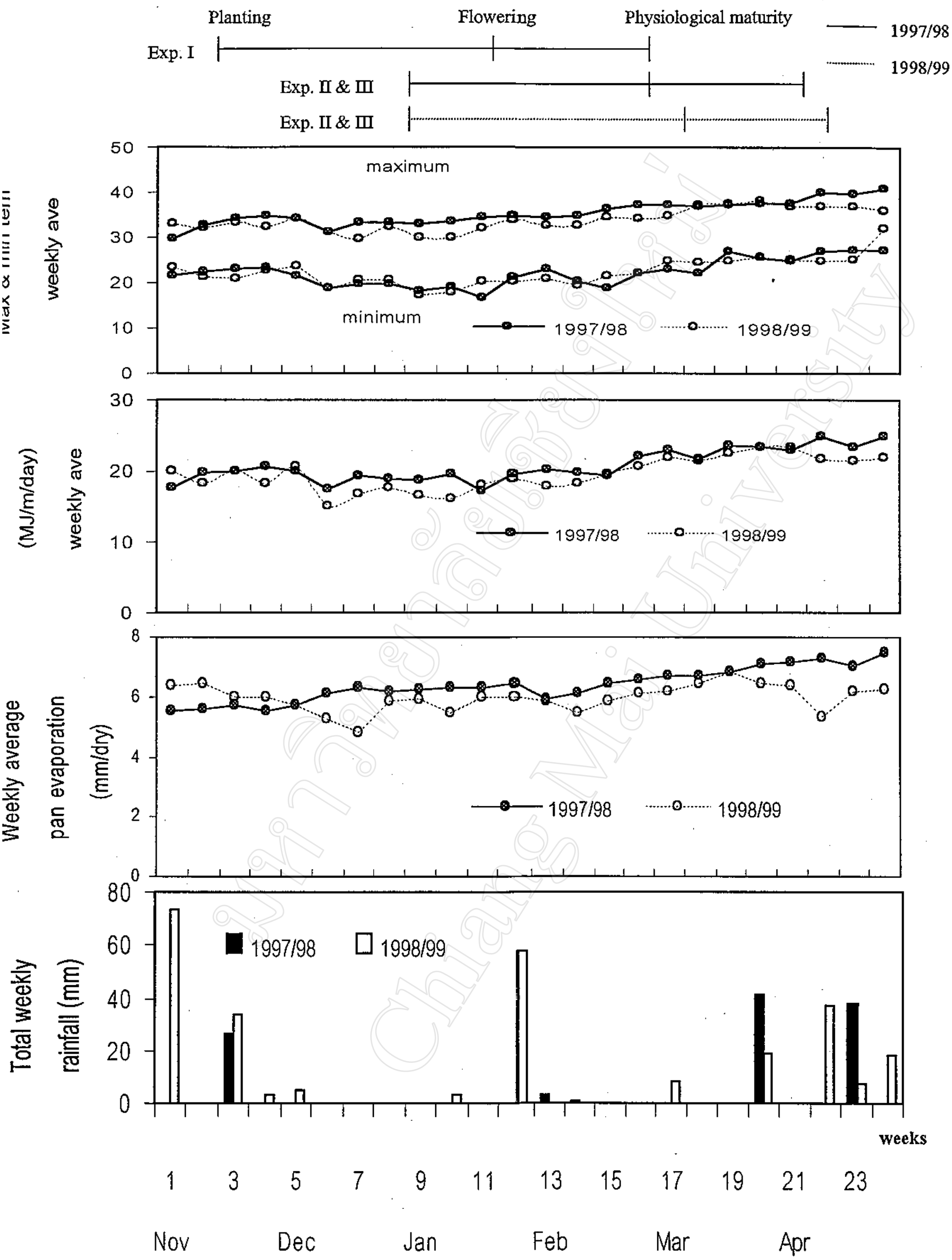

Figure 2 Weekly values of rainfall, pan evaporation, solar radiation and maximum and minimum temperature during the crop growth period in 1997/98 and 1998/99

Results and Discussion

Phenotypic Correlation

Significant phenotypic correlation was observed between grain yield and many of the traits measured under wet and dry regimes of thirty-one genotypes as shown in Table 2. Among other traits and kernel yield, phenotypic correlation was quite low and inconsistent. This is because the analysis involved a large number of observations. However, biomass (r = 0.648** and 0.541**) showed correlation with grain yield larger than other traits in both regimes. Bolaños and Edmeades (1993a) mentioned that a high degree of linear correlation between biomass and kernel yield for six maize cultivars grown in six moisture environment. Biomass, ear length, kernel per ear, ear height were positively associated with kernel yield in both wet and dry regimes, while the ASI value was negatively correlated with kernel yield only for dry regime. In addition, Bolaños and Edmeades (1993b) and Bolaños and Edmeades (1996) indicated that ASI correlated more strongly and more negatively with kernel yield as increased in moisture stress, but it correlated weakly under well-watered condition. Edmeades *et al.* (1996) also confirmed that kernel yield among maize progenies showed a strong dependence on ASI and ears per plant under severe drought.

Screening for drought tolerance

According to Table 3, kernel yield in all thirty-one maize genotypes reduced with increased water stress. Pioneer 3012 and Cargill 922 genotypes significantly showed the highest kernel yield in wet and dry regimes, respectively. The drought index and drought susceptibility index among the thirty-one genotypes indicated that the drought tolerant genotypes which showed the value of DI greater than 1.0 and lower DSI were Cargill 922, Cargill 919, NSX 9605, Cargill 717, SW 3601, G 5431, Cargill 7140, DK 888, CP 222, G 5445, NSX 9608, NTX 9703, NSX 9601, NSX 9210, KK-DR, NSX 9213 and NSX 9607 respectively. Other genotypes classified as drought susceptibility type due to the values of DI less than 1.0 and greater DSI values. Most drought tolerance maize genotypes usually had the lowest percentage of yield losses (Manupeerapan *et al.*, 1997) and have the largest DI values (Fischer *et al.*, 1983). In addition, Sukjaroen *et al.* (1997) found that G-5431 and G-5440 were the top yielding varieties among the 14 common entries and had higher drought indices. Results also showed that not all hybrids performed better than the open-pollinated varieties under drought environment. Manupeerapan et al. (1997) found that one of the synthetic varieties showed higher yield potential and more drought tolerance than some hybrids.

The relationships between grain yield potential (intercept) and drought susceptibility (slope) for these thirty-one genotypes are presented in Figure 3. Genotypes, which fell in the upper right quadrant, are more drought resistance (least reduction in yield per unit decline in water supply). Similarly the genotypes falling upper left quadrant can be identified as drought susceptibility type. Among the thirty-one genotypes, Cargill 7140, Cargill 919, Cargill 717, G-5431 and SW 3601 were classified as drought tolerant genotypes, while DK 888, NSX 9607, NSX 9210 and G-5445 were moderately drought tolerant. Moreover, Pacific 700, Pioneer 3012, Cargill 7122, Cargill 727, Pioneer 3013, Pacific 300, Cargill 7118, G-5449 and NS 1 were identified as drought susceptible genotypes. Senthong *et al.* (1986) also reported that soybean genotypes which fell in the upper right quadrant, were greater drought resistance.

Table 2 Phenotypic correlation coefficients among traits for wet regime (above diagonal, N = 31) and dry regime (below diagonal, N=31) of thirty-one maize genotypes in 1998.

	Kernel yield	Biomass	Ear Plant^{-1}	Ear width	Ear length	Kernel ear^{-1}	Kernel weight	Plant height	Ear height	ASI^{+}	Days to anthesis
Kernel yield		0.648**	0.221	0.151	0.438*	0.639**	0.024	0.537**	0.444*	-0.086	-0.070
Biomass	0.541**		0.338	0.177	0.438*	0.287	0.029	0.485**	0.416*	-0.098	0.434*
Ear plant^{-1}	0.230	0.207		-0.422*	-0.170	-0.250	-0.331	0.354	0.601**	-0.007	0.120
Ear width	0.125	0.192	-0.543**		0.386*	0.276	0.502**	-0.093	-0.242	0.185	0.037
Ear length	0.489**	0.470**	-0.094	0.425*		0.507**	0.307	0.214	0.039	0.319	0.150
Kernel ear^{-1}	0.459**	0.335	-0.101	0.250	0.576**		-0.150	0.524**	0.310	0.197	0.078
Kernel weight	0.219	0.172	-0.340	0.693**	0.450**	-0.140		-0.161	-0.300	-0.079	-0.221
Plant height	0.291	0.390*	0.320	0.040	0.284	0.472**	-0.370*		0.776**	0.296	0.443*
Ear height	0.413*	0.514**	0.442**	-0.160	0.169	0.377*	-0.452*	0.754**		0.106	0.338
ASI	-0.376*	0.079	0.049	0.166	0.132	-0.184	0.181	-0.060	-0.100		0.329
Days to anthesis	0.024	0.492**	0.154	-0.214	0.202	0.182	-0.261	0.323	0.422*	-0.051	

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

+ Anthesis-silking interval

Table 3 Average kernel yield (kg/ha) of thirty-one maize genotypes under different water regimes in 1998.

Entries	Water regimes			DSI (%)	DI
	Wet	Intermediate	Dry		
Water applied(mm)	412	259	137		
NSX9210	7306b-g*	6343b-h	5418b-i	25.8	1.02
NSX9213	6918c-h	5974fgh	5116b-i	26.1	1.02
NSX9601	6567e-h	6164e-h	4941c-i	24.8	1.04
NSX9605	6353gh	6230d-h	5241b-i	17.5	1.14
NSX9607	7661a-g	6704a-g	5638a-g	26.4	1.01
NSX9608	6550d-h	6677a-g	5149b-i	23.7	1.05
NTX9701	7068c-h	5892a-d	4723e-i	33.2	0.92
NTX9702	7315b-g	6859a-d	5060b-i	30.8	0.95
NTX9703	6819d-h	6542b-h	5202b-i	23.7	1.05
SW3601	7367b-g	6656b-h	6017a-e	18.3	1.13
CP222	5807h	5744gh	4483f-i	22.8	1.06
DK888	8281abc	7319a-f	6452ab	22.1	1.07
PIO3012	8840a	7768ab	5773ab	34.7	0.90
PIO3013	8204a-d	7354a-f	5454a-f	33.5	0.92
PAC300	7547a-g	7462a-e	4923b-h	34.8	0.90
PAC328	6393gh	6309c-h	4000c-i	37.4	0.86
PAC700	8118a-d	8160a	4086hi	49.7	0.69
G 5449	7782a-g	7230a-f	5453b-h	29.9	0.97
G 5445	8005a-e	7425a-f	6132a-e	23.4	1.06
G 5431	7192b-h	6536b-h	5821a-f	19.1	1.12
CARG717	7456a-g	6733a-h	6122a-e	17.9	1.13
CARG727	8357abc	8114a	5520b-h	33.9	0.91
CARG919	7519a-g	7460a-e	6330abc	15.8	1.16
CARG922	7953a-e	7200a-f	7015a	11.8	1.22
CARG7118	7408b-g	7319a-f	5177b-i	30.1	0.96
CARG7122	8569ab	8140a	5563b-g	35.1	0.89
CARG7140	7912a-f	7746abc	6185a-d	21.8	1.08
KK-DR	6492fgh	5999fgh	4802d-i	26.0	1.02
NST89101	6489fgh	5338h	4257ghi	34.4	0.91
NS1	7328b-g	6576b-h	4885c-i	33.3	0.92
SW1	6820d-h	6367b-h	4719e-i	30.8	0.95

CV = 11.4 % * Values within a column followed by the same letter are not significantly different at the 5% level by DMRT.

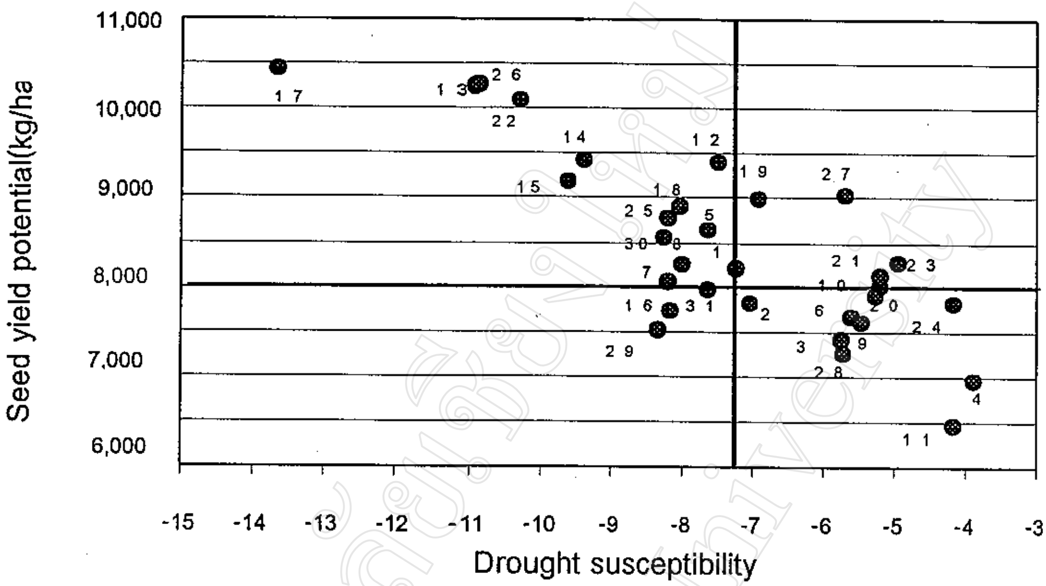

Fig. 3 Relationship between kernel yield potential (intercept, a) and drought susceptibility (slope, b) of thirty-one maize genotypes in 1998.

1. NSX 9210
2. NSX 9213
3. NSX 9601
4. NSX 9605
5. NSX 9607
6. NSX 9608
7. NTX 9701
8. NTX 9702
9. NTX 9703
10. SW 3601
11. CP 222
12. DK 888
13. PIONEER 3012
14. PIONEER 3013
15. PACIFIC 300
16. PACIFIC 328
17. PACIFIC 700
18. G 5449
19. G 5445
20. G 5431
21. CARGILL717
22. CARGILL 727
23. CARGILL 919
24. CARGILL 922
25. CARGILL 7118
26. CARGILL 7122
27. CARGILL 7140
28. KK-DR C4S1
29. NST 89101
30. NS 1
31. SW 1