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Identification of maize (*Zea mays* L.) genotypes for rainfed condition based on modeling of plant traits

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Abstract

Nine maize (*Zea mays* L.) genotypes were evaluated in 8 field experiments during *kharif* (June to October) seasons of 1994 to 2001 under rainfed conditions in a semi-arid alfisol. Performance of these cultivars was analyzed based on grain yield, dry weight, fresh weight, days to 75% silking, anthesis to silking interval, and cob/plant height ratio under above and below normal rainfall conditions. When other plant traits were taken into account in addition to grain yield, performance of some genotypes was comparatively better. These included African Tall (fresh weight, anthesis to silking interval and cob/plant height ratio); DHM-105 (dry and fresh weight); HGT-3 (days to 75% silking); and Trishulata (fresh weight). Correlation and regression analysis of plant traits with grain yield indicated positive and significant relations between grain yield, fresh and dry weights for all the genotypes. African Tall was found to have a maximum yield predictability (R^2) of 0.97, while HGT-3 had the lowest predictability of 0.89. On the basis of estimates of sustainability measured over different seasons DHM-105 and Trishulata were found to be highly sustainable with an index of 0.96 and were the potential maize cultivars suitable for rainfed conditions in semi-arid alfisols.

Key words : Maize, plant traits, sustainability, correlation and regression analysis

Introduction

Maize (*Zea mays* L.) is an important cereal crop grown under rainfed conditions in semi-arid alfisols of Andhra Pradesh and Karnataka, semi-arid vertisols of Madhya Pradesh and Rajasthan, dry sub-humid inceptisols of Uttar Pradesh, Punjab and Jammu region. The crop has less water requirement and is grown in shallow to medium soils having low water holding capacity. It is grown both as a sole crop and also as an intercrop with pigeonpea, soybean, groundnut, sunflower and safflower in different regions. Multivariate statistical procedures have been explored for assessing the genetic divergence among maize inbreds and restricting traits for group constellation [1]. Analysis of variance procedures have been used for assessing the response of maize under different selection criteria [2]. Evaluation of maize genotypes in different seasons indicated that HGT-3 and African Tall were superior for grain yield under rainfed conditions [3, 4]. However, there is a need for careful consideration of important parameters like grain yield, fresh and dry weight, days to 75% silking, anthesis to silking interval, and cob/plant height ratio under rainfed conditions over a period of time. An attempt has been made in this paper to identify superior maize genotypes which are sustainable for semi-arid rainfed alfisols using correlation and regression procedures [5] and estimates of sustainability [6].

Materials and methods

Nine maize genotypes comprising of composites and hybrids (African Tall, Ashwini, DHM-105, Harsha, HGT-3, Madhuri, Megha, Trishulata and Varun) were evaluated during *kharif* 1994 to 2001 in a shallow alfisol at Hayathnagar Research Farm of Central Research Institute for Dryland Agriculture, Hyderabad under semi-arid rainfed condtions. The genotypes were assessed based on their performance for days to 75 % silking, anthesis to silking interval, cob/plant height ratio, fresh weight (at days to 75 % silking), dry weight and grain yield (at harvest) in different seasons. The trials were conducted in a randomized block design with three replications. Each replication consisted of 8 rows of 5 m length with inter and intra-row spacing of 60 and 20 cm respectively. A basal fertilizer dose of 40 kg/ha of N and 30 kg/ha of P was applied and a top dressing of 20 kg N/ha was given at 30 days after sowing. All other normal agronomic practices were followed while conducting the field experiments. Observations on different plant traits were recorded in each season from 5 plants randomly taken from each experimental plot and were averaged for further analysis.

The mean annual rainfall during 8 seasons was found to be 782 mm and ranged from 491 mm in 1999 to 948 mm in 1996 with a variation of 19.2 %. However, during the crop growth period, i.e., 15th June to 15th October, a mean rainfall of 680 mm was received with a variation of 23.5 % and ranged from 421 mm to 869 mm during the respective years. Both the annual rainfall and the rainfall received during the crop growth period were taken into account for the purpose of grouping as above normal in 5 seasons (1994, 1995, 1996, 1998 and 2001) and below normal in 3 seasons (1997, 1999 and 2000).

Correlation and regression procedures, assessment and usefulness of regression models, and measure of sustainability [5, 6, 7, 8] were taken into account to identify superior genotypes which are stable and sustainable for rainfed conditions under semi-arid alfisols. Correlations have been measured to assess the performance of genotypes separately under below normal rainfall condition, which occurred in 3 seasons and above normal rainfall in 5 seasons. However, for making a meaningful selection of superior and sustainable genotypes over a period of time, the measurement of sustainability has to consider different rainfall situations. Based on the sustainability measurement procedure discussed in [6, 8, 9], regression models have been calibrated for the data of all the 8 seasons and the estimates of sustainability of genotypes have been derived. The sustainability (η) of a genotype 'i' over seasons could be measured as

$$\eta_i = [(\mu_i) - (\sigma_i)] / Y_{max}$$

where μ is the mean yield of genotype 'i'; σ is the estimate of error of genotype 'i based on a regression model; and Y_{max} is the maximum yield attained by any genotype in any season in the study. Based on the estimates of sustainability, superior genotypes with maximum sustainability could be selected.

Results and discussion

The mean grain yield of different genotypes ranged from 20 (Madhuri) to 233 g/plant (HGT-3); fresh weight from 39 to 588 g/plant; dry weight from 31 to 667 g/plant in 5 seasons with above normal rainfall. Similarly, the number of days to 75 % silking was from 61 to 90; anthesis to silking interval from 5 to 10 and cob/plant height ratio from 0.40 to 0.62 under above normal rainfall situation. In the below normal rainfall received during 3 seasons, grain yield ranged from 9 (Madhuri) to 54 g/plant (DHM-105), fresh weight from 30 to 64 g/plant and dry weight from 21 to 164 g/plant. Similarly, days to 75 % silking had ranged from 61 to 85, anthesis to silking interval ranged from 5 to 9 and cob/plant height ratio from 0.41 to 0.62 under below normal rainfall condition. The descriptive statistics which indicate the performance of genotypes *viz.*, range, mean and coefficient of variation for different plant traits under above and below normal rainfall conditions are given in Table 1.

The correlations of plant traits indicated a positive and significant relationship of grain yield with fresh and dry weights; and fresh weight with dry weight under above normal rainfall condition for all maize genotypes (Table 2). Grain yield had a positive and significant correlation with fresh weight for Ashwini, HGT-3 and Megha, and with dry weight for Ashwini under below normal rainfall condition. Similarly, dry weight had a positive and significant relation with fresh weight for DHM-105, Madhuri and Trishulatha, while there was negative correlation for Varun. The relationship of all the remaining traits with grain yield, fresh and dry weight varied under below and above normal rainfall conditions. Further, some of the traits like days to 75 % silking (DS), Anthesis to silking interval (AS) and cob/plant height ratio (CP) appeared to be relatively more important under below normal rainfall condition. While DW and DS were found to be positively related, GY and CP were negatively related in majority of the genotypes. Such correlation was not found in above normal rainfall condition.

Table 1. Performance of maize genotypes in above and below normal rainfall conditions

Genotypes	Above normal rainfall			Below normal rainfall		
	Range	Mean	CV (%)	Range	Mean	CV (%)
Dry weight (g/pl)						
African tall	32-523	212.8	94.2	47-164	87.4	75.7
Ashwini	42-236	124.6	76.5	24-37	28.4	27.1
DHM 105	45-383	193.0	72.4	29-44	38.7	21.3
Harsha	38-340	151.4	91.7	25-36	31.1	18.4
HGT 3	51-667	263.4	90.0	30-50	41.6	25.3
Madhuri	31-211	91.4	82.5	21-23	22.2	4.8
Megha	45-200	121.0	56.3	25-35	30.2	16.2
Trishulatha	50-269	146.2	59.9	28-41	36.1	19.9
Varun	47-406	155.6	101.0	24-35	30.5	18.6
Fresh weight (g/pl)						
African tall	49-510	203.6	88.7	47-63	55.7	14.0
Ashwini	47-300	149.8	77.7	31-40	37.0	14.8
DHM 105	51-446	214.0	75.2	51-64	58.8	12.0
Harsha	45-588	217.4	103.7	44-48	46.2	4.4
HGT 3	48-541	210.5	94.1	41-56	47.6	15.5
Madhuri	39-342	130.3	98.1	30-32	30.9	3.3
Megha	52-350	153.7	80.3	38-43	40.5	6.9
Trishulatha	58-404	178.7	78.2	45-56	50.4	10.3
Varun	59-487	189.2	96.7	42-43	42.6	1.2
Grain yield (g/pl)						
African tall	49-197	87.3	71.2	26-47	38.3	27.8
Ashwini	45-155	81.3	56.8	20-42	30.5	36.2
DHM 105	56-221	111.0	61.3	33-54	46.6	25.3
Harsha	46-209	104.3	65.0	31-47	41.0	20.6
HGT 3	49-233	96.7	80.0	29-46	38.5	21.9
Madhuri	20-140	52.2	96.8	9-20	14.1	39.3
Megha	55-170	90.8	52.5	27-43	37.4	24.8
Trishulatha	62-227	113.9	61.1	32-48	42.3	20.5
Varun	54-192	96.4	61.1	31-42	37.6	16.2
Anthesis to silking interval						
African tall	7-10	8.5	13.6	8-9	8.1	5.0
Ashwini	7-9	7.6	8.6	6-7	6.5	7.7
DHM 105	6-7	6.5	9.4	6-7	6.7	3.7
Harsha	5-8	6.4	19.6	6-7	6.3	9.1
HGT 3	6-10	8.0	17.5	7-9	8.0	11.2
Madhuri	5-8	6.6	18.9	6-8	6.4	15.1
Megha	6-9	7.1	12.6	5-7	5.7	16.2
Trishulatha	5-8	6.7	16.7	6-7	6.6	6.1
Varun	6-7	6.1	7.6	6-7	6.3	4.0

Table 2. Correlation between plant traits of maize under different rainfall conditions

Traits	African tall	Ashwini	DHM-105	Harsha	HGT-3	Madhuri	Megha	Trishulatha	Varun
Above normal rainfall									
DW, FW	0.88**	0.97**	0.96**	0.95**	0.94**	0.98**	0.88**	0.94**	0.98**
DW, GY	0.87**	0.85*	0.94**	0.98**	0.96**	0.95**	0.81*	0.91**	0.97**
DW, DS	0.13	–0.43	–0.31	0.01	0.68	0.50	–0.36	–0.29	0.48
DW, AS	–0.59	0.24	–0.81*	0.18	0.15	–0.21	0.58	–0.48	–0.73
DW, CP	0.65	–0.95**	0.27	0.37	0.65	–0.05	–0.70	0.02	0.34
FW, GY	0.99**	0.95**	0.98**	0.98**	0.98**	0.98**	0.98**	0.98**	0.98**
FW, DS	0.27	–0.47	–0.20	0.02	0.85*	0.54	0.03	–0.17	0.44
FW, AS	–0.82*	0.03	–0.92**	–0.06	0.19	–0.35	0.31	–0.55	–0.77
FW, CP	0.92**	–0.98**	0.27	0.61	0.67	0.01	–0.90**	–0.16	0.32
GY, DS	0.35	–0.38	–0.09	–0.03	0.85*	0.63	0.12	–0.26	0.47
GY, AS	–0.77	–0.19	–0.96**	0.04	0.03	–0.48	0.20	–0.54	–0.77
GY, CP	0.87**	–0.93**	0.42	0.54	0.56	0.01	–0.91**	–0.12	0.34
DS, AS	0.17	0.45	0.06	–0.63	–0.16	–0.37	–0.26	–0.26	–0.16
DS, CP	0.29	0.45	–0.01	–0.24	0.29	0.65	–0.37	–0.79	0.78
AS, CP	–0.86**	–0.03	–0.50	–0.35	0.71	0.08	–0.40	0.76	0.21
Below normal rainfall									
DW, FW	–0.93**	0.58	0.98**	0.68	–0.05	0.80*	0.36	0.87**	–0.87**
DW, GY	0.23	0.94**	–0.50	–0.78	–0.40	–0.07	–0.12	–0.46	–0.18
DW, DS	–0.54	0.55	0.97**	0.96**	0.93**	–0.17	0.97**	0.97**	0.93**
DW, AS	0.94**	–0.90**	–0.93**	0.72	–0.55	0.66	0.01	–0.81*	0.80*
DW, CP	–0.65	–0.68	0.53	0.72	0.82*	–0.54	0.14	0.53	0.15
FW, GY	–0.57	0.82*	–0.64	–0.07	0.94**	–0.66	0.88**	–0.84*	–0.33
FW, DS	0.81*	–0.37	0.98**	0.86**	–0.42	0.46	0.14	0.92**	–0.63
FW, AS	–0.75	–0.88**	–0.98**	–0.01	–0.80*	0.98**	–0.93**	–0.97**	–0.40
FW, CP	0.89**	–0.98**	0.67	–0.01	–0.61	–0.94**	–0.88**	0.88**	0.35
GY, DS	–0.94**	0.23	–0.68	–0.58	–0.71	–0.97**	–0.34	–0.55	–0.53
GY, AS	–0.12	–0.98**	0.78	–0.98**	–0.54	–0.79	–0.98**	0.90**	–0.73
GY, CP	–0.89**	–0.89**	–0.98**	–0.98**	–0.85*	0.88**	–0.98**	–0.97**	–0.97**
DS, AS	–0.22	–0.12	–0.97**	0.50	–0.20	0.62	0.23	–0.86**	0.97**
DS, CP	0.98**	0.24	0.71	0.50	0.97**	–0.74	0.36	0.61	0.51
AS, CP	–0.36	0.93**	–0.80*	0.98**	0.02	–0.99**	0.97**	–0.93**	0.72

*,**Significance at 5 and 1 % level respectively; DW : Dry weight (g/pl); FW : Fresh weight (g/pl); GY : Grain yield (g/pl); CP : Cob/plant height ratio; DS : Days to 75 % silking; AS : Anthesis to silking interval

Based on the pooled data of genotypes over seasons, the above mean performance of a genotype for a plant trait could be treated as 'High' and below mean performance could be treated as 'Low'. Similarly, the coefficient of variation of genotypes for plant traits could be considered as 'High' or 'Low', if the estimates are above or below mean variation respectively. Based on the graphical plots of the pooled data of genotypes, plant traits have been categorized into 4 groups *viz.*, 'High Mean with Low Variation', 'High Mean with High Variation', 'Low Mean with Low Variation' and 'Low Mean with High Variation' as indicated in Table 3. The graphical plots for various plant traits against coefficient of variation of genotypes (Fig. 1 and 2) indicated that the desirable 'High Mean with Low Variation' existed for grain yield for all the cultivars except Madhuri. Other plant traits also exhibited this trend in some of the cultivars *viz.*, African Tall (fresh weight, anthesis to silking interval and cob/plant height ratio), DHM-105 (fresh and dry weight) and Trishulatha (fresh weight). Further, Ashwini, Madhuri, Megha, Trishulatha and Varun were found to have desired 'Low Mean with Low Variation' for the number of days to 75 % silking in different seasons. It was also observed that maximum number of genotypes have 'High Mean with Low Variation' for grain yield; 'High Mean with High Variation' for fresh weight; 'Low Mean with Low Variation' for days to 75 % silking; and 'Low Mean with High Variation' for anthesis to silking interval, cob/plant height ratio and dry weight.

The regression functions of grain yield of each genotype through different plant traits indicated a high and significant predictability ranging from 0.89 for HGT-3 to 0.97 for African Tall (Table 4). The contributions of plant traits as measured by the regression coefficients in the models calibrated for each genotype implied that fresh and dry weights, days to 75 % silking and cob/plant height ratio were significant in African Tall. Similarly, fresh weight was found to be significant for Ashwini and Trishulatha ; and anthesis to silking interval for Madhuri genotypes in the study. The unexplained variation in the grain yield of a genotype as measured

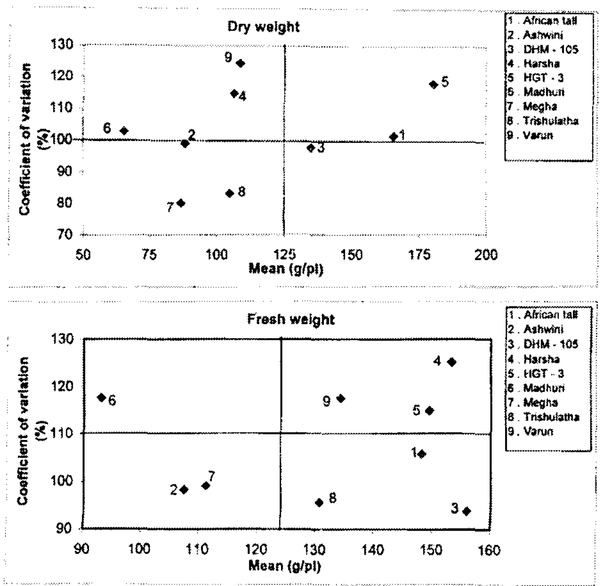

Fig. 1. Grouping of maize genotypes based on mean and variation of dry and fresh weight

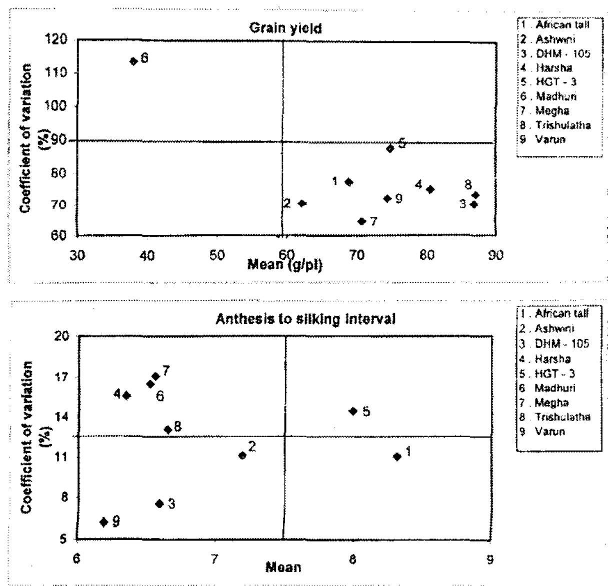

Fig. 2. Grouping of maize genotypes based on mean and variation of grain yield and anthesis to silking interval

Table 3. Grouping of maize genotypes based on mean and variation of plant traits

Genotypes	High mean low variation	High mean high variation	Low mean low variation	Low mean high variation
African Tall	FW, GY, AS, CP	DW, DS		
Ashwini	GY		DW, FW, DS, AS	CP
DHM-105	DW, FW, GY		AS, CP	DS
Harsha	GY	FW	CP	DW, DS, AS
HGT 3	GY, DS	DW, FW, AS, CP		
Madhuri			DS	DW, FW, GY, AS, CP
Megha	GY		DW, FW, DS	AS, CP
Trishulatha	FW, GY		DW, DS, CP	AS
Varun	GY	FW	DS, AS	DW, CP

DW : Dry weight (g/pl); CP : Cob/plant height ratio; FW : Fresh weight (g/pl); DS : Days to 75 % silking; GY : Grain yield (g/pl); AS : Anthesis to silking interval.

Table 4. Prediction equations of maize yield through different plant traits

Genotypes	Multiple regression equation	R^2	σ	η
African tall	GY = 851** - 0.08* (DW) + 0.56** (FW) + 0.99* (DS) – 2.88 (AS) – 1556.72** (CP)	0.97**	3.44	0.75
Ashwini	GY = 31 - 0.69 (DW) + 0.90** (FW) + 2.27 (DS) + 4.68 (AS) – 383.72 (CP)	0.90*	9.99	0.67
DHM-105	GY = –865 - 0.34 (DW) + 0.87 (FW) + 0.68 (DS) + 59.87 (AS) + 928.98 (CP)	0.92*	17.38	0.96
Harsha	GY = –6 + 1.44 (DW) - 0.63 (FW) - 3.63 (DS) –35.42 (AS) + 1043.22 (CP)	0.96**	7.87	0.88
HGT 3	GY = –29 + 0.14 (DW) + 0.21 (FW) + 2.03 (DS) – 2.47 (AS) – 165.91 (CP)	0.89*	8.41	0.82
Madhuri	GY = –31 + 0.45 (DW) + 0.08 (FW) + 1.44 (DS) – 9.30* (AS) + 4.39 (CP)	0.96**	6.45	0.40
Megha	GY = –202 + 0.17 (DW) + 0.37 (FW) + 3.21 (DS) – 6.06 (AS) + 109.87 (CP)	0.93*	12.57	0.77
Trishulatha	GY = 242-0.04 (DW)+0.54* (FW)-2.99 (DS)+3.84 (AS) –107.22 (CP)	0.92*	14.63	0.96
Varun	GY = –52 - 0.25 (DW) + 0.57 (FW) + 1.80 (DS) + 15.81 (AS) – 278.40 (CP)	0.96**	7.43	0.81

*,**Significance at 5 & 1 % level; DW: Dry weight (g/pl); FW: Fresh weight (g/pl); CP: Cob/plant height ratio; DS: Days to 75 % silking; σ : Estimate of error (g/pl); η : Sustainability yield index; R^2: Coefficient of determination; GY: Grain yield (g/pl); AS: Anthesis to silking interval

by the estimate of error was found to range between 3.44 g/plant for African Tall to 17.38 g/plant for DHM-105 in different seasons.

The estimates of sustainability for each genotype were derived using the procedure described in [6] and superior genotypes which are highly stable and sustainable over the seasons have been identified. Trishulatha and DHM-105 were found to be highly sustainable with an estimate of 0.96, while Madhuri had a low sustainability of 0.40 (Table 4) among different maize genotypes evaluated under rainfed alfisols. These two cultivars had also attained a maximum mean grain yield with a significant predictability of 0.92, and a high mean and low variation for grain yield and fresh weight. African Tall, although had a high mean with low coefficient of variation for a maximum number of 4 plant traits *viz.*, fresh weight, grain yield, anthesis to silking interval and cob/plant height ratio, and a maximum grain yield predictability of 0.97, was found to have a relatively low sustainability of 0.75. Thus, DHM-105 and Trishulatha were found to be comparatively superior to other maize cultivars evaluated in the present study implying their suitability for rainfed semi-arid alfisols under rainfed conditions.

It is interesting to note that these two specific genotypes are the hybrids (compared to others representing composites) probably implying the role of heterosis in better adaptability and sustainability. However, this issue needs to be further assessed using appropriate experimental material.

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