Study of Stability Parameters for Drought Resistance in Sunflower Hybrids Derived from Interspecific Crosses[1]

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Abstract

The purpose of this research was to evaluate stability parameters of characteristics related to drought resistance in sunflower experimental hybrids. Two experiments were performed in 1994 in two locations of Friuli under irrigated-rainfed field conditions. A trifactorial experimental design was utilised (locations (A), moisture level (B) and hybrids (C)) with three replications. Five hybrids were tested 887xT+ and HA89xBaracca (*H. annuus x H. argophyllus*), 887xPNMR 6.5.1 (*H. annuus x H. anomalus*), HA89x3801 and Pulsar as tester (*H. annuus*). Drought conditions were manifested during the reproduction phase in both experiments in rainfed treatments. The ANOVA analysis showed significant differences ($P \leq 0.05$ and 0.01) for factors A, B and C and their interactions. A stepwise regression analysis revealed two different biocybernetic models for irrigation and rainfed. In this latter, 6 of 10 characteristics were related significantly ($p \leq 0.05$ and 0.01) to seed yield, especially leaf area index and leaf area duration. It was observed that some of these characteristics were enhanced under drought. The stability parameters analysis showed that the most stable characteristics were: head diameter, leaf area index, leaf area duration, oil percent and seed yield. The most stable hybrids for seed and oil percentage were: 887xPNRM 6.5.1 and HA89xBaracca.

Key words: stability parameters, drought, sunflower

Introduction

Improved drought tolerance is a major objective in plant breeding programmes for rainfed crops in Mediterranean regions. It has been demonstrated that drought resistance traits exist, constituting functional mechanisms, which require the presence of water deficits to be expressed (Castañón, 1991), which means that the expression of these traits needs the contribution of the genotype-environment interaction to be manifested.

Drought resistance is a quantitative and multifactorial adaptive process which includes a genetic component (G) and a genetic-environment interaction (GE) (Muñoz, 1992).

The Bucio Alanís (1966) genotype model allows the calculation of the genotype-environment interaction by defining the estimated genotype value of the ith variety in the jth environment $\hat{Y}ij$ such that $= \mu + g_i + Biej$, where μ is the overall mean; g_i is the genotype effect of the ith variety, Bi = (1+bi) is the regression coefficient of the genotype-environment interaction and ej is the environmental effect in the jth environment considered as a fixed variable. Finally, Biej expresses the genotype-environment interaction (GE) as a function of the environmental effects. Then, in the model of Bucio Alanís the performance of individual genotypes is regressed on a environmental index consisting of the average performance of all genotypes grown in a given environment.

Many methods and statistics are currently available for the evaluation of phenotypic stability of plant cultivars. The most widely used criteria for selecting for high and stable performance are mean yield, regression response on site mean yield, coefficient of determination and deviations from regression (Eberhart and Russell, 1966; Finlay and Wilkinson, 1963; Langer *et al.*, 1979). Finlay and Wilkinson (1963) proposed that regression coefficients approaching zero indicated stable performance. However, Eberhart and Russell (1966) pointed out that varieties with a regression coefficient (β) < 1 usually have mean yields below the overall mean and that selection for regression coefficients near zero results in selection for low mean yields. The Eberhart and Russell model defines a stable variety as having an above-average mean yield, a regression coefficient of unity (β=1), and non-significant mean square of deviations from regression (SD=0). Marquez (1973) demonstrated that the model the Bucio equation is the predicted value of Eberhart and Russell (1966) model, where the phenotype value of the ith variety in the jth environment Yij is = $\mu_i + \beta_i I_j + \delta ij$; the symbols μ_i, β_i, I_j are equivalent to ($\mu + g_i$), Bi and ej respectively in the model of the Bucio equation and δij (=SD) is the deviation from the regression. The decision whether to select for high mean yield with either unit regression (β for Eberhart and Russell model or Bi for Bucio one) or low and negative regression, and then for lower mean yield, depends on circumstances. In commercial agriculture, a high average return is often the desired objective, but in temperate and Mediterranean-type environments, where the available water is scarce and expensive, creation of stable drought-resistant hybrids should provide the best solution.

The purpose of this research was to evaluate stability parameters of characteristics related to drought resistance in four experimental sunflower hybrids and a tester in two experiments in two locations of Friuli under irrigated-rainfed field conditions.

Material and methods

In 1994 five hybrids were tested: 887xT$^+$ and HA89xBaracca (*H. annuus x H. argophyllus)*, 887xPNMR 6.51 (*H. annuus x H. anomalus*), HA89x3801 and Pulsar as tester (*H. annuus*) in two experiments in two locations of Friuli under irrigated-rainfed field conditions.

This region has a humid climate, according to the Thornthwaite and Mather (1955) parameters, with 1440 mm total annual rain fairly well distributed during the year. The lowest monthly mean temperature is 3.7 °C in January and the highest is 22 °C in July. The first location, Udine, is characterised by deep medium clay loam soil, the second, San Vito, by a shallow and very permeable soil (Udifluvent USDA). During the summer months in this latter location, excessive drainage and the thin soil cover can lead to very serious hydric stress. Both locations are representative of the region's soils.

Figure 1 shows the thermopluviometric trend for the two locations during the growing season.

The irrigation treatments involved two levels:

- rainfed plots: never irrigated,
- irrigated plots: irrigation with 40 mm each week from bud stage to physiological maturity.

A trifactorial experimental design was used (locations (A), moisture level (B) and hybrids (C)) with three replicates (each experimental unit was 22.5 m^2). The hybrids were sown on 21st April at a density of 5 plants/m^2 (after thinning out) and were harvested between 5th August and 5th September, depending on the rainfed or irrigated conditions and on the location. In addition to the usual fertilisation (100-60-50), boron was applied (1 Kg ha^{-1}), to avoid boron deficiency phenomena.

The following parameters were measured in both dry and irrigated plots and at both locations head diameter, leaf area per plant (LA) (dm^2), calculated using the relationship followed by Pouzet *et al.* (1985) at flowering, 21 days after flowering and 42 days after flowering to calculate leaf area index (LAI) and leaf area duration (LAD).

At harvest, ten plants were taken manually at random from the central two rows of each plot and the following measurements were performed on the seeds

- Seed weight (1000 achene weight) in g
- seed oil content, measured by nuclear magnetic resonance (N.M.R.).
- grain yield (dry matter) in quintal per hectare.

All the data acquired were submitted to analysis of variance which tested the effects of the treatments and their interactions. Stability analysis was conducted for each hybrid using the genotype model of Bucio Alanís (1966) to determine stability regression coefficients (Bi).

The regression coefficients (β) obtained were subjected to a *t*-test to determine significant deviations ≠ 0 (Eberhart and Russell, 1966). The coefficient of determination (r^2) was also used as a stability index (Eberhart and Russell, 1966) and because other researchers have found correlations about 0.90 between r^2 (=1) and SD (=0) (Langer *et al.*, 1979; Santos *et al.*, 1982; Becker and Léon, 1988), we considered the r^2 significance comparable to deviations from the regression (SD).

Results and discussion

The statistical analysis of treatments and interaction effects is reported in Table 1. Significant differences were found between locations (A), moisture (B) and hybrids (C) and the (AxB), (AxC) and (BxC) interactions for yield.

LAI and LAD were influenced by location, moisture and genotypes and LAD by (AxC) interactions. Seed weight was influenced by location, moisture and genotype and by (AxB) and (BxC) interactions. Head diameter was influenced only by genotype and oil by moisture level, hybrid and (AxB) and (BxC) interactions. A stepwise regression analysis revealed two different biocybernetic models for irrigation and rainfed. In this latter, LAI and LAD were significantly related ($P \leq 0.05$ and 0.01) to seed yield, while under irrigated conditions only head diameter was significantly related to seed yield (data not shown).

According to the Eberhart and Russell (1966) model, the LAD for the hybrids 887xT$^+$, 887xPNRM 6.5.1 and HA89xBaracca (Table 2) can be defined as stable.

The negative regression coefficients for yield (from -0.235 to -0.4) and oil content (from -0.249 to -0.429) in 887xPNRM 6.5.1 and HA89xBaracca revealed a better response by these hybrids to unfavourable rainfall conditions rather than under irrigated conditions (Table 2). Under irrigated conditions the yield of both these hybrids were always lower than the other hybrids, but in contrast these hybrids were the best under rainfed conditions according to the Eberhart and Russell model (data not shown).

The analysis of the environmental index values showed that the two locations were similar under irrigated conditions, while in rainfed conditions, because of soil type, the hydric stress was notably more intense at San Vito (environmental index e4 = -15.6) than at Udine (e2 = -1.4). Moreover, the Udine rainfed conditions (e2) corresponded to the mean effect of the environment studied (Fig. 2).

Under San Vito rainfed conditions, HA89x3801 and 887xPNMR 6.5.1 were the best hybrids, while under Udine rainfed conditions, the best hybrids were 887xT$^+$, Pulsar and HA89x3801 (Fig. 2).

Conclusions

The stability parameter study of these five hybrids, already previously selected for drought resistance, in two locations and in two moisture levels in our region, allowed us to emphasise clear environmental differences existing in our region, caused by soil type under the same thermopluviometric conditions, so these results will allow progress to be made in the selection for drought resistance.

We recommend that the restorers of the HA89xBaracca, 887xPNMR 6.5.1 and HA89x3801 hybrids are used in combination with drought resistant male sterile material to evaluate their SCA (specific combining ability).

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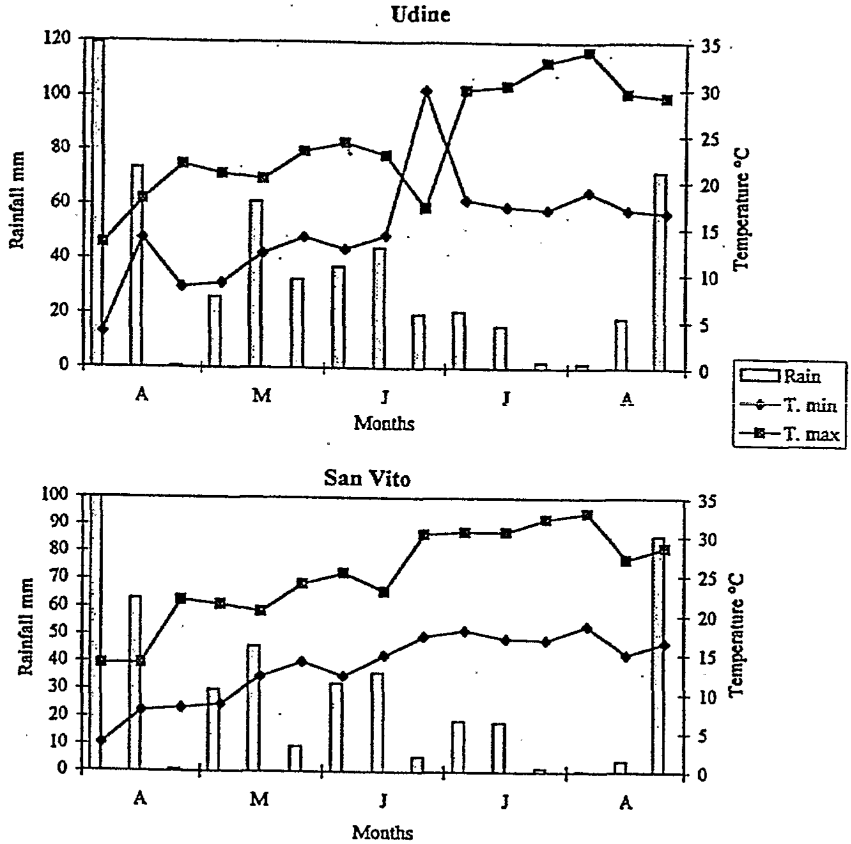

Figure 1 - Ten days values of rainfall and temperatures throughout the growing season in the two locations.

Table 1 - Analysis of variance for hybrids characters analyzed during the trial.

Sources	df	Head diameter	LAI	LAD	Seed weight	Oil	Yield
	Mean squares						
Locations (A)	1	177.848	30.774**	2404.261**	2105.153*	39.350	929.841*
Moisture (B)	1	74.593	3.866**	373.252*	6084.294**	552.249*	2768.963**
AxB	1	39.204	0.105	105.152	900.163*	403.678*	874.017**
Hybrids (C)	4	129.863	2.223*	80.043**	593.502**	296.685**	78.365**
AxC	4	12.057	0.441	46.903**	251.753	39.254	123.079**
BxC	4	43.340	0.358	11.112	367.584**	58.782*	70.400**
ABC	4	36.954	0.237	10.382	71.561	17.705	30.232
Error	32	24.117	0.444	8.084	60.915	22.648	12.446

*,**Significant at the 0,05, 0,01 probability respectively.

Tab 2 - LAD, Oil, Yield stability parameters of the 5 hybrids evaluated in the two location and in the two humidity levels.

LAD			
Hybrids	$\overline{x}$	r^2%	β
887xT+	11.4	94*	0.824*
887xPNMR 6.5.1	13.4	92*	0.481*
Ha89xBaracca	13.4	92*	0.613*
HA89x3801	9.8	12	0.309
Pulsar	7.3	85	-0.314
Oil			
Hybrids	$\overline{x}$	r^2%	β
887x T+	45.33	21	0.235
887xPNMR 6.5.1	39.7	36	-0.249
Ha89xBaracca	48.3	56	-0.429
HA89x3801	52.4	3	0.132
Pulsar	50.6	55	0.571
Yield			
Hybrids	$\overline{x}$	r^2%	β
887x T+	34.7	50.5	0.517
887xPNMR 6.5.1	29.5	87	-0.4
Ha89xBaracca	28.2	68	-0.387
HA89x3801	32.5	19	-0.235
Pulsar	31.8	64	0.221

$\overline{x}$ = mean yield, r^2 = coefficient of determination, β = coefficient of regression;
* Significantly different from Bi ≠ 1.0 for the regression coefficients and from r^2= 0 for determination coefficient.

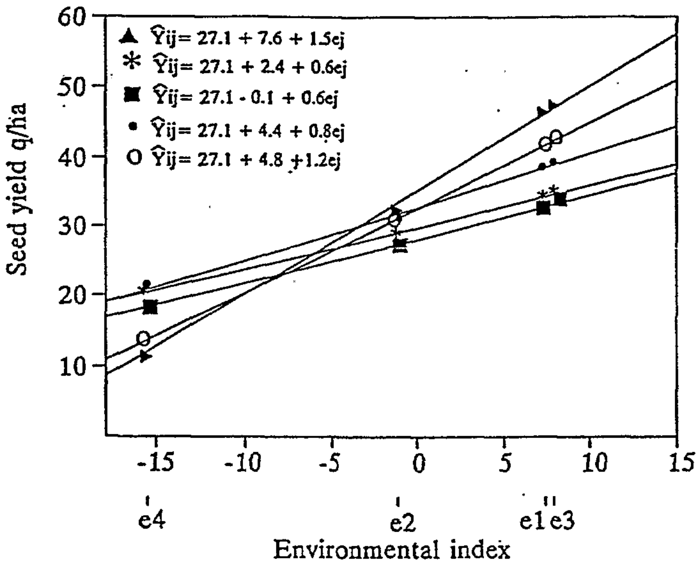

Figure 2 - Estimated (Yij) seed yield (q/ha) for hybrids ▲ 887xT^{+}, • 887xPNMR 6.5.1, ■ HA89xBaracca, • HA89x3801, O Pulsar, according to the model of Bucio (1966) $\hat{Y}ij= \mu + g_i + Bi\ e_j$; growing in two irrigated (e1 and e3) and two drought (e2 and e4) environments, corresponding two localities of Friuli Venezia-Giulia, Italy: e1-e2 Udine, e3-e4 San Vito al Tagliamento.