GENERATING A SELECTION INDEX FOR DROUGHT TOLERANCE IN SUNFLOWER.

II. Morphophysiological Characteristics and Yield.

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SUMMARY

An experiment was stablished in order to identify a selection index for morphophysiological characteristics related with drought tolerance for the reproductive phase in sunflower. Eight genotypes was seeded, three of them coming from interspecific crosses. Drought was induced and controled with plastic mulch on the furrows. A split plot experimental design was used with three replicates. Twenty one phenological and morphophysiological characteristics were measured. A multiple regresion analysis selected a group of nine variables significatively correlated with yield (R^2= 0.9507). The factor analysis determined a group of four factors with an accumulated variance of 86.1 %. For Durango conditions plants better adapted can be selected considering: An ample reproductive stage, dry matter weight at the begining of bloom mainly constituited for stem weight, dry matter weight at physiological maturity, high harvest index and high plant and head growth rate.

INTRODUCTION

Cultivated sunflower (*Helianthus annuus* L.) has a moderately adaptation to water stress. To increase this adaptation is recommended the introduction in some genotypes physiological characteristics, that contribute to drought resistance (Benvenuti e Vannozzi, 1988). Have been found a significatively correlation among many phenological, morphological and physiological characteristics with drought avoidance and tolerance in sunflower (CETIOM-INRA, 1983; Fereres et al., 1986; Gómez et al., 1990 and Gómez et al., 1991).

The "Principal Factor Analysis" is an statistic technique used to reduce the number of variables correlated with yield, to a small number of variables or factors not correlated among them (Catell, 1965). These factors can be utilized instead of more numerous original variables. They explain the largest part of variation in a group of data (Catell, 1965).

The "Stepwise Regression Analysis" computes a series of regresion equations adding or discarding in each step, an independent variable in the order which contribute with variance to the dependent variable (yield), until the regression equation is satisfactory (Draper and Smith, 1980). With the support of these analysis is identified the selection index.

The objective of this work was to identify a selection index for phenological, morphological and physiological characteristics related with drought tolerance and yield in sunflower during reproductive phase.

MATERIALS AND METHODS

This experiment was established at the Instituto Nacional de Investigaciones Forestales y Agropecuarias (INIFAP) at Durango, Mexico. This experiment consisted in two sowing dates (april 6 and 30 1990) under drought conditions. Were seeded these genotypes: 1. cms UP-02, 2. cms UP-24, 3. cms UP-42 (these last three coming from interspecific crosses: *H. annuus x H. argophyllus, H. annuus x H. debilis* and *H. annuus x H. bolanderi*, respectively), 4. CIANOC-2, 5. Victoria (tester), 6. Sereno, 7. Rib-77 and 8. INRA (these last five are *H. annuus*). All these genotypes were selected for their outstanding yield and Water Use Efficiency under irrigated and rainfed conditions (Gómez et al., 1990 and Gómez et al., 1991). Except number 8 that is an open pollinated variety from France.

In both sowing dates were applied a presowing irrigation plus two irrigations during vegetative phase, 40 and 20 days before blooming date. Drought was induced and controled with plastic mulch on the furrows. An experimental design of a split plot on randomized blocks with three replications was used. The main plot was sowing dates and the small one genotypes. There were obtained measures of 21 phenological, morphological and physiological characteristics and achene yield. The statistical analysis of these characteristics were made with the Stepwise Regression Analysis and the Factor Analysis used by Catell (1965) and Draper and Smith (1980).

RESULTS

Stepwise Regression Analysis

The independent variables were 20 characteristics (Vn) and yield (V14) was the dependent variable. In accord with the equation calculated by the multiple regression analysis, the best selected model includes 9 variables with an $R^2 = 0.9507$ (Table 1). In accord with "F" value the variables most related with grain yield were: dry weight of heads at physiological maturity g/m^2 (V13), total dry matter weight at physiological maturity g/m^2 (V15), yield efficiency $g/m^2/day$ (V17), and plant growing rate during reproductive stage $g/m^2/day$ (V18), every one of them with a probability of $p<0.0001$. The other variables had a significative correlation at $p<0.05$, days to blooming date (V1), days to physiological maturity (V3), plant hight (cm) at physiological maturity (V7), dry weight of leaves at the beginning of bloom g/m^2 (V9) and leaf/stem ratio at the beginning of bloom g/m^2 (V21)., reproductive index expresed in days (V5) had a positive correlation at $p<0.08$.

Factor Analysis

There were 4 factors with a contribution of 86.1 % of the total variance (Table 2). The first factor did the contribution most important to total variance with 47.83 %, approximately the half of total variance. The variables with largest contribution to total variance were: days to end of blooming (V2), days of effective reproductive period (V4), days of blooming period (V6), dry weight of stems at the beginning of bloom g/m² (V8), total dry matter weight at the beginning of bloom g/m² (V10), dry weight of stems at physiological maturity g/m² (V11) and dry weight of leaves at physiological maturity g/m² (V12).

The second factor had 16.57 % of the total variance, with positive values of: total dry matter weight at physiological maturity g/m² (V15), harvest index (V16), yield efficiency g/m²/day (V17), head growing rate g/m²/day (V19), and with a negative value for leaf/stem ratio at physiological maturity g/m² (20). The third factor contributed with 12.35 % of total

Table 1. Multiple regression analysis. Grain yield (V14) is the dependent variable. INIFAP. Durango, Mexico. 1990.

Variable	Estimated parameter	Standard error	Sum of squares	F	Prob.>F
Interception	-617.85	169.67	10463.27	13.26	0.0008
V1*	14.83	4.02	10724.93	13.59	0.0007
V2	-7.02	2.85	4772.44	6.05	0.0186
V5	808.48	460.31	2434.25	3.08	0.0871
V9	0.95	0.36	5528.60	7.01	0.0118
V10	0.40	0.15	5440.18	6.89	0.0124
V13	-0.46	0.08	22067.75	27.97	0.0001
V15	-0.25	0.02	72831.09	92.30	0.0001
V17	99.98	6.85	168055.55	212.97	0.0001
V18	71.55	5.45	135690.73	171.96	0.0001

Source	D.F	MS	F	Prob.>F
Regression	9	64371.301	81.58	0.001
Error	38	789.104		

R^2= 0.9507 * Names of variables are present in Results text.

variance, the only variable in this factor was days of reproductive index (V5), with positive value. The fourth factor contributed with 9.35 % of total variance, it was represented by grain yield g/m² (V14) and plant growth rate during reproductive stage g/m²/day (V18).

DISCUSSION

The discussion of results is centered in genotypes contrasting in length of their biological cycle (Gómez et al., 1990, Gómez et al., 1991), these are Victoria with 97 days to physiological maturity, cms UP-02 with 114 days and Sereno with

124 days, respectively. In order to improve plant's drought tolerance it is necessary to consider the folowing factors.

First factor indicated the importance to have an ample effective reproductive period (V4), through a large blooming period (V6), to obtain a greater pollination and a greater period of photosynthates caption by achenes (V17). Thus is assured a greater quantity of formed achenes with heavy weight (Figure 1). This first factor shows also the importance to have a greater biomass weight at the beginning of bloom (V10), constituted mainly for heavy stems (V8). All these facts mean that if the plant has enough assimilates accumulated in the stems at the begining of bloom and if the plant can translocate them to achenes, even if the plant is under water stress conditions, then the plant can tolerate this kind of water stress caused by drought at the beginning of bloom (Figure 2).

Table 2. Principal factor analysis in sunflower under drought conditions. INIFAP Durango, Mexico. 1990.

	F A C T O R S			
Variables	1	2	3	4
V2*	0.891	0.119	0.334	0.018
V4	0.824	0.173	0.514	-0.122
V5	0.647	0.229	0.625	-0.261
V6	0.789	0.313	0.449	-0.225
V8	0.803	0.225	-0.511	-0.088
V10	0.752	0.293	-0.563	-0.036
V11	0.902	0.323	-0.031	-0.084
V12	0.952	-0.094	0.071	0.002
V14	0.192	0.061	0.125	0.867
V15	-0.636	0.662	-0.033	0.138
V16	0.442	0.645	0.274	-0.147
V17	-0.588	0.647	0.113	0.363
V18	0.368	-0.362	0.202	0.600
V19	-0.590	0.719	-0.108	0.137
V20	0.588	-0.666	-0.325	-0.070
Variance (%)	47.83	16.57	12.35	9.35
Variance accum. (%)	47.83	64.40	76.75	86.10

* Names of variables are present in Results text.

Second factor its constituted by yield characters as: total dry matter (V15), harvest index (V16), yield efficiency (V17) and head growing rate (V19). These factor mean that if a plant increase the accumulation of its total dry matter at physiological maturity, specially head weight, and if the plant makes at the same time a good combination of high level of harvest index (V16), yield efficiency (V17) and head growing rate (V19), then the plant will can elevate yield even if is under water stress conditions.

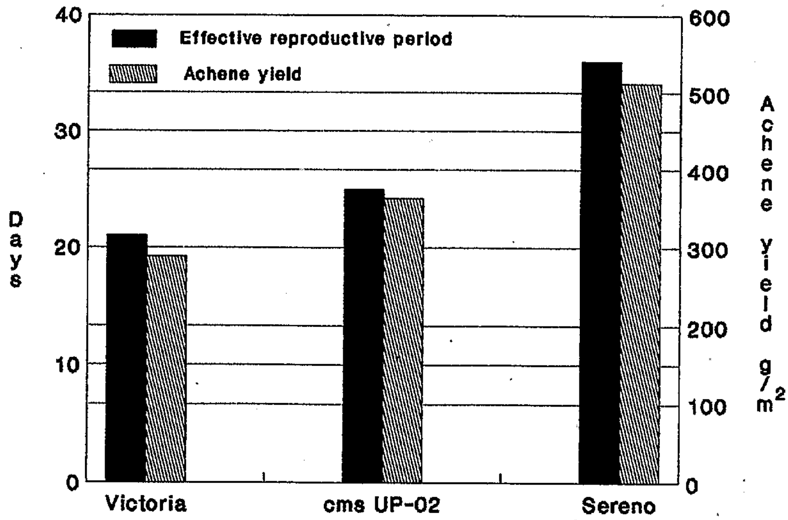

Figure 1. Relation between effective reproductive period and achene yield in sunflower under water stress during reproductive phase. INIFAP. Durango, Mexico. 1990.

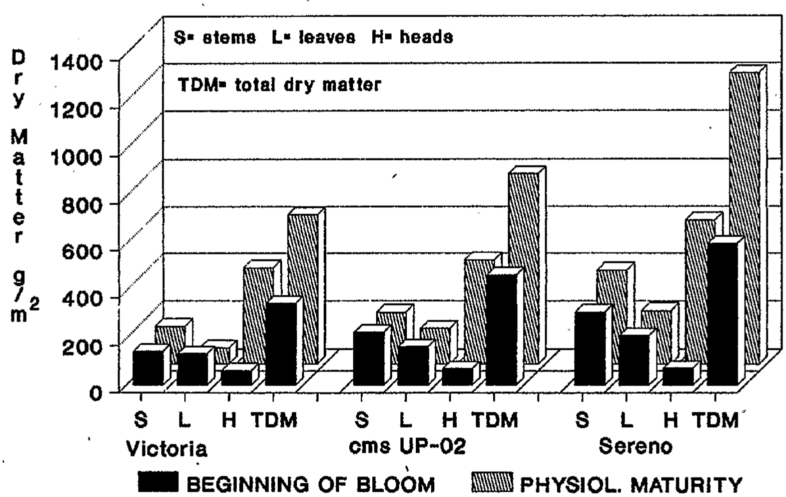

Figure 2. Dry matter of stems, leaves, heads and total dry matter at the beginning of bloom and physiological maturity in sunflower under water stress. INIFAP Dgo. Mexico. 1990.

Third factor is represented by reproductive index (V5). This factor emphasize the importance to increase the reproductive phase of the plant and decrese at the same time its vegetative phase, but without increase its total biological cycle. This kind of plant will require also a capacity of produce, in less time a greater quantity of dry matter at the beginning of bloom, mainly constituted by stem weight.

Fourth factor indicates the importance to identify plants with high growing vegetative and reproductive rate (V18) in order to increase yield under water conditions.

CONCLUSIONS

Plants better adapted to water stress conditions during reproductive phase, can be developed considering the following characteristics: medium and long season genotypes, effective reproductive period, total dry matter weight at the beginning of bloom, dry weight of stems at the beginning of bloom, total dry matter weight at physiological maturity, harvest index, plant growing rate during reproductive stage and head growing rate.

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