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DEVELOPMENT OF DROUGHT TOLERANT SUNFLOWER FOR SEMIARID TRACTS OF INDIA: DURATION OF GENOTYPES INFLUENCE THEIR PERFORMANCE UNDER IMPOSED MOISTURE STRESS

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SUMMARY

Sunflower is rapidly becoming an important oilseed crop in India with major area under rainfed conditions. Increasing emphasis is being laid to develop genotypes resistant to intermittent moisture stress. This study reports results of a field screening at two growth stages of 24 sunflower genotypes for performance under imposed moisture stress. Late genotypes, on average, performed better than early types. This was due to their intrinsically higher recovery growth rates on alleviation of moisture stress. Pot culture experiments on contrasting genotypes indicated that the rate of leaf area recovery on alleviation of stress formed an important parameter in determining the resistance to moisture stress. We dicuss the strategies for improving sunflower productivity under rainfed conditions in peninsular India.

Key words: Sunflower, drought, leaf area recovery, duration influence, genotypic variation

INTRODUCTION

The area under sunflower cultivation in India has been steadily increasing since its introduction (anonymous, 1989). However much of this area is under rainfed condition where the crops are generally subjected to intermittent moisture stress due to highly variable precipitation patterns. The effect of such intermittent moisture stress on crop growth ranges from inadequate biomass accumulation to poor seed development (Rawson and Turner, 1982a, 1983; Yeggappan et al., 1980, 1982; Ravishankar et al., 1990), depending upon the growth stage at which the dry spells occur. As a part of an All India Co–ordinated Programme to identify drought tolerant germplasm lines of sunflower, we examined the effect of imposed moisture stress at early and late vegetative stages on the growth and yield od twenty–four sunflower genotypes. In this paper, we show that the growth and yield performance of genotypes under moisture stress is strongly associated with their duration and that within a duration group, there exists intrinsic differences among the genotypes in the performance. We also show that the field evaluation of genotypes is correlated with their performance under severe moisture stress in pot culture studies. We discuss these results in the context of sunflower improvement programmes for the semi–arid tropics of peninsular India.

MATERIAL AND METHODS

Twenty–four sunflower genotypes obtained from the Project Coordinating Unit (Sunflower), Bangalore were subjected to the following treatments: a) control (where plants were irrigated at weekly intervals throughout their growth period), b) eargly stress (where irrigation was withdrawn 41 to 71 days after sowing (DAS)) and c) late stress (where irrigation was withdrawn 58 to 93 DAS) in a split plot design with two replications during January–May 1989 at GKVK farm, University of Agricultural Sciences, Bangalore, India. There was no precipitation during the period of stress.

Plant characteristics: The data on the days taken to 50% flowering (DFF), seed yield (g)/plant, 100 seed weight (test weight), leaf area (cm^2/plant) and total dry matter (TDM)/plant at harvest were recorded on five randomly selected plants of each genotype in each replication.

Drought susceptability index *(DSI)* DSI is a reflection of intrinsic ability of genotype to withstand moisture stress. The DSI was calculated for each genotype following Fischer and Maurer (1978) considering TDM and seed yield

$$DSI = (1 - Ys/Yc)/D$$

where
Ys = TDM or seed yield under moisture stress condition
Yc – TDM or seed yield under control condition
D = mean reduction in TDM or seed yield under moisture stress over all the genotypes. This is also referred to as drought intensity.

Leaf area recovery on alleviation of moisture stress

On 5 pre–labelled plants of each genotype per replication leaf area was measured at the end of early stress. Fifteen days after alleviation, the leaf area of these plants were again recorded and the per cent recovery in leaf area was calculated as

$$\frac{\textit{leaf area on alleviation} - \textit{leaf area at end of stress}}{\textit{leaf area at end of stress}} \times 100$$

Effect of duration of genotypes on their performance under moisture stress

The duration (in terms of days taken to 50 per cent flowering) of genotypes in the study ranged from 55 to 75 days (see Table 1). To examine if the relative performance of genotypes were related to their duration, we conducted simple correlation analysis of DFF with seed yield and TDM under control, early and late stress conditions separately following Snedecor and Cochran (1967).

Table 1. Classification of genotypes into duration classes based on days taken to 50 per cent flowering (DFF) under control condition

Duration class	DFF	N	Genotype (Sl.No.)
I	55–60	4	5,17,22,21
II	61–65	12	1,2,3,6,7,9,10,15,16,18,23,24
III	66–70	4	8,11,19,20
IV	71–75	4	4,12,13,14

Standardized normal distribution of 12 genotypes belonging to 61–65 DFF

The DSI values for TDM and seed yield for the 12 genotypes of 61–65 DFF category was normalized and the Z scores obtained as follows:

$$Z = \frac{X_i - X}{\sigma}$$

where

X = mean over all genotypes

X_i = value of ith genotype

σ = standard deviation

Based on the Z scores of the genotypes the standardized normal distribution was plotted.

Table 2. Drought susceptibility index of the genotypes based on filled seed wight and TDM under early and late stress conditions

Genotype sl.no.	Genotype/Acc. no.	Drought susceptibility index			
		Seed yield		TDM	
		Early stress	Late stress	Early stess	Late stress
1	BSH–1	1.22	1.21	1.06	0.99
2	66	1.23	1.38	1.17	1.51
3	88	1.00	1.03	1.09	0.84
4	179	0.93	1.114	1.12	1.06
5	217	1.04	0.21	0.94	0.26
6	226	0.98	1.20	1.08	1.21
7	266	1.34	1.24	1.31	1.21
8	275	0.42	0.000	0.88	0.74
9	314	1.38	1.69	1.39	1.74
10	333	1.63	1.67	1.27	0.90
11	418	1.22	1.43	1.21	0.90
12	430	0.75	0.67	0.97	0.44
13	436	0.48	1.13	0.45	1.19
14	438	0.44	0.90	0.83	0.28
15	KBBSH–1	1.19	1.75	0.95	1.00
16	872	1.27	1.50	1.33	1.24
17	154	0.65	1.07	0.79	1.37
18	37	1.37	1.12	1.29	1.26
19	EC–68415	0.68	0.35	0.97	1.24
20	MFSH–8	0.89	1.25	0.80	1.34
21	MORDEN	1.35	0.94	0.85	0.70
22	MFSH–17	0.77	0.86	0.68	0.37
23	EC–68414	0.72	0.30	0.71	0.38
24	188	1.02	1.76	0.83	1.16
	Drought intensity	0.53	0.42	0.56	0.34

Comparison of field performance of a contrasting pair of genotypes with that under imposed moisture stress in pot culture

Based on the standardized normal distribution under both early and late stress, two contrasting genotypes namely, EC 68414 and Acc. no. 314 were identified as tolerant and susceptable, respectively. These two genotypes were sown in the same pot (two plants/pot) and moisture stress was imposed 21 DAS by progressively reducing the amount of water applied. Data on leaf elongation for the first six leaves from the top was recorded on alternate days from the day of commencement of stress. On the 11th day after stress imposition, the pots were rewatered to field capacity and the recovery in leaf area recorded after 10 days.

RESULTS

Moisture stress at early and late stages of crop growth significantly reduced the seed yield and TDM. The DSI calculated on the basis of seed yield and TDM showed considerable variation among genotypes (Table 2). For instance, the DSI values based on TDM ranged from 0.69 to 1.39 under early stress and from 0.37 to 1.74 under late stress. Similarly, the DSI based on seed yield ranged from 0.42 to 1.37 under early and

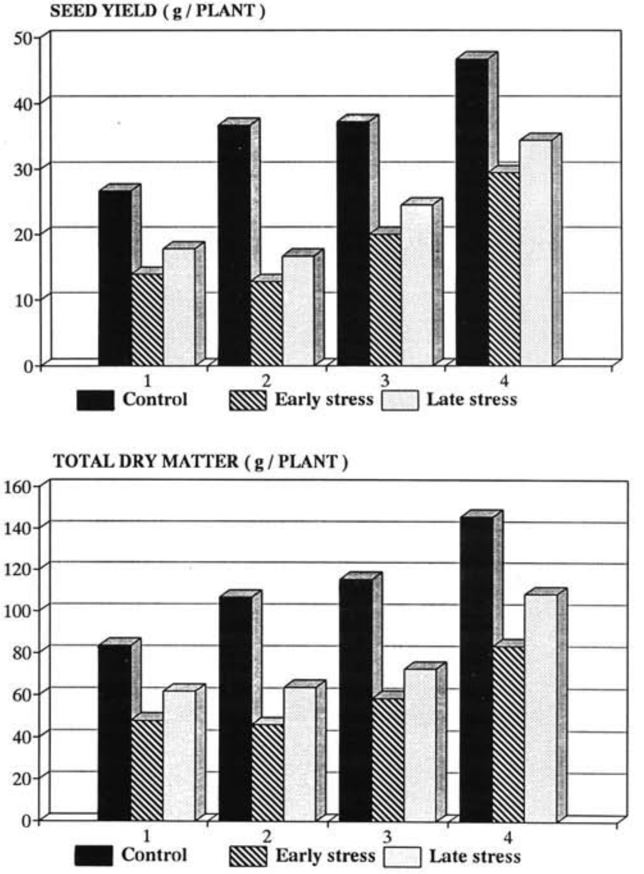

Fig. 1. Duration wise mean of seed yield (g/plant) and total dry matter (g/plant) under control, early and late stress conditions.

0.00 to 1.75 under late stress. The drought intensity based on TDM and seed yield was higher (0.56 and 0.53, respectively) under early compared with that under late stress (0.34 and 0.42, respectively). The DSI values of genotypes calculated on the basis of both TDM and seed yield was negatively correlated with the duration of genotypes under both early and late stress (Table 3). The absolute performance of genotypes with respect to TDM and seed yield under both early and late stress was significantly and positively correlated with their duration (Table 4). The mean TDM and seed yield increased with duration of genotypes under control, early and late stress (Figure 1).

Table 3. Correlation between DFF and DSI values (based on seed yield) under early and late stress conditions

Early stress	Late stress
–0.481*	–0.307

Table 4. Correlation of DFF with seed yield and TDM under control,early and late stress conditions

Treatment	Seed yield	TDM
Control	0.441**	0.676**
Early stress	0.297*	0.348*
Late stress	0.517**	0.546**

* – Significant at P (<0.05)
** – Significant at P (<0.01)

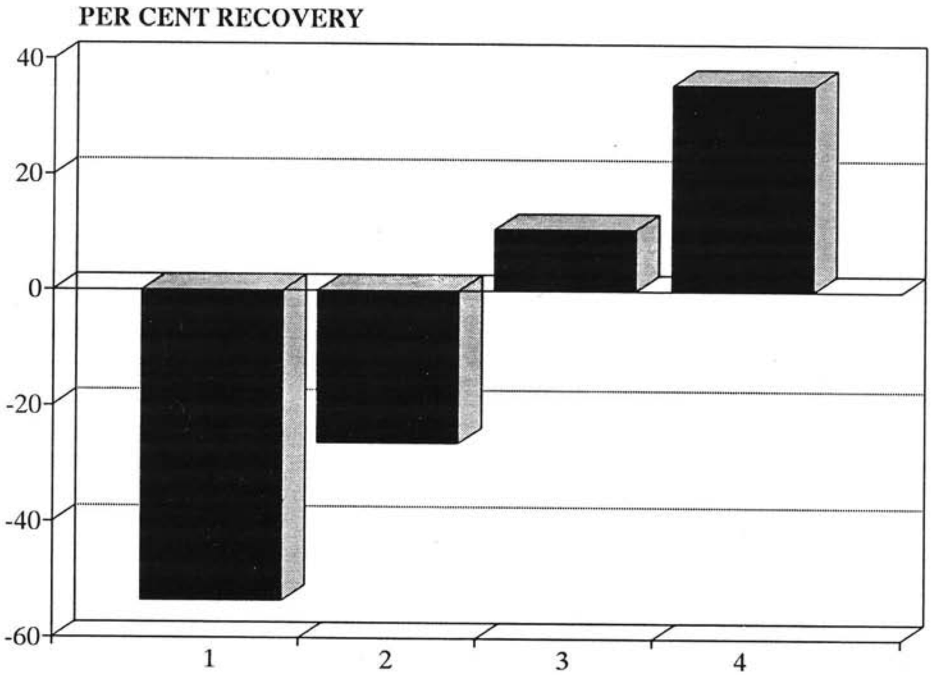

Fig. 2. Recovery in leaf area (%) over 71 days (day of alleviation) under early stress

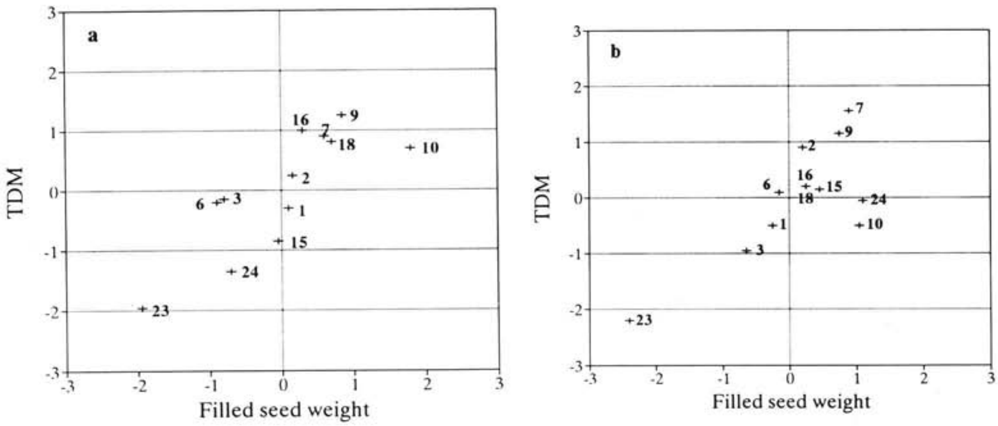

Fig. 3. Standardized normal distribution of genotypes belonging to II duration group under a) early stress and b) late stress considering drought susceptability index for filled seed weight and TDM

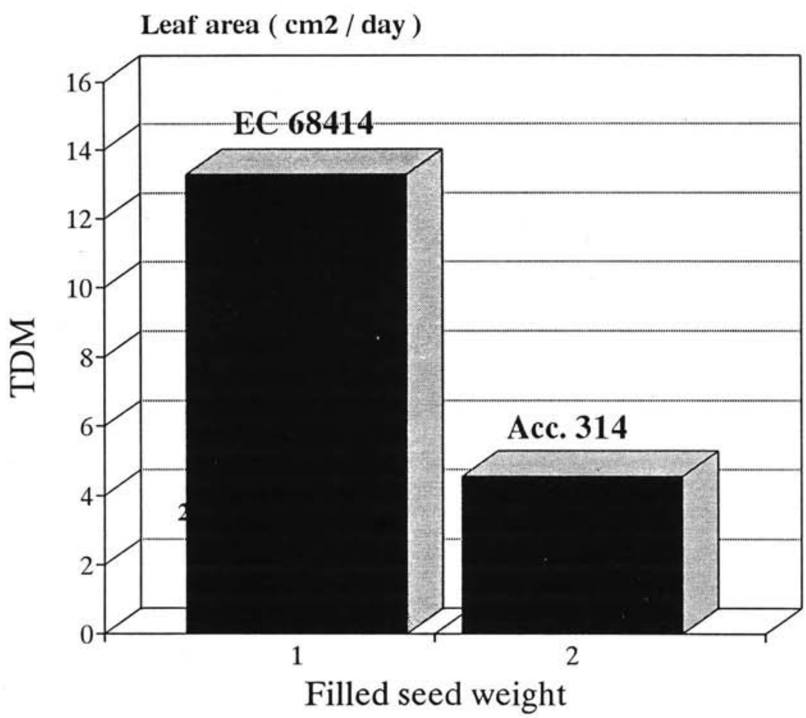

Fig. 4. Leaf growth rate of the first seven leaves from top during the alleviation period (during recovery from stress)

The extent of recovery of leaf area on alleviation of moisture stress was significantly different among the genotypes belonging to the various duration groups (Figure 2). Early genotypes (55–60 and 61–65 DFF) did not show any recovery; in contrast, there was nearly 10.6% and 34.8% recovery of leaf area growth in the genotypes of 66–70 and 71–75 DFF duration category, respectively.

Based on the standardized normal distribution plot, genotypes were found to predominantly occupy the I and III quadant. The gentypes in the I quadrant are characterized by high DSI for both TDM and seed yield while those in the III quadrant by low DSI for both TDM and seed yield. In other words, genotypes in the I quadrant may be considered as relatively drought susceptible while those in the III quadrant as tolerant (Figure 3).

To confirm the categorisation of genotypes as relatively susceptaible or tolerant by such standardized normal distribution plots, a contrasting pair, namely acc no. 314 (susceptible) and EC–68414 (tolerant) were selected and evaluated for their performance under imposed moisture stress in pots. The recovery in leaf growth rate after alleviation of moisture stress was significantly higher in the tolerant genotype EC–68414 compared with the susceptible acc no. 314. This pattern was consistent over two independent sets of experiments (Figure 4).

DISCUSSION

Our results showed that moisture stress at early and late crop growth stages significantly reduced the total plant dry matter and seed yield. The effect of early stress was especially pronounced and is reflected by the higher values of drought intensity (Table 2). Indeed few workers have reported that early stress in sunflower results in substantial reduction of leaf area development, dry matter accumulation (Rawson and Turner, 1982a, 1982b; Talha and Osman, 1975) and inhibition of inflorescence primordia development (Yeggapan et al., 1980).

However, the extent of reduction in the two parameters was found to be highly duration dependent as evident from the negative correlation of DSI with DFF and the significant positive correlation of DFF with seed yield and TDM (Tables 3&4). Earlier workers have recognized the role of mid to late varieties in obtaining higher productivity under moisture stress condition (Rawson and Turner, 1982a, 1983; Giminez and Fereres, 1986; Shehagiri Rao, 1989; Ravishankar, 1990). They argued that such is possible, simply due to features associated with greater duration and not due to differences in the genetic potential of the genotypes. Giminez and Fereres (1986) also showed that late maturing cultivars of sunflower performed better than early because of their ability to use soil moisture from greater depths.

An important parameter governing the TDM and seed yield under moisture stress is the rate and extent of leaf area recovery on alleviation of moisture stress (Rawson and Turner, 1982a, 1983) showed that seed yield, in sunflower is highly related to the maximum leaf area. According to them, better recovery of leaf area in long duration genotypes could be facilitated by virtue of them having a larger number of young leaves and primordia at the time of cessation of stress. In our study, the leaf area recovery on alleviation of early moisture stress was significantly related to the duration. Early duration genotypes (<65 DFF) did not show any recovery.

Turner and Begg (1981) suggested that earliness is advantageous in small grain cereals under dryland conditions. However, studies of Rawson and Turner (1982a; 1983) and Giminez and Ferers (1986) showed that early duration genotypes are disadvantageous under rainfed conditions. Results of our study also support the above contention.

It is likely, however, that intrinsic genotypic variation does exist for performance under moisture stress within a duration category. The standardized normal distribution plot of genotypes belonging to 61–65 DFF category based on the DSI values of TDM and seed yield in fact showed that there are distinct groups of genotypes (either poor or good performers). We examined if a contrasting pair of genotypes, each from the I (poor seed yield and TDM) and III (good seed yield and TDM) quadrant do in fact show differences in their intrinsic leaf recovery growth rate. EC–68414, belonging to quadrant III had a significantly higher rate of recovery than acc. no 314 of quadrant I. Thus, our results show that marked differences exist in genotypes belonging to the same duration group with respect to recovery growth after alleviation of moisture stress.

Since the positive relationship between maximum leaf area and seed yield are valid under intermittent moisture stress conditions (Rawson and Turner, 1982a, 1983) and the lack or little genotypic variations in physiological responses to water relations and osmotic adjustment (Connor, 1985; Giminez and Fereres, 1986) among genotypes, we propose that recovery in leaf growth after alleviation of stress might form one of the important characters for screening genotypes belonging to same duration group under rainfed conditions.

We conclude that a two – pronged strategy be adopted to counter the effect of intermittent moisture stres prevalant in the large sunflower tracts of peninsular India. First, mid to late duration genotypes should be preferred over early types and second, that within a duration category, screening for intrinsic drought tolerance based on leaf area recovery growth on alleviation of moisture stress be conducted.

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DESARROLLO DE GIRASOL TOLERANTE A SEQUIA PARA REGIONES SEMIARIDAS DE INDIA, INFLUENCIA DE LA LONGITUD DE CICLO DE LOS GENOTIPOS EN SU COMPORTAMIENTO BAJO ESTRES HIDRICO

RESUMEN

El girasol está llegando a ser en cultivo oleaginoso importante en India con la mayor parte de la superficie bajo condiciones secas bajo un incremento del estrés hídrico intermitente. Este estudio reporta los resultados de una evaluación en campo en dos estados de crecimiento de 24 genotipos de girasol para su comportamiento bajo estrés hídrico provocado. Los genotipos de ciclo largo, como media, se comportaron mejor que los tipos precoces. Esto fué debido a su mas alta tasa de recuperación del crecimiento cuando el estrés hídrico fué disminuido. Experimentos en macetas con genotipos opustos indicaron que la tasa de recuperación del área foliar con la disminución del estrés constituyó un parámetro importante en la determinación de la resistencia al estrés hídrico. Se discuten las estrategias para mejorar la productividad del girasol bajo condiciones secas en la India peninsular.

DÉVELOPPEMNT DE TOURNESOLS TOLÉRANTS POUR LES ZONES SEMI-ARIDES EN INDE: LA DURÉE DE VÉGÉTATION INFLUENCE LEUR COMPORTEMENT FACE À DES STRESS HYDRIQUES CONTROLÉS.

RÉSUMÉ:

Le tournesol est rapidement devenu un culture oléagineuse importante en Inde avec un aire de développement essentiellement située dans les régions pluvieuses.L'intérêt croissant de cette culture a conduit au développement d'hybrides résistants à des stress hydriques intermittents. Cette étude présente les résultats d'un screening en champ de 24 génotypes pour leur comportement face à des stress hydriques imposés au cours de deux stades de croissance. En moyenne, les génotypes tardifs se comportent mieux que les génotypes précoces. Cela s'expliquerait par leurs taux de recouvrement de croissance intrinséquement plus élevé au cours des périodes de chocs hydriques moindre. Les expérimentations conduites en pots montrent que le taux de recouvrement de la surface foliaire au cours des période de moindre stress constitue un paramétre important pour la détermination de la résistance aux stress hydriques. Nous discutons également les statégies relatives à l'amélioration de la productivité du tournesol dans les conditions pluviométriques de la péninsule indienne.