THE EFFECT OF SOIL WATER CONTENT ON SUNFLOWER SEEDLINGS

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ABSTRACT

The experiments were conducted in growth chamber. Two Romanian sunflower hybrids, Select and Ro 2112, were grown in PVC tubes filled with a peat-sand mixture (1:1). Two watering regimes for each genotype were used: control variant in which plants were maintained during the whole experimental period at 30% soil water content (C) and stress treatment without watering. Decreasing of photosynthesis rate, leaf area, root length and area, stomatal conductance, transpiration rate, chlorophyll content and dry matter accumulation showed important metabolism disturbances of sunflower plants grown under severe drought stress (D), but no significant differences were registered between the two hybrids under study. The possibility of using certain physiological traits as screening criteria in drought breeding sunflower programmes is discussed.

Key words: limited water supply, photosynthesis, root, stomatal conductance, sunflower.

INTRODUCTION

Water stress is a major factor accounting for high yield variability although it varies according to the season in which drought occurs and its duration. Drought tolerance has been defined by Blum (1998) as yield performance stability accros environments differing in their water status.

Sunflower is a well preadapted to drought crop, essentially because of the powerful water uptake due to its efficient root system (Belhassen, 1995). Although rooting is known to be important in drought tolerance, there have been rather few attempts to include root attributes in a screening programme comparable to that for durum wheat carried out by Monneveux (1992).

Previous reports underlined the high genetic diversity of hibrid sunflower roots and the influence of soil environmental conditions on the rooting system (Þerbea et al., 1994; Petcu et al., 1997; Agüera et al., 1997).

The present paper reports the reactions of two sunflower genotypes, one tolerant and the other susceptible to drought, to a reduced water supply. The goal was to identify morpho-physiological traits that could be used as screening criteria in a breeding programme for drought tolerance and that could be rapidly measured using plants grown in a controlled environment.

MATERIALS AND METHODS

Seeds of two sunflower hybrids, Select and Ro 2112, were germinated and then planted at a depth of 10 mm in PVC tubes (36 cm long and 90 cm diameter) filled with a peat-sand mixture (1:1).

Each genotype was tested in ten replicates and water content was kept at 30% (W/W) until the plants became established. The growth chamber conditions consisted of a 16 hours photoperiod, photon flux density of 250 μMol $m^{-2}s^{-1}$ and a day and night temperature of 27° C and 18° C respectively.

After three days, watering was stopped for half of the plants (D), while the controls were watered daily in order to maintain the water content at 30% (W/W) (C). For reducing evaporation from the control tubes, the soil surface was loosely covered with plastic sheeting. The soil water content was estimated by daily weighing of the experimental tubes. A mild and increasing stress was created in the limited water supply treatment (D).

Eleven days from the treatment outset, it became evident that the stressed plants had grown less quickly than the control ones. Light saturated net photosynthetic rate A (max) and stomatal conductance (gws) were measured by a LI-COR 6400 portable photosynthesis system (LI-COR, Lincoln, Nebraska). The chlorophyll concentration was assessed using a SPAD-502 chlorophyll meter (Minolta, Japan). After these physiological measurements had been made, the seedlings were harvested and the rooting medium was washed out from the roots. The leaf area (LA) and total projected seedling root area (RA) were measured using a LI-COR area meter model 3100 and Delta T area meter (Delta-T Devices, Cambridge) respectively.

Leaf area ratio was calculated as the ratio of total leaf area to total plant weight.

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The root volume was measured by water displacement from a filled beaker.

The biomass of the above and below-ground parts was measured after drying them to the constant weight. The root surface area was estimated by multiplying the projected root area by T. Water efficiency was estimated as the water demand per mg of dry matter.

The data were assessed using a two-way analysis of variance.

RESULTS

Soil water content. In water stressed sunflower tubes, after eleven days of testing, the soil water content decreased to 14.5% at Select hybrid and to 14.2% at Ro 2112 hybrid (Table 1).

Photosynthesis and stomatal conductance. The drought treatment significantly reduced photosynthesis and stomatal conductance in Ro 2112 hybrid. In Select hybrid, known as more drought tolerant than Ro 2112, stomatal conductance was higher in stressed plants as compared with control ones (Table 2).

Chlorophyll concentration increased in response to drought in both sunflower hybrids, but more in Select as compared with Ro 2112 (Table 3).

Table 1. Soil water content evolution (%) during the experimental period in droughted sunflower pots

Genotype	Sampling time					
	4 March	5 March	6 March	9 March	10 March	11 March
Select	25.9	24.7	18.9	17.3	16.7	14.5
Ro 2112	26.1	25.0	19.2	16.8	15.5	14.2

Table 2. Net photosynthetic rate (Ph.r.) and stomatal conductance (gws) in control (C) and limited water supply (D) sunflower seedlings

Genotype	Variant	Net photosynthetic rate (Ph.r.)		Stomatal conductance (gws)	
		$\mu MCOm^2/sec$	D - C	$MH_2O\ m^{-2}sec^{-1}$	D - C
Select	C	11.7	-5.0	0.75	-0.5^{OO}
	D	6.7		0.12^{OOO}	
Ro 2112	C	19.1*	-8.1^{O}	1.26	+0.18
	D	11.1		0.30^{OO}	
Mean		12.14		0.607	
LSD 5%		4.89	6.9	0.163	0.23

Table 3. The effect of water shortage on leaf chlorophyll content in control (C) and droughted plants (D)

Hybrids	Chlorophyll content (SPAD Units)	
	C	D
Select	33.4	43.8
Ro 2112	40.6	44.5
LSD 5%	10.4	10.5

Table 4. The effect of water shortage on shoot dry weight (DW), leaf area (LA), water content (θ) and water efficiency (QE)

Hybrids	DW		LA (cm^2/pl)		θ		QE	
	C	D	C	D	C	D	C	D
Select	1.06	0.80	22.2	13.2	0.940	0.950	427.7	280.3
Ro 2112	1.19	0.70	24.8	11.1	0.960	0.943	466.7	242.7
LSD 5%	0.46	0.31	1.24	6.02	0.001	0.008	115.8	89.5

Table 5. The effect of water shortage on root morphology

Hybrids	Rooting depth (m)		Root volume(cm^3)		Root length(m)		Root radius (mm)	
	C	D	C	D	C	D	C	D
Select	0.59	0.60	7.0	4.1	55.1	193.5	0.034	0.008
Ro 2112	0.55	0.54	8.1	3.0	11.1	92.6	0.056	0.005
LSD 5%	0.018	0.059	1.64	2.17	134.2	145.7	0.027	0.047

Root and shoot size. Leaf area was significantly reduced in both sunflower genotypes grown under drought (Table 4). The leaf water content of the stressed plants was significantly lower in sunflower hybrid Ro 2112. The limited water supply increased root volume, root length and total root area of the drought tolerant sunflower hybrid Select (Table 5). Also, deep rooting was practically the same in control plants and in plants grown under LWS in both hybrids, while the root volume was reduced under LWS with 40% in Select and 62.5% in Ro 2112. The main cause of the reduced volume was the reduction of the root diameter (Table 5).

In both sunflower hybrids, the effect of drought treatment consisted in significant decreases of root and shoot dry weight, less in the more drought tolerant hybrid Select and more in the less tolerant hybrid Ro 2112 (Table 6).

Water efficiency of control plants was different in both hybrids. Select consumed 427 ml water for one mg dry weight and Ro 2112, 466 ml. The water demand per one mg of dry weight in drought stressed plants was 280 ml for Select and 242 for Ro 2112 (Table 6).

DISCUSSIONS

The decrease of soil water supply between 30 and 14% during the experimental period underlined important differences between these two hybrids concerning water consumption and water efficiency.

As Tardieu (1996) sunflower is a plant with anisohydric behaviour and leaf water potential is not maintained, so appears to be in good correlation with stomatal conductance in spite of the absence of controlling effect.

Roots have an essential role in drought perception through the emission of a chemical message which circulates to shoots via xylem (Tardieu, 1996). This message contributes to the control of stomatal aperture, leaf expansion rate, etc. During water deficit, CO_2 concentration in chloroplasts decreases in the susceptible genotype Ro 2112, because of the reduced stomatal conductance. As a result, an appreciable fraction of high energy intercepted by photo systems is not used by photochemistry, thereby causing a reduced electron use by the normal photosynthesis process.

The results obtained by Pancovic et al. (1997) showed that photosynthesis decrease of sunflower leaves, caused by decreased stomatal conductance, is associated with decreased carboxylation and RuBP and Pi regeneration. At the same time, the content of Rubisco protein and total soluble proteins increased and these modifications were higher in the leaves of drought tolerant sunflower hybrid, which suggested that they constitute a component of the adaptation mechanism to water deficit.

Huck et al. (1970) studied the diurnal changes in the diameter of cotton individual roots and reported that after four days of root water potential decreasing, the root diameter was about 60% of the initial one. The same reaction was found by Faiz (1973) in sunflower (cited by Russel, 1977).

Development of fine root branches has been associated with increasing of water absorbing root surface (Smucker and Aiken, 1992). With this respect, the hybrid Select seems to be higher drought tolerant in comparison with Ro 2112. Differences between seedlings root area and root and shoot dry weight under normal soil moisture and drought are higher in Ro 2112 than in Select, which could be explained also by the high level of photosynthetic activity of this hybrid.

Previous experiments concerning drought tolerance under field and greenhouse conditions displayed a net superiority of Select as com-

Table 6. The effect of water shortage on root area (A), dry weight (DW) water content (θ) and water efficiency (QE)

Hybrids	A (cm^2)		DW (g)		θ		QE	
	C	D	C	D	C	D	C	D
Select	282	300	0.310	0.240	0.943	0.950	427.7	280.3
Ro 2112	300	204	0.320	0.170	0.962	0.943	466.7	242.7
LSD 5%	432	325	0.021	0.101	0.018	0.011	115.8	89.5

pared with Ro 2112 (Petcu et al., 1997). Decreasing soil water content in the seedling pots up to 14.2-14.5%, caused a high soil water deficit level and thus the differences in drought reaction between these two hybrids became smaller. Under severe drought, all metabolism reactions are more or less affected, depending on hybrid tolerance (Passioura, 1996).

CONCLUSIONS

The results reported in this paper underlined the genetic variability of the investigated traits, especially in dryland treatments. Differences in physiological and morphological characteristics related to drought tolerance have been already seen in plant seedling stage, which presents a great interest for large scale screening of sunflower early breeding material.

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