Physiological traits for quantification of drought tolerance in sunflower

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ABSTRACT
Five Romanian sunflower hybrids were grown in the greenhouse under two watering regimes for each genotype: control variant – in which plants were maintained at 70% from TSWC (total soil water capacity)] and *stress treatment* in which sunflower seedlings were irrigated no more than 40% from TSWC. The results showed that water stress induced the decrease of leaf area, shoot size, chlorophyll content and yield. Some differences between the tested sunflower hybrids were recorded.

Key words: biomass – chlorophyll content – drought – leaf area – sunflower.

INTRODUCTION
Drought is probably the most important factor limiting crop yields worldwide, and in Romania, too. Because of its complexity, drought tolerance is probably the most difficult trait to improve through conventional plant breeding. The challenge is even greater for developing drought tolerant cultivars for Romanian environment where the occurrence, timing and severity of drought may fluctuate from year to year.

In Romania, NARDI at Fundulea has devoted considerable effort during the past ten years to improve drought tolerance in wheat, maize and sunflower. Extensive research has been conducted in the area of breeding, agronomy, and most recently, physiology.

The physiology work has focused on morpho-physiological traits induced by drought and associated with drought tolerance of plants, and the elaboration of screening methods for rapidly measuring of drought tolerance using plants in an early stage of vegetation.

Sunflower is a well adapted to drought crop, essentially because of its powerful water uptake due to its efficient root system (Belhassen, 1995).

The present paper reports the responses of five Romanian sunflower genotypes to water stress. The aim was to identify morpho-physiological traits that could be used as screening criteria in a breeding programme for drought tolerance, and which could be rapidly measured using plants in an early stage of vegetation.

MATERIALS AND METHODS
Seeds of five sunflower hybrids: Alex, Favorit, Justin, Romina and Splendor were germinated and then planted at a depth of 3–4 cm in PVC tubes (35 cm long and 11 cm diameter) and in Mitcherlich pots filled with a soil-sand mixture (1:1). The plants were grown in a greenhouse up to the four leaf stage for the experiment from PVC tubes, and up to harvest maturity for another experiment.

In both experiments each genotype was tested in five replicates and two watering regimes: control variant – [in which plants were maintained at 70% from TSWC (total soil water capacity)] and stress treatment (where sunflower seedlings were irrigated no more than 40% from TSWC).

The biomass of the above and below-ground parts was measured after drying them to the constant weight.

The chlorophyll concentration was assessed using a SPAD-502 chlorophyll meter (Minolta, Japan).

Leaf area was calculated with the formula: L x l x 0.66 where: L = leaf length; l = leaf width and 0.66 = correction coefficient for sunflower. The root volume was measured by water displacement from a filled beaker.

RESULTS AND DISCUSSION
Under water stress conditions the reduction in leaf area and height of plants was recorded. Leaf area was insignificantly reduced in sunflower seedlings grown for one week under drought conditions (from 0.4% for Romina up to 15% for Justin hybrid) and significantly reduced in all sunflower genotypes grown for two weeks under drought conditions (up to 50%). It is obvious that young plants are a little more sensitive than mature

ones when water stress acts for two weeks (Table 1). This response could be considered as a usual reaction of sunflower plants in order to reduce water use.

In all sunflower hybrids, the effect of drought treatment consisted of a significant decrease in height of plants, less in hybrid Alex and more in hybrid Justin (Table 2).

Table 1. The effect of water stress on leaf area of sunflower seedlings

Hybrids	Relative reduction of leaf area due to water stress (%)			
	Seedlings (stressed one week)	Seedlings (stressed two weeks)	Plants (stressed one week after flowering)	Plants (stressed two weeks after flowering)
Alex	8.5	55.2	23.8	48.0
Favorit	0.8	52.6	24.3	48.7
Justin	15	42.4	24.1	44.7
Romina	0.4	47.8	25.5	30.9
Splendor	4.3	50	24.2	36.3

Table 2. The effect of water stress on shoot size of sunflower seedlings

Hybrids	Variants	Height of plants	
		mm	%
Alex	Control	621	100
	Water stress (2 weeks)	457	73.6
Favorit	Control	641	100
	Water stress (2 weeks)	459	71.6
Justin	Control	600	100
	Water stress (2 weeks)	385	64.2
Romina	Control	659	100
	Water stress (2 weeks)	450	68.3
Splendor	Control	571	100
	Water stress (2 weeks)	413	72.3

The significant positive correlation between leaf area and plant height under water stress condition is obvious (r = 0.953***, Fig. 1).

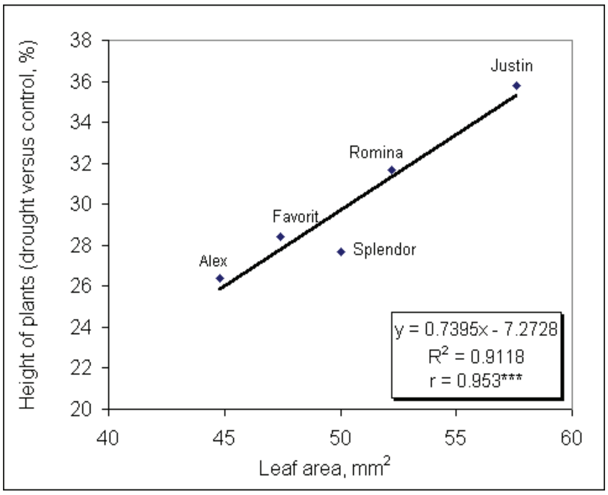

Fig. 1. Relationship between leaf area and height of plants.

The chlorophyll content is considered one of the most important indicators of vegetation stage and its degradation is normally considered a measure of drought resistance (Beard, 1973; Kim et al., 1989). The total chlorophyll content (expressed as SPAD units) was reduced under drought conditions, except for Favorit and Justin which presented the same SPAD units after first water stress period (Fig. 2).

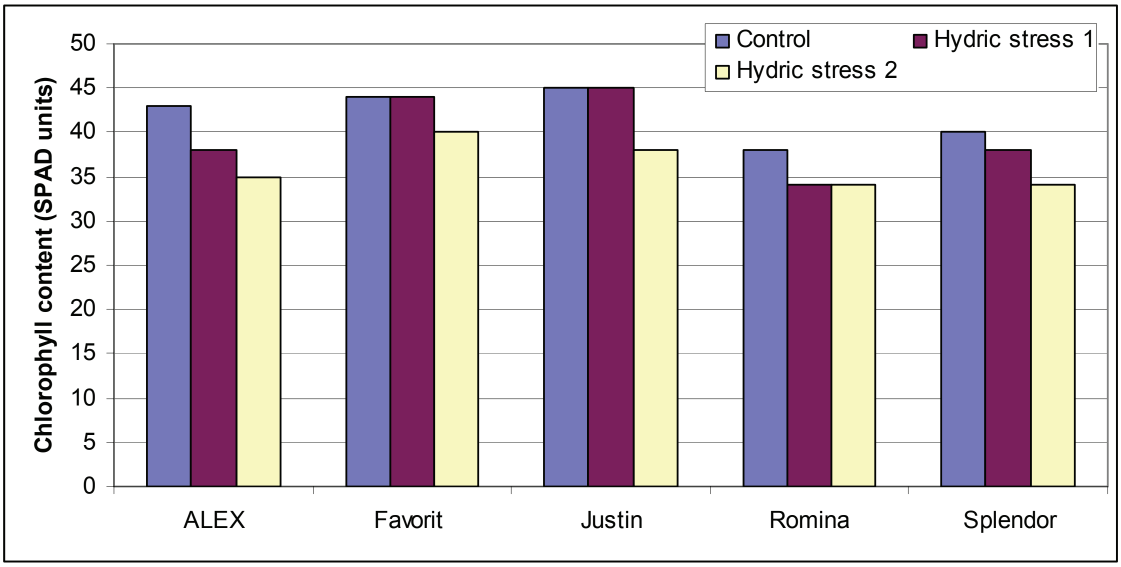

Fig. 2. Effect of water stress on chlorophyll content in sunflower leaves

Dry matter production of shoots, leaves and roots was significantly reduced under water stress conditions for all tested genotypes. Besides the genetic variability of tested sunflower hybrids, differences were recorded between the analyzed organs, too. It is obvious that leaves and shoots were more influenced by water stress than roots.

Thus, dry matter accumulation in roots of Favorit hybrid under drought was higher than under the control. Also, the values of the rest of the tested sunflower hybrids were up to 70%. Under water stress conditions, the root/shoot ratio increased. The increase in the Favorit hybrid was obvious (72%) and from 23 to 45.8% in Romina and Justin, respectively. These results show that the total root mass increases with drought stress (Table 3).

Table 3. The effect of water stress on biomass accumulation in seedling sunflower hybrids

Hybrids	Experimental variants	Biomass accumulation (g dry matter) Leaves		Shoots		Roots		Roots/shoot	
		g	%	g	%	g	%	ratio	%
Alex	Control	2.87	100	4.37	100	2.35	100	0.32	100
	Water stress (2 weeks)	1.48	51.5	1.93	44.1	1.42	60.42	0.42	131.2
Favorit	Control	3.24	100	4.60	100	1.52	100	0.19	100
	Water stress (2 weeks)	1.86	57.4	2.87	62.2	1.58	103.9	0.33	173.6
Justin	Control	2.72	100	4.97	100	1.86	100	0.24	100
	Water stress (2 weeks)	1.70	62.5	2.91	58.5	1.60	86.02	0.35	145.8
Romina	Control	3.22	100	5.29	100	1.83	100	0.22	100
	Water stress (2 weeks)	2.22	68.9	2.5	47.2	1.29	70.49	0.27	123
Splendor	Control	3.12	100	4.88	100	1.87	100	0.23	100
	Water stress (2 weeks)	1.81	58.0	3.51	71.9	1.60	85.56	0.30	130.4

The shoot/root mass ratios consistently decrease under drought stress, which is a universal expression of adaptation (Blum, 1988). The increase in root/shoot ratio is mentioned in literature (Sharp and Davies, 1985; Sharp and Boyer, 1986). Previous reports underlined the genetic diversity of hybrid sunflower roots and the influence of soil environmental conditions on the rooting system (Terbea et al., 1995; Petcu et al., 1997; Agüera et al., 1997).

Our results show that during the first days of water stress the nutritive reserves of sunflower seedlings were conducted towards developing the roots, in order to facilitate deep soil moisture extraction. This happened in detriment of shoot development, and, in this case, a drift occurred in the main sink to survive. Concerning the root/shoot ratio, the response of mature plants to water stress is different from seedling response as the sink is different.

The root/shoot ratio of mature plants decreased under drought stress in Favorit and Splendor but increased in Alex, Justin and Romina hybrid. So, some differences between the tested genotypes in response of drought were noticed (Table 4).

Table 4. The effect of water stress on biomass accumulation in mature sunflower plants.

Hybrids	Experimental variants	Biomass accumulation (g dry matter)						Roots/shoot	
		Shoots		Leaves		Roots			
		g	%	g	%	g	%	ratio	%
Alex	Control	36.8	100	20.4	100	10.8	100	0.19	100
	Water stress (2 weeks)	21.6	58.7	18.6	91.18	9.4	87.1	0.23	123.8
Favorit	Control	36.8	100	38	100	21.2	100	0.28	100
	Water stress (2 weeks)	35.6	96.7	21.4	56.32	6.4	30.1	0.11	39.6
Justin	Control	34.4	100	29.2	100	9.4	100	0.15	100
	Water stress (2 weeks)	17.4	50.5	18	61.64	6.6	70.2	0.19	126.1
Romina	Control	28.8	100	18.8	100	7.6	100	0.16	100
	Water stress (2 weeks)	15.6	54.1	18.2	96.81	7.2	94.7	0.21	133.4
Splendor	Control	29.4	100	31.2	100	22.4	100	0.37	100
	Water stress (2 weeks)	21.4	72.7	23.4	75.00	10.4	46.4	0.23	62.8

It is well known that water stress has a profound effect on sunflower yield (Muriel and Downes, 1974; Talha and Osman, 1975). In our experience, the yield was affected by water stress with the low status treatment yielding 10-13% less than the control (Fig. 3). The highest productive hybrids under drought conditions were Favorit and Justin but Romina presented a high stability in yield level, both when plants were stressed for one week and for two weeks, too.

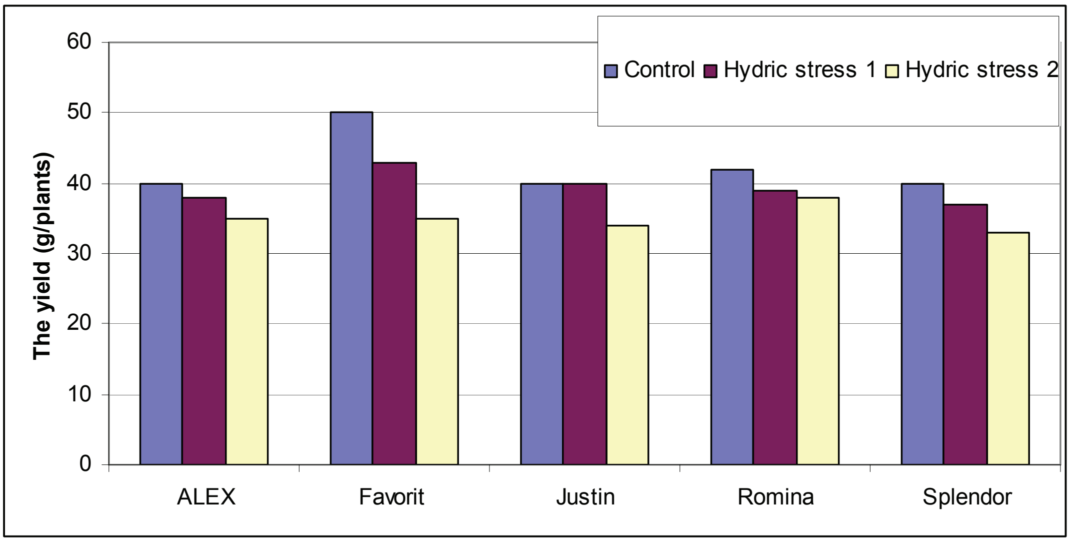

Fig. 3. The effect of water stress on yield of the tested sunflower hybrids

This suggests that although in Justin hybrid most of the nutritive reserve was conducted towards root development, its yield is not influenced.

CONCLUSIONS

The reduction in leaf area, shoot size and biomass accumulation of sunflower seedlings under water stress conditions determined the increase in root/shoot ratio. This suggests that for young plants the main sink was survival. In a late stage of vegetation, the root/shoot ratio decreased under drought stress in some hybrids but increased in other hybrids, this suggesting that for mature plants the main sink was the yield.

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