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CHANGES IN MACRO AND MICRO PLANT NUTRIENTS OF SUNFLOWER (*Helianthus annuus* L.) UNDER DROUGHT STRESS

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Abstract

Determination of the ability to leverage of plants from nutrients found in the soil in irrigation and dry conditions contributes to the work done. The objective of this study was to determine the effect of drought stress on macro and micro plant nutrients of the leaves of three sunflower genotypes (Tarsan, Sanbro and TR-3080) at 30% (drought stress) and 60% (well-watered) irrigation from soil water capacity. Stress treatment where starting with emergence until R1 stage (bud visible) in pods under controlled conditions of greenhouse. Drought stress significantly affected by changing P, K, Mg, Ca, Fe, Zn, Cu, Mn, Na contents of sunflower leaves. The results of our study under conditions of drought stress indicating that there were significantly differences among the all sunflower cultivars in terms of plant nutrients concentrations response to drought stress. Leaf P, Mg and Cu contents tend to decrease in the leaves of all sunflower genotypes under drought stress. Overall, on the basis of percent reduction consistently in accumulation plant nutrients in leaves, Sanbro cv. showed minimum reduction of percentage among the others under drought stress condition. However, differences in macro and micro nutrients used among all sunflower cultivars may also be related to differences in photosynthetic capacity under drought stress condition. It could also be confirmed that measuring macro and micro nutrients of leaves can be used to selection criterion for developing sunflower drought tolerance genotypes.

Key words: *sunflower, drought stress, plant nutrients.*

INTRODUCTION

Drought stress cause low productivity in crop production because of commonly limited mineral supply (Canavar et al., 2014). Micro nutritional disorders are common nutritional imbalance in plants and affect greatly plant performance and their response to surrounding environment (Hajiboland 2012). Many studies have explained that drought stress is caused by limited rainfall during the growing season that affects plants biochemical, molecular, and physiological attributes and influences various cellular and whole plant processes, which significantly reduces crop yield and quality (Andrich et al., 1996; Krizmanic et al., 2003). Therefore, drought resistance and its components are almost constantly being redefined to express the outstanding inventive capacity for terminology. Hu et al. (2007) point outed that under drought stress, nutrient uptake by the roots is reduced, in part because the decline in soil moisture results in a decreased rate of diffusion of nutrients from the soil matrix to the absorbing root surface (Viets, 1972 and Pinkerton and Simpson, 1986). Moreover, nutrient transport from the roots to the shoots is also restricted by the reduced transpiration rates and impaired active transport and membrane permeability, altogether resulting in a reduced root adsorbing power of crop plants (Kramer and Boyer, 1995). Thus, the reduced nutrient availability is one of the most important factors limiting plant growth under drought.

The objective of this study was to investigate the effect of these conditions on the spatial distribution of macro- and micronutrients along the growing leaves of sunflower under drought stress condition.

MATERIALS AND METHODS

Plant material and experiment establishment

The greenhouse experiment was carried out at the research greenhouse of the Crop Science department of the Agriculture and Horticulture Faculty in Humboldt University, Germany in 2012. Tarsan and TR-3080 sunflower genotypes, which were improved by Directorate Trakya Agricultural Research Institute in Turkey and Sanbro sunflower genotype was adapted by Syngenta®, were tested for variation under controlled drought stress and well-watered environmental conditions of approximately light/dark regime 12/12 h, at 25/15 ±3°C and relative humidity 30-50% respectively. The sunflower cultivars were planted in Mitschelin pots (30-cm deep 25 cm dia.) the plant populations were maintained (3 plants in a pot) in the greenhouse with only the natural sunlight of the summer months. Clay loam soil was used to fill pods and the cultivars were arranged completely in a randomized block design with five replications. Required amounts of chemical fertilizers were applied according to the instructions from 1 g nitrogen from 3.70 g KAS fertilizer as the field condition and then the seeds were sown. The soil water factor included two irrigation regimes including irrigation at 30% (water deficit) and 60% (well-watered) of field capacity.

Determination of water holding capacity of soil

To determine the field capacity of soil, the field soil which had already been taken from the field experiment area was air-dried and ground to pass through a 5 mm sieve at room temperature. Water holding capacity was determined using a gravimetric method with five replicates as the amount of moisture (percentage). Firstly the bottoms of 100 cm^3 five cylindrical tubes were covered with paper and a plastic strap for the filter and they were tared without soil and then filled completely with soil (by compression). Each cylindrical tube with soil was weighed and settled in a tray, which was approximately as deep as the height of the cylindrical tube. The tray was fully filled with water up to the top of the cylindrical tube and 3 h were allowed for saturation. Then, all cylindrical tubes were left on the quartz soil for 2 h (for drainage and filtering). After that, all the saturated cylindrical tubes were cleaned and weighed again (wet weight). Then all the tubes were oven-dried at 105 °C 24 h and the weight of the oven-dry soil samples was measured (dry weight). The field capacity of undisturbed soil was calculated according to the following formula;

$$\text{F. C. \%} = \frac{\text{wet soil weight (saturated)} - \text{dry weight}}{\text{dry weight}} * 100$$

Drought stress treatment

To adjust for the amount of watering of the pots in terms of the 30% and 60% irrigation regimes of field capacity, the soil water content was continuously monitored and maintained by watering at 30% and 60% levels of field capacity during the experiment. Changes in the soil water of each pod were measured and checked daily by weighing each pod at the beginning and end of the removed plant. Plants were harvested 50 days after sowing when plants were at the R3 stage (bud visible).

Plant Nutrients analysis

Before the plant nutrients analysis, when all the plants were harvested, 5-6 leaves fully developed leaves were collected from the middle of plant (neither young nor old leaves) for each replicate in all cultivars from both water treatments. All leaves were immediately settled in an ice box for transfer and stored at -20°C. The frozen leaves were directly dried using the method of lyophilization, which is 5 or 10 heated shelves Ø 200 mm, freezing separately, drying outside the ice condenser chamber with CHRIST Lyophilizer GAMMA 1-16 LSC model (London, England) with 5 temperature shelves Ø 200 mm, temperature range -40°C to +50° C.

Dry leaves were ground in a Retsch ball milling machine (Germany) and weighed (0.5 g). The mineral composition (P, K, Ca, Mg, Na, Fe, Zn, Cu, Mn,) of the leaves was digested by dry ashing method (Kacar and İnal, 2008). The digested sample was filtered and used for the determination of nutrients. Phosphorus (P) was analyzed by spectrophotometer (Shimadzu, UV-160A), (Jackson, 1958). K, Na and Ca were determined by flame photometer (Jenway, PFP-7) and Mg, Fe, Zn, Cu and Mn was determined by atomic absorption

spectrophotometer (Varian, 220FS) (Kacar and İnal, 2008). Leaf nutrient concentrations derived from the leaf nutrients analysis, were calculated by leaf dry weight (data were not shown).

The results were analyzed using the TARIST package software (Açıkgöz et al., 1994) to determine the effect of nitrogen and water dosages on the sunflower genotypes.

RESULTS AND DISCUSSIONS

It was determined that drought stress had a statistically significant impact on the all leaf nutrients analyzed in the sunflowers in Table 1 (ANOVA table). Drought stress × genotype interaction was also statistically significant in terms of the all nutrients (Table 1). Table 2 shows that sunflower cultivars response differently to in terms of leaf nutrient contents against the drought stress condition. (Table 2). On the contrary, under drought stress condition leaf Fe and Mn contents of all sunflower genotypes tend to increase. In terms of K, Ca, Na and Zn contents in Sanbro cv. tend to increase, whereas Tarsan tend to decrease. On the other hand, TR-3080 sunflower cv. tends to decrease except Zn under drought stress condition (Table 2).

Table 1. The result of variance analyses for all leaf nutrients measured of three sunflower genotypes under drought and well watered conditions

Variance Source	d.f	Calculated of mean square								
		P	K	Ca	Mg	Na	Fe	Zn	Cu	Mn
G	2	**	**	**	**	**	**	**	**	**
C	1	**	*	**	**	**	**	**	*	**
GxC	2	**	**	**	**	*	**	**	**	**

* P<0.05, ** P<0.01; ns: non-significant, G: Genotype, C: Condition, d.f: degree of freedom.

Table 2. The effect of drought stress on leaf nutrients contents of three sunflower cultivars (mg LDW^{-1})

Cultivars	Conditions	P (mg)	K (mg)	Ca (mg)	Mg (mg)	Na (mg)	Fe (mg)	Zn (mg)	Cu (mg)	Mn (mg)
Sanbro	WW	16.965	142.470	45.290	17.773	0.099	0.400	0.101	0.060	0.103
	DS	15.002	158.576	53.403	14.096	0.199	1.258	0.333	0.057	0.559
Tarsan	WW	22.526	195.920	75.020	25.228	0.570	0.742	0.224	0.072	0.190
	DS	11.999	145.464	46.664	15.354	0.198	0.946	0.219	0.050	0.344
TR-3080	WW	18.183	135.276	48.115	20.436	0.248	0.624	0.164	0.053	0.148
	DS	8.388	80.136	29.770	8.460	0.110	0.795	0.248	0.029	0.364

As compared with the well watered and drought stress condition, under the drought stress condition, the highest P, K, Ca, Na, Fe, Zn, Cu and Mn contents were determined except Mg in Sanbro sunflower cv. The highest Mg content was found in Tarsan sunflower cv. The lowest P, K, Ca, Mg, Na, Fe and Cu contents were found in TR-3080 cv. while the lowest Zn and Mn contents were found Tarsan cv. (Table 2).

It was observed under drought stress condition that percentage of reduction in terms of leaf P, Mg and Cu contents in TR-3080 was higher than that of Sanbro and Tarsan sunflower cv. Sanbro cv. showed minimum reduction of percentage among the others.

It could be considered in our research that induced leaf nutrients such as P, Mg and Cu under drought stress due to the uptake of nutrients usually decreased due to diminishing absorbing power of roots (Dunham and Nye (1976) or hindered the nutrient uptake process (Honda 1971). Especially, Tarsan and TR-3080 sunflower cultivars showed higher decline than Sanbro cv. in terms of many leaf nutrients under drought stress. These findings are corroborated with previous research Nahar and Gretzmacher, (2002), who pointed out that there is a tendency of diminishing concentrations of N, P, K, S, Na, Ca and Mg with increasing water stress by the tomato plants.

In addition to sugars and osmolyte, some plants also accumulate other low or high molecular mass compounds such as K is the main osmotic solute in plants (Fournier et al., 2005). Its accumulation in the cell leads to osmotic water uptake and generates the cell turgor required for growth and stomatal opening (De La Guardia and Benlloch 1980). Therefore, it may be considered that the photosynthesis capacity of Sanbro cv. was higher than that of Tarsan and TR-3080 because of the high K accumulation in leaves of Sanbro cv. under drought stress.

CONCLUSIONS

Since water is essential for plant growth, it is axiomatic that water stress, depending on its severity and duration, will affect plant growth, yield and quality of yield. The osmotic adjustment as accumulation of solutes within the cell helps in maintaining turgor at decreasing water potentials. On the basis of percent reduction consistently in accumulation plant nutrients in leaves, Sanbro cv. showed minimum reduction of percentage among the others under drought stress condition. However, differences in macro and micro nutrients used among all sunflower cultivars may also be related to differences in photosynthetic capacity under drought stress condition. It could also be confirmed that measuring macro and micro nutrients of leaves can be used to selection criterion for developing sunflower drought tolerance genotypes.

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