RESPONSE OF SOME MAIZE INBRED LINES SEEDLINGS TO LIMITED WATER SUPPLY

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ABSTRACT

The aim of this study was to establish the influence of limited water supply on some physiological traits of four maize inbred lines differing in their drought tolerance. The experiments were conducted in grown chamber, maize plants were grown in peat-sand (1:1) mixture in PVC tubs (36 cm long and 9 cm diameter). Limited water supply (LWS) determines in maize tolerant inbred line 1268 H a significant increase of photosynthesis rate, length and lateral root area. Significant decrease of photosynthesis rate, leaf area, root and length area, stomatal conductance, transpiration rate and chlorophyll content showed a high drought sensitivity of B 73 inbred line. The results showed that under normal soil moisture, genetic variability of these parameters was less pronounced in maize, but differences were more pronounced with the decrease of water soil content. The genotype response to soil water content is different.

Key words: limited water supply, maize, photosynthesis rate, root leaf area.

INTRODUCTION

The main reason for the varying yield in South -part of Romania is the variation in the amount of precipitation during the growing season and water deficit relative to plant water requirements. Drought disturbs growth and development of plants and decreases their productivity (Cvetkovic, 1993). Critical progress evaluation in plant breeding over a period of several decades, has demonstrated a genetic yield improvement under both favourable and stress conditions (Blum, 1988).

Breeding for drought resistance through selection and incorporation of physiological or morphological traits to drought resistance have been suggested as an alternative to direct selection for yield in stressed environments (Blum, 1990).

In previous research works, several physiological traits have been proposed as possible selection criteria to improve drought resistance in maize (Þerbea et al., 1994).

Under field conditions, different genotypes can have different responses in respect with the same moisture soil conditions. The reaction of different maize inbred line seedlings to soil water content decrease and the possibility to use some physiological traits as screening criteria in early maize breeding programme will be discussed in this paper.

MATERIALS AND METHODS

Four maize inbred lines were grown in peat-sand mixture (1:1) in PVC tubs (36 cm long and 9 cm diameter). These pots were placed in growth chamber under the following conditions: 16 h of 250 µE $m^{-2}sec^{-1}$, light, day and night temperature of 27°C and 18°C respectively (Figure 1).

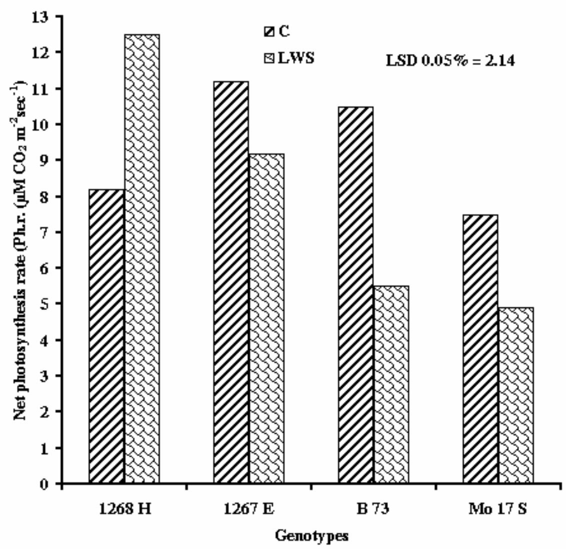

Figure 1. Net photosynthesis rate (ph.r.) in maize seedlings grown under normal (C) and limited water (LWS) conditions

After germination, seeds were planted at 1 cm depth in these tubs, 10 replications per genotype, and soil water content of 30% (W/W). In the following period, two watering regimes for each genotype were used: five replications were watered daily and maintained at 30% soil water content (C, control plants) and five replications have been withheld from watering all experimented period, so that SWC decreases at 20-21.7% (LWS). We intended to create a mild stress by unwatered maize pots.

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In order to reduce soil water evaporation in control pots, soil surface was covered with plastic sheeting.

After 11 days, when symptoms revealed plant water defficity, withholding water net photosynthetic rate (Ph.r) and stomatal conductance (gws) were measured using LI-COR 6400, portable photosynthesis system.

Chlorophyll content expressed in "Spad Units" was measured using a chlorophyll meter SPAD-502, Minolta.

After these physiological measurements have been made, the seedlings were harvested and the rooting medium was washed from the roots. The leaf area (LA) and total projected root area (RA) of the seedlings 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. Root weight to total biomass and the ratio of leaf area to root weight were calculated as an indication of the amount of root needed to support an unit area of transpiring surface. The biomass of the above and below-ground parts was measured after drying to constant weight. The surface area of the roots was estimated by multiplying the projected root area by 3.14. Water efficiency was estimated as the ratio between the number of ml of water needed for producing 1 mg of dry matter. The data were analysed using a two-way ANOVA. The least significantly differences are presented at p = 0.05.

RESULTS

Water loss

The drought treatment was effective in reducing soil water content (Table 1) from 30% (W/W) at the beginning of experiment to 20% at the end.

Table 1. Soil water content evolution (%) during the experimental period in maize grown in pots with limited water supply

Genotype	Sampling time					
	4 March	5 March	6 March	9 March	10 March	11 March
1268 H	26.8	26.2	25.5	22.8	21.4	20.1
1267 E	26.8	26.0	25.3	23.8	22.6	21.4
B 73	26.8	25.8	25.3	23.4	22.3	21.7
Mo 17S	26.8	25.9	25.3	23.1	21.9	21.1

Altought there were no significant differences between the resistant and susceptible genotypes, the rate of water loss from susceptible maize genotypes seemed to be evident by the end of the experiment.

Photosynthesis and stomatal conductance

Figure 1 shows the effect of the drought treatment on the light saturated rate of net photosynthesis (Ph.r.) and stomatal conductance.

The drought treatment did not lead to a reduction in Ph.r. for the two drought resistant lines. Indeed, 1268 H showed a significant increase. On the other hand, the susceptible lines showed a large decrease, although this was only significant in B73. The stomatal conductance results generally follow the same pattern but are less clear. The drought treatment significantly reduced stomatal conductance in susceptible maize inbred line B 73 and increases in genotypes 1268 H and Mo 17H (Figure 2).

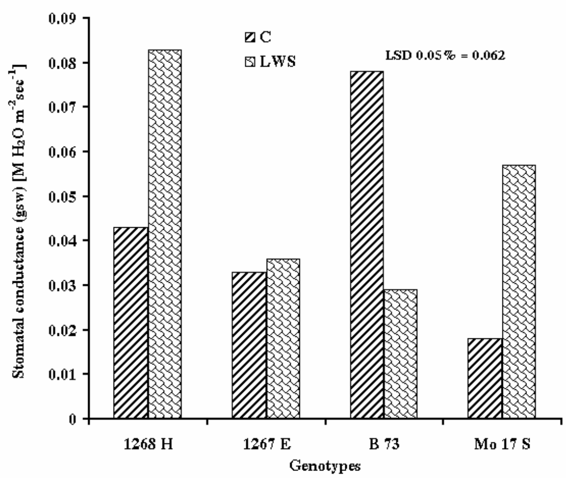

Figure 2. Stomatal conductance (gsw) in maize seedlings grown under normal (C) and limited water supply (LWS) conditions

Chlorophyll concentration

The chlorophyll concentration was significantly reduced under drought in the susceptible maize lines while in the resistant lines this concentration increased (Table 2).

Table 2 . The effect of water shortage on leaf chlorophyll content

Attribute:	Chlorophyll content (SPAD units)	
Treatment:	C	LWS
126S H	39.2	39.8
1267 E	37.0	41.7
B 73	44.0	39.1
Mo l7 H	39.5	37,2

LSD	4.80	4.70
Mean R	38.1	40.8
Mean S	41.8	38.2

There was no consistent relantionship between chlorophyll con centration and Ph.r. In three out of the four maize lines Ph.r. decreased more than proportionally with chlorophyll concentration. An exception was made by 1267 E.

Root and shoot size

Leaf area was significantly reduced in all maize genotypes grown under drought except the maize inbred line 1268 H (Figure 3B). The leaf water content of the stressed plants was significantly lower in all maize inbred lines (Figure 3E). The shoot biomass was not significantly influenced by drought except maize

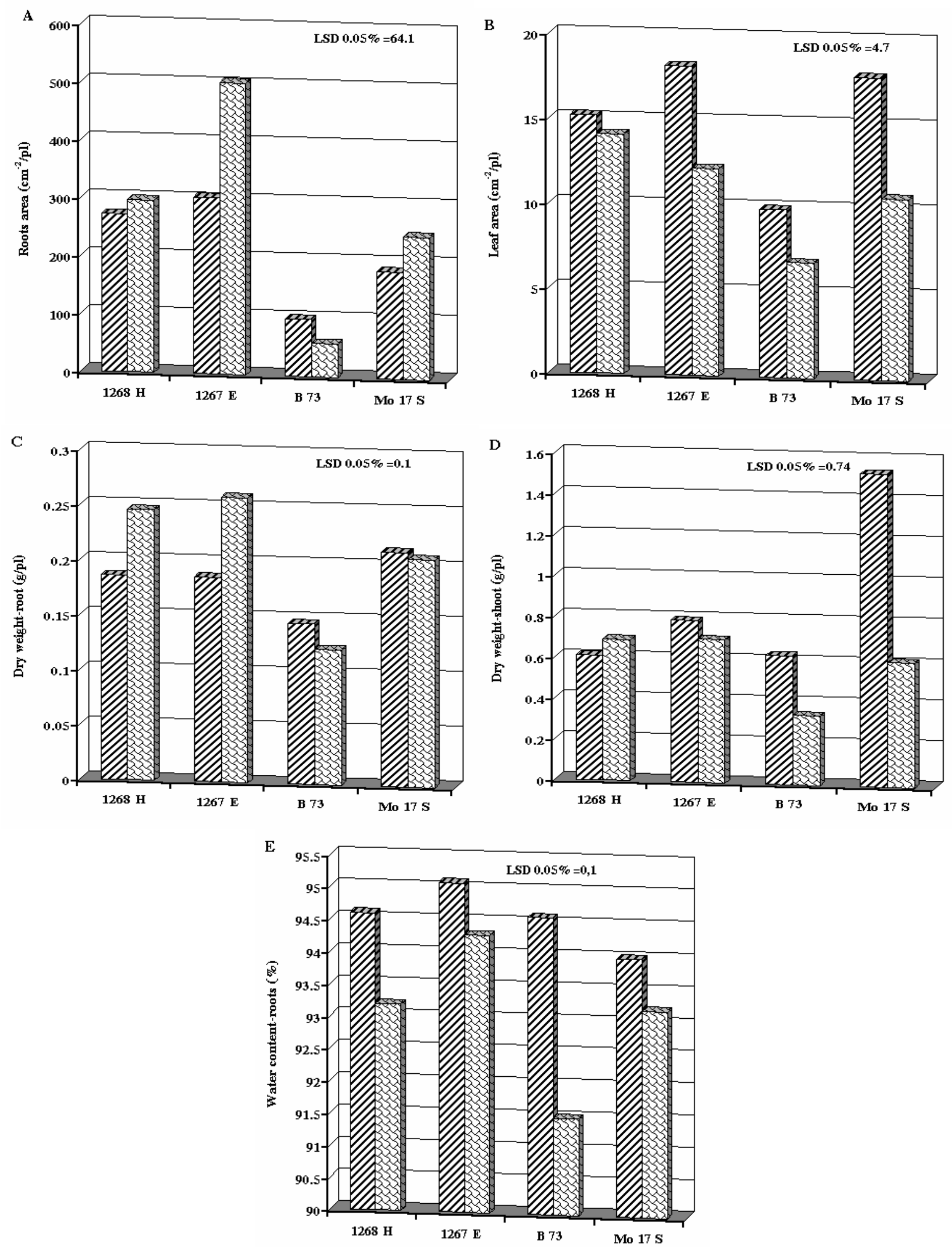

Figure 3. Roots and leaf (A, B), dry matter accumulation (C) and water content (D) in roots and shoots maize seedlings grown under normal (C) and limited water supply (LWS)

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inbred line Mo 17 H (Figure 3D). In the drought resistant inbred lines 1268 H and 1267E, the roots biomass increased under drought, but this was not significant (Figure 3C). Drought treatment increased significantly root area of 1267 E line (Figure 3A).

Derived parameter

Total biomass at the end of the experiment showed no significant response to the drought treatment.

Under drought, total fresh biomass registered a small increase in resistant maize inbred lines and an evident decrease in sensitive ones, even if these modifications were not statistically assured (Table 3). The drought treatment didn't influenced the leaf area ratio in all genotypes. Root weight ratio registered a significant increase only in 1267 E maize line.

Leaf area ratio was not influenced by limited water supply. Usually, the drought treatment determines a less increase of root weight ratio, significantly only in maize inbred line 1267 E and significantly decrease of ratio leaf area/root weight (Table 2).

Only Mo 17 H had a significant more water consumption per dry weight unit (water efficiency). Drought treatment caused a significant decrease of water efficiency in the sensitive inbred line B 73.

Root morphology

Line Mo 17 H was found to have a superficial root system and produced no crown roots in the drought treatment. The drought resistant maize inbred lines 1268 H, 1267 E and the sensitive line Mo 17 H showed an increase of total root area and length in the drought treatment (Table 4). Measurements of root length showed big differences among genotypes.

Limited water supply increased root length in all drought resistant genotypes and reduced it in the sensitive ones.

DISCUSSIONS

Decrease of soil water supply between 30 and 20% during the experimental period determined more pronounced differences in maize genotypes under limited water supply, showing genetic differences concerning water consumption and water efficiency. In the resistant drought maize lines, usually the water efficiency is the same in control and treated plants, while in the sensitive lines water efficiency decreased significantly.

The greater water loss from the stressed maize plants was consistent with the more efficient water consumption associated with the C4 metabolic pathway of maize.

Table 3. The effect of water shortage on derived parameters in maize

Atribute	Total fresh biomass (g)		Leaf area ratio (m^2/kg)		Root weight ratio		Leaf area/root wt (m^2/kg)		Water efficiency QE	
Treatment	C	LWS	C	LWS	C	LWS	C	LWS	C	LWS
1268 H	9.23	10.0	1.41	1.36	0.30	0.27	4.03	3.77	136.7	104.7
1267 E	13.2	14.3	1.36	1.29	0.20	0.29	4.89	3.72	130.0	122.7
B 73	9.8	4.7	1.53	1.63	0.22	0.25	4.95	4.90	115.7	87.0
Mo l7 H	13.7	8.6	1.33	1.25	0.19	0.25	5.27	3.56	152.3	96.3
LSD	2.74	7.0	0.14	0.38	0.039	0.072	1.44	2.04	22.3	21.8
Mean R	112	12.1	1.38	1.32	0.25	0.28	4.46	3.74	133.3	113.7
Mean S	11.7	6.6	1.43	1.44	0.21	0.25	5.11	4.23	134.0	91.6

Table 4. The effect of water shortage on root morphology

Attribute	Rooting depth (m)		Root volume (cm^3)		Root radius (mm)		Root length (m)		Root area (cm^3)	
	C	LWS	C	LWS	C	LWS	C	LWS	C	LWS
1268 H	0.45	0.63^{++}	2.2	3.3	0.030	0.0067	430.7	462.3	272	297
1267 E	0.46	0.57	4.0	3.7	0.093	0.0057	184.3	499.9	304	523
B 73	0.45	0.35°°	2.6	2.0	0.024	0.0400	35.0	16.9	99	58
0.55	0.55	0.56	3.0	2.2	0.040	0.0040	231.7	81.1	185	246
LSD	0.077	0.031	1.25	2.85	0.020	0.0210	151.8	255.3	74	128
Mean R	0.45	0.60	3.1	3.5	0.061	0.0060	307.0	381.1	288	410
Mean S	0.50	0.45	2.8	2.1	0. 032	0.0040	133.3	48.5	142	152

As Tardieu mentioned (1996), maize belongs to the isohydric behaviour which controls stomatal conductance in such a way that plants maintain day-time leaf water status almost constant. In our situation, only the resistant genotypes had no significant modifications of stomatal conductance.

Lateral branches, normally arise in maize on the root ax; these first order laterals can similarly give rise to second order laterals etc. (Russell,1977).

Considerably higher rates of root elongation in excess of 6 cm/d^{-1} have been reported in maize (Blacklow, 1972, cited by Russell, 1997) as depending of soil water supply, temperature, soil mineral nutrition etc. (Terbea et al., 1994).

Roots have an essential role in drought perception, by the emission of a chemical message which travels to shoots via xylem (Tardieu, 1996). This message contributes to the control of stomatal aperture, leaf expansion rate, chlorophyll senescence and probably many other processes. During water deficit, the concentration of $C0_2$ in chloroplast decreases in sensitive genotypes B 73 and Mo l7 H because of decreased stomatal conductance. As a consequence, an appreciable fraction of high energy intercepted by photosystems is not used by photo chemistry, thereby causing a reduced electron use by the normal process of photosynthesis (Lambers et al., 1998).

There is normally a decrease in net photosynthesis in response to water stress (Stankovic and Petrovic, 1991). However, Kristic et al. (1997) found a significant negative correlation in an experiment with only 35% (WIW) of the available soil water. This increased rate of carbon fixation associated with drought resistance was also found by Blum (1990). Venora and Calcagno (1991) found that cultivars which are able to maintain stomata opened during water stress are more stable in terms of yield. This process may have an appreciable role in leaf senescence. The decreasing of chlorophyll content of stressed sensitive maize genotypes may be in relation to leaf senescence.

Senescence can be considered as a whole-plant mechanism which reduces leaf area, in the presence of stress, in order to reduce transpiration and the difference in potential between roots and leaves and to remobilize assimilates to seeds or growing organs (Tardieu, 1996).

Intensification of the light saturated rate of net photosynthesis in resistant maize drought genotypes associated with lack of modifications of water efficiency, increasing of chlorophyll concentrations and root weight ratio, or stomatal conductance, are in feed-back relation with root growth, this probably making carbon available for root growth.

It has often been observed (Atkinson, 1989) that root length increases with soil water deficit. Thus generally there is often a relationship between the amount of root and the use of soil resources. The morphological characteristics of drought tolerant plants show that high drought resistance includes a large root mass (Saxena et al., 1995), such as shown by drought resistant maize line 1268 H.

Intensification of photosynthesis, but over a smaller leaf area, permits enough assimilation to allow roots to fully explore the soil volume (Raev, 1997). On the other hand, intensification of root growth (length, lateral area, volume etc.) can be a support for sustainable shoot growth.

Using the categories of Levitt (1980) and Turner (1979), the maize inbreds 1268 H and 1267 E exhibit drought avoidance with an increase of water uptake due to both an increase in root biomass and in its efficiency (Stikic et al, 1997; Huck at al., 1970, 1983). Earlier stomatal closure in susceptible lines such as B 73 compared with partial closure in resistant ones is in agreement with the results of Stikic et al. (1997). Maize plants of line 1267 E grown under limited water suppply show a beneficial adaptation of the root system, but total photosynthesis decreases due to a significant decrease in leaf area. A similar situation is evident for the maize inbred line Mo 17 H.

A significant decrease of photosynthesis rate, leaf area, root area and stomatal conductance shows the high drought sensitivity of B73 maize.The decrease of chlorophyll content of this line in the drought treatment is associated with changes linked to metabolism disturbance.

CONCLUSIONS

The results obtained show that genetic variability of the studied parameters were more pronounced in the dry treatment. Breeding for drought resistance should be based on comparative investigations of morphological and physiological responses to drought taking into account their interactions at the whole plant level and the consequences on yield. Genotypes empirically found to be resistant or susceptible to drought in terms of yield showed differences in morphological and physiological characteristics. Such differences related to drought tolerance were already seen while plants were still rather small. This is of a great interest for large scale screening of early breeding material.

The experimental results showed that the measurements made on young plants can be used to predict the performance of mature plants.

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Table 2. The effect of water shortage on leaf chlorophyll content

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	(S units)	
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1267E	37.0	41.7
B73	44.0	39.1
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B73	9.8	4.7	1.53	1.63	0.22	0.25	4.95	4.90	115.7	87.0
Mol7H	13.7	8.6	1.33	1.25	0.19	-0.25	5.27	3.56	152.3	96.3
LSD		7.0	0.14	038	0.039	0.072	1.	2.04	22.3	21.8
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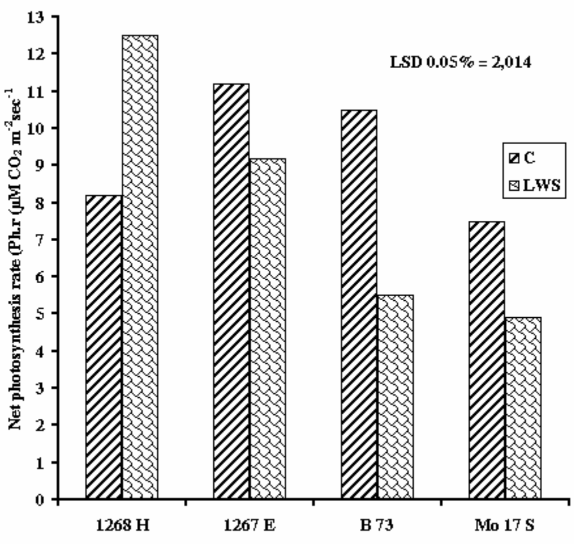

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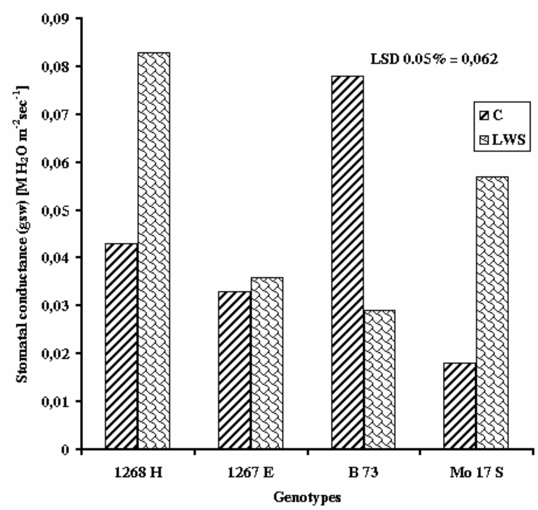
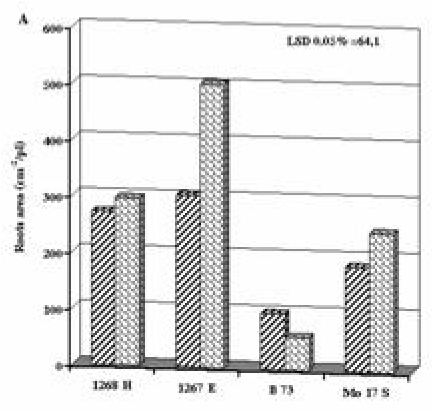


Figure 2. Stomatal conductance (gsw) in maize seedlings grown under normal (C) and limited supply (LWS) conditions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LSD 0.05% =64,1
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