S15-022

Lack of genetic adaptation and its effect on dark respiration

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keywords: respiration, adaptation, sorghum

Introduction

Plant productivity is limited by genetic and environmental factors. Temperature is a driving factor for plant growth and production. Sorghum crop is growing in high contrasting environments in Mexico. One million of hectares (50 % of the all area in Mexico) are growing with sorghum in the northeast corner of the country, mainly under dryland conditions. In this semi-arid environment, the average grain yield is 2 T ha^{-1} using commercial hybrids from different private out state companies. This low grain yield is quite different with the one from the central part of Mexico with record yield of almost 16 T ha^{-1}, one of the highest around the world. Central and Northeast parts of Mexico are distinct by night temperature; having the former higher temperature than the latest. High night temperature has been documented by Eastin (1976) and Eastin *et al*. (1976) to affect negatively grain yield, being more important with the lack of adaptation of the genotype to high night temperature environments, probably due to high respiration rates. However, Akita (1993) mentioned high yield with high respiration rates up to certain limit. Excessive growth in early stages can decrease grain yield.

High respiration rates are considered to influence biomass production by decreasing the amount of CO_2 products being fixed during the day. Negatively effects of night respiration on dry matter production was also reported by Wilson and Jones (1982). By reducing respiration rates, it is possible to manipulate unnecessary respiration and increasing the respiratory efficiency; however, genetic constitution of an individual, play an important role due to the differences in adaptation. Therefore, the identification of the thermal kinetic window reported by Burke (1993) could be important to explain the differences in respiration rates.

The main objective of this study was to compare the response of dark respiration among sorghum genotypes (lines and hybrids) due to differences in night temperatures.

Materials and methods

Two experiments were conducted at the Experimental Station of the Facultad de Agronomía, Universidad Autonoma de Nuevo Leon, at Marin, Nuevo Leon, Mexico during 1995 and 2001. Marin is located at 25°53' North Latitude and 100°03' West Longitude. This region has a BS_1(h')hx'(e') type of climate and it is characterized by low rainfall pattern and high temperature.

Two sorghum hybrids were used in 1995 with different degree of adaptation to this area. In 2001, nine sorghum genotypes from different sources were used. Among them, four were hybrids (H1, H2, H3, H4) and five lines (L1, L2, L3, L4, L5). In the first experiment, the seed was sown in rows 0.8 m apart and 5 m long in March 13. The plants were 10 cm apart within the row. The plot size was four rows for each genotype and they were randomized as a complete block design with two replications. Eighty five days after planting, the respiration was measured in all the plants within one meter in the central row using an infrared gas analyzer LI-COR 6200 (LI-COR, Co. USA). The sensor head of the instrument was allocated inside of a plexiglass chamber with the following dimensions: 1 m long, 1 m tall and 0.8 m width. The chamber was set on top of a wood base to isolate the plants during the measurements. The measurements were made at 9:00 P.M. and 5:00 A.M. under dark conditions. The instrument was set to take air samples for 2.5 minutes. After the measurements, all the plants were harvested and weighted them to get the dry weight.

The second experiment was planted in April 6, 2001, using 5 gallon buckets. The seed was sowed in soil with sand, soil of the area, and compost (1:1:1 ratio). The nine genotypes were planted as a random complete design. The plants were grown under good conditions without water stress. Sixty seven days after planting, the respiration measurements were taken at 9:00 P.M. and 5:00 A.M. under dark conditions, using an infrared gas analyzed LI-COR 6200 (LI-COR, Co., USA). For this experiment, one quarter liter chamber was used to isolate a section of the "flag" leaf in each plant. The instrument was set to take air samples for 1.5 minutes. After the measurements, the leaf area inside the chamber was measured in cm^2. The respiration measurements were based on the CO_2 released m^{-2} sec^{-1}.

Results

Respiration rates from the first experiment are in Table 1. The experimental sorghum hybrid H2183210351 showed lower respiration rate than the commercial hybrid Pioneer 8244 during the night. However, the later one had bigger differences (3.8 vs 0.7 μMol CO_2 Kg^{-1} s^{-1}) between the two respiration measurements. The respiration rates were higher in the first measurement for both genotypes, when the temperature was also relatively high.

Table 1. Respiration rates in two sorghum hybrids. Marin, N.L. Mexico. 1995.

GENOTYPE	21:00 h		05:00 h		RESPIRATION
	TEMPERATURE °C	RESPIRATION $\mu MolCO_2 Kg^{-1}s^{-1}$	TEMPERATURE °C	RESPIRATION $\mu MolCO_2 Kg^{-1}s^{-1}$	DIFERENCE $\mu MolCO_2 Kg^{-1}s^{-1}$
Pioneer 8244®	25.4	15.6	22.8	11.8	3.8
H2183210351	25.3	4.5	23.1	3.8	0.7

For the second experiment, the results are shown in Table 2. All genotypes showed higher respiration rates at 21:00 h than at 5:00 h, when the temperature was high. H1 and H2 showed high respiration differences between the two measurements compared with H3 y H4. In general, H1 and H2 presented 266 % higher differences than H3 and H4. The lines, L1 and L2 showed the higher values for the respiration differences than L3, L4 and L5. In average L1 and L2 were 164 % higher than L3, L4 and L5 together.

Table 2. Respiration rates in nine sorghum genotypes. Marin, N.L. Mexico. 2001.

GENOTYPE	21:00 h		05:00 h		RESPIRATION
	TEMPERATURE °C	RESPIRATION $ppmCO_2\ m^{-2}s^{-1}$	TEMPERATURE °C	RESPIRATION $ppmCO_2\ m^{-2}s^{-1}$	DIFERENCE $ppmCO_2\ m^{-2}s^{-1}$
H1	35.1	117.286	28.5	83.082	34.204
H2	32.1	80.681	28.6	34.925	45.756
H3	34.3	34.359	28.8	22.633	11.726
H4	33.6	104.418	28.7	91.00	18.418
L1	34.6	127.465	28.8	80.401	47.063
L2	32.1	116.831	28.4	61.746	55.085
L3	32.2	69.369	28.4	44.862	24.507
L4	33.0	106.958	28.4	74.017	32.941
L5	32.7	98.223	28.4	59.381	38.842

Discussion

The results from both experiments, clearly show that the hybrids less adapted to semiarid tropical environments, are more sensitive to temperature changes by having high respiration differences in the measurements during the dark period. Pioneer 8244@, H1 and H2 are hybrids adapted to cooler night environments and are more sensitive to high night temperature. This response has been observed by Burke (1993) and it is due to the differences in average temperature where the genotype was developed and the average temperature where the genotype is being grown. Hybrids such as H2183210351 and H3 and H4 were developed in breeding programs located in environments similar to the target areas; therefore, their response was more stable to the differences in night temperatures.

Sorghum lines (homozygous) showed the same dark respiration pattern than the hybrids.

L1 and L2 were developed in temperate environments than the L4 and L5, which were developed in environments of the Northeast part of Mexico, similar to the test environment. L3 eventhough came from northern latitudes, the screening process followed during the breeding process, was using stress environments (water and high temperature stress) from Western Kansas in USA.

When comparing lines and hybrids, such as H3 (the hybrid) versus L5 (female parent) and L4 (male parent) or a group of hybrids such as H1, H2, H3, and H4 versus L1, L2, L3, L4, and L5; in general, hybrids tend to have less respiration rates than lines, probably due to a negative heterosis (like day to flowering) for dark respiration in the late growth stages necessary to increase grain yield, almost always present in the hybrids.

The selection environment is very important in the breeding process for genotypes more adapted to specific target areas, basically due to environmental factors such as temperature that can have a great influence during the respiration process. The manipulation of an efficient respiration is important to enhance biomass production and grain yield.

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