Effects of selection for drought tolerance on pearl millet seed physical and chemical composition

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Introduction

Pearl millet (Pennisetum glaucum (L) R. Br.) is a cereal crop that is rich in essential nutrients and serves as an important food and feed resource in developing countries. More than 60% of the population in Senegal relies on agriculture for their livelihood, and pearl millet is the second major staple food grown in the country. It also has major socio-economic and nutritional importance. It is commonly used in various forms such as couscous, porridge, bread, cakes, and fermented drinks, food for women, babies and elderly people. Pearl millet is more tolerant and adapted to dry and nutrient-poor condition than most major crops. However, due to the recurrent and severe drought experienced in pearl millet growing areas in recent decades, the need for pearl millet cultivars with improved drought tolerant has increased. Often though, the main criteria associated with improved drought tolerance is only grain yield under stress. This aspect of selection for drought tolerance may result in unintended changes in other important crop attributes such as the nutritional profile.

Objective

We hypothesized that selection for drought tolerance in millet cultivars may indirectly influence grain nutritional composition. The objective of this study is to compare millet grain nutritional composition among and between putative drought tolerant and drought sensitive millet cultivars and lines.

Materials and Methods

Plant material

Twenty cultivars of pearl millet differing in vapor pressure deficit (VPD) tested previously under water stress in field conditions in Senegal were used in this study.

Sensitive
Sosat C88

Medium
Thialack

Tolerant
SL40

Materials and methods

- ✓ Seed samples were collected from each cultivar used for investigation from an irrigated field experiment conducted at the UT-ENSA/ISRA-Bambey (14°42' N; 16° 28' W) project site.
- ✓ The cultivars were grown in a split plot experiment with four replications during the dry season. Based on previous testing, lines were grouped into sensitive, tolerant, and medium VPD groups.
- ✓ Main plots were two irrigation treatments, late season water stress (terminal drought), and no water stress.
- ✓ Fertilizer was also applied as following: at pre-plant 150 kg ha^{-1} 15-15-15, and 100 kg ha^{-1} of urea after planting (50 kg after plant thinning, and 50 kg during plant heading).

Measured parameters

Pearl millet grain composition was assessed using near infrared spectroscopy (NIR) (FOSS XDS, Eden Prairie, MN). Grains were analyzed for minerals nutrients, ash, starch, fat, crude fiber, protein, soluble protein, soluble carbohydrate, lignin, and amino acids. The weight of 100 grains, and test weight was also determined.

Statistical analysis

Analysis of variance was performed using PROC GLM of SAS v 9.3 (SAS Institute, 2011) to evaluate the impact of millet drought tolerance grouping on grain composition. When significant differences were identified by ANOVA, mean separations using Tukeys test with a probability level of (P<0.05) was used to compare differences between groups.

Results

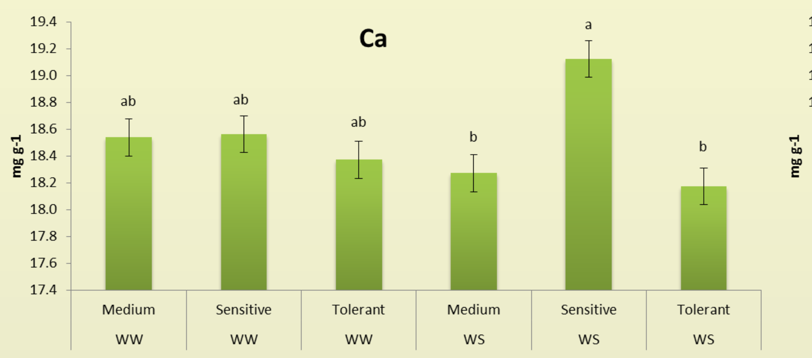
Source	Ca	Cu	Fe	K	Mg	Mn	Na
	------------------------------------Pr>F------------------------------------						
Water Regime	ns	ns	**	**	ns	ns	***
VPD Group	**	ns	ns	**	ns	ns	***
WR x VPD	*	ns	**	ns	ns	ns	*

Source	Protein	Soluble Protein	Soluble Carbohydrate	Starch	Lysine	Methionine
	--------------------------------Pr>F--------------------------------					
Water Regime	ns	ns	ns	ns	**	ns
VPD Group	***	***	ns	***	***	***
WR x VPD	ns	ns	ns	ns	*	*

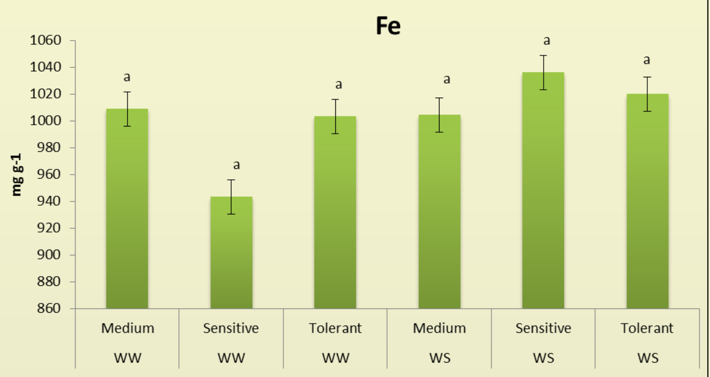
Source	Ash	Fat	Lignin	Grain weight	Test Weight
	-------------------------Pr>F-------------------------				
Water Regime	ns	ns	ns	ns	ns
VPD Group	ns	***	ns	*	**
WR x VPD	ns	ns	ns	ns	ns

ns - not significant
*,**,*** - significant at the 0.10, 0.05 and 0.01 level, respectively.

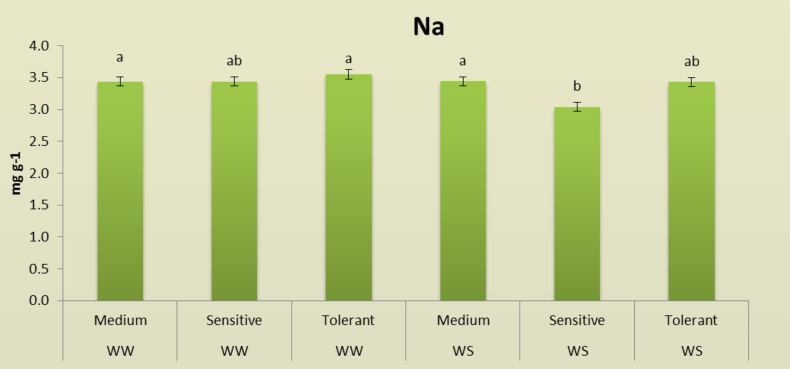
➢ Nutrient content variation based on water regime and VPD group



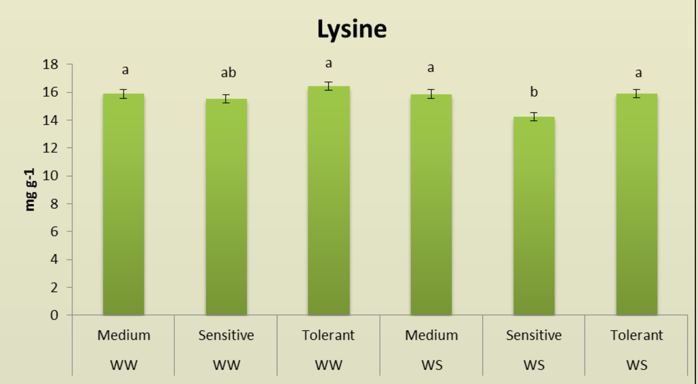
Millet grain calcium concentration varied among VPD groups, but only under water stress.



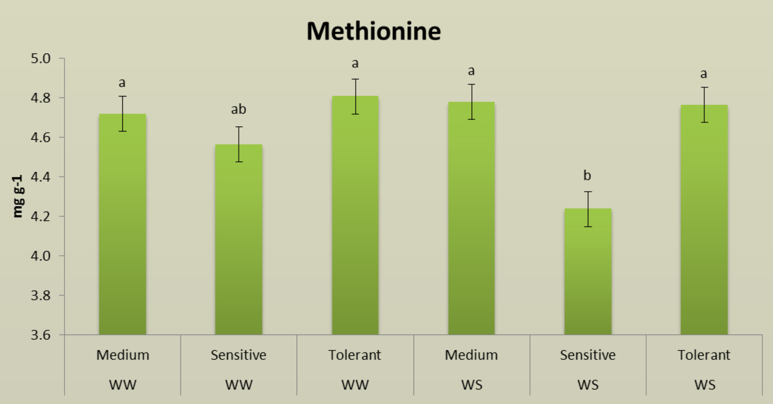
No differences in grain Fe concentration were detected among treatments.



Sodium concentration was lower in sensitive lines grown under water stress compared to medium and tolerant lines with no water stress.

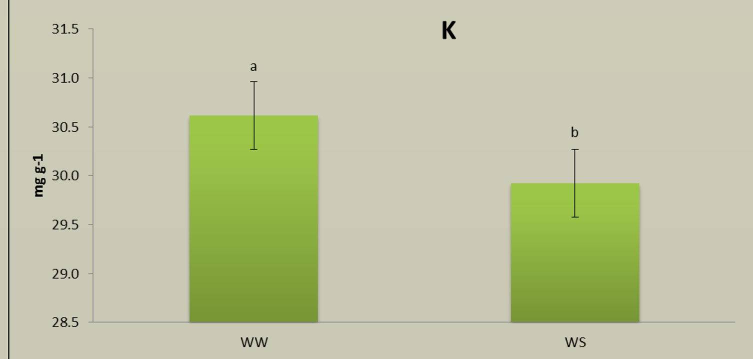


Grain lysine content under water stress conditions was lower for sensitive lines than medium or tolerant.



Similarly, Methionine concentration in grain under water stress was lowest for sensitive lines.

➢ Changes in nutrient content based on water regime



Grain potassium concentration was lower under water stress conditions when averaged over VPD groups.

WW= Well Watered **WS**= Water Stress

➢ Variation in nutrient content based on VPD-group

	K		Protein		Soluble Protein		Starch		Fat		Grain weight		Test Weight	
VPD Stress Group	----------------------------mg g^{-1}----------------------------										g 100 grain^{-1}		kg m^{-3}	
Medium	30.24	ab	139.45	a	105.39	b	461.40	b	39.09	b	0.81	a	761.69	a
Sensitive	30.63	a	135.68	b	165.14	a	472.76	a	42.86	a	0.82	a	772.80	a
Tolerant	29.93	b	139.49	a	105.60	b	459.24	b	38.68	b	0.75	a	769.37	a

means within a column followed by the same lowercase letter are not significantly different (P<0.10).

- ✓ Lines in the sensitive VPD group have higher concentrations of K, soluble protein, starch and fat than lines in the tolerant and medium VPD groups, but the opposite trends exists for grain protein content.
- ✓ 100 grain weight and grain test weight did not significantly differ between VPD groups .
- ✓ Overall, composition of grain from the Medium VPD group was most similar to the tolerant VPD group.

Discussion

- ✓ Plants employ several physiological and chemical mechanisms as a response to water stress. The efficiency for how well plants tolerate water stress is determined by genetic heritage and selection. One mechanism for drought stress tolerance is an increase in Ca-binding proteins within plant cells. This may explain why sensitive cultivars had higher Ca concentration when stressed.
- ✓ Abscisic acid (ABA) content also increases in plants to reduce plant water lost through transpiration. This ABA signaling effect is reported to induce the loss of K from cells during stress. Kholova et al. (2010) reported that tolerant pearl millet cultivars had higher ABA levels than sensitive lines in well-watered conditions. It is hypothesized that tolerant varieties naturally produce more ABA, and therefore have lower K concentration. Our study shows that K did decrease with water stress, and was lowest in the tolerant group.
- ✓ Amino acid accumulation in cells is another way for plants to avoid water loss under drought. It is documented that plants that accumulate high concentrations of organic osmolytes are more tolerant to drought (Ashraf et al., 2011). This may explain why lysine and methionine values for the tolerant VPD groups were higher under well-watered conditions, and lower for the sensitive group under water stress. Higher grain protein values in the tolerant group may be explained by greater levels of amino acids in the lines in this group.

Conclusions

- ❖ In well watered condition we observed very few differences in the parameters measured between VPD-groups. However under water stress, sensitive lines were found to have lower lysine and methionine content than the medium or tolerant lines.
- ❖ We observed very few difference in nutritional composition of drought tolerant lines between well-watered and drought conditions.
- ❖ Sensitive cultivars, when exposed to drought, tend to exhibit higher potassium, soluble protein, starch and fat than tolerant varieties.
- ❖ Under both well watered and water limited conditions, grain composition of the medium group was similar to the tolerant group.
- ❖ Selection for drought tolerance alone can affect pearl millet seed physical and chemical content.

References:

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