SULPHUR SUPPLY INCREASES THE POTENTIAL OF MASSAI GRASS FOR CADMIUM PHYTOEXTRACTION

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Introduction

Cd is a potentially toxic element present in the environment and when is taken up by plants it changes numerous physiological processes, decreasing the biomass production of plants (Benavides et al., 2005). Thus, it's important to reduce the concentration of the heavy metal in the environment to avoid the decrease in food production and the contamination of organisms by Cd. In this context, phytoremediation is a promising alternative to meet this demand, since the technique is viable and inexpensive (Koptsik 2014). However, it's necessary to identify the plants that have potential to accumulate heavy metals without substantially reduce on the biomass production (Rabêlo, 2014).

It's important to mention that damage caused by Cd is inevitable, but can be attenuated when there is adequate sulfur (S) supply (Capaldi et al., 2015). Sulfur participates in the synthesis of chlorophyll and is a component of metabolic compounds like amino acids (cysteine), antioxidants (reduced glutathione - GSH), phytochelatin (PCs) and metallothionein (MTs), which operate in Cd detoxification (Rabêlo, 2014; Capaldi et al., 2015). In this context, our objective with this study was to evaluate, through the tillering capacity and leaf production, if the S attenuates the damage caused by Cd and the *Panicum maximum* cv. Massai potential for phytoextraction of Cd when there is medium and high S supply.

Methods

The Massai grass was grown in a greenhouse, using pots with 2 L of nutrient solution. Combinations of three S rates (0.1, 1.9 and 3.7 mmol L^{-1}) and three Cd rates (0.0, 0.1 and 0.5 mmol L^{-1}) were tested in nutrient solution modified (Hoagland and Arnon, 1950). Seeds were putted to germinate in expanded vermiculite irrigated with deionized water in the first 14 days and in nutrient solution modified to achieve 0.1 mmol L^{-1} S (diluted to 25% of ionic strength) in the 9 days following. After 23 days of growth, 5 seedlings were transplanted to the modified nutrient solutions to meet only S rates. Nineteen days after this stage was provided the nutrient solutions modified to meet S and Cd rates for a period of 7 days.

Seven days after the Cd exposure, plants were harvested and the number of leaves and tillers recorded. The leaf appearance rate and tillering rate were obtained by dividing the number of leaves and tillers by the growth days of Massai grass, as reported by Rabêlo (2014). Leaves and tillers were collected, oven-dried at 60 ºC, for 72 hours, and weighted. Data were submitted to analysis of variance (F test) and comparison of means by Tukey test (p<0.05).

Results

The tillers dry mass production (TP), leaves number (LN), leaf appearance rate (LR) and leaves dry mass production (LP) of Massai grass grown without Cd were higher with S supply of 1.9 mmol L^{-1}, while the tillers number (TN) and tillering rate (TR) have not changed significantly by S supply (Table 1). On the other hand, when Massai grass was exposed to Cd, the S supply did not changed significantly the TN, TR, LN and LR, but changed the TP and LP of plants exposed to 0.5 mmol L^{-1} Cd. The TP and LP these plants grown with 1.9 mmol L^{-1} S was 108% and 167% higher compared to plants grown with higher S rate. When evaluated only Cd effect we noted that the TN, TR, TP, LN, LR and LP of plants exposed to 0.1 mmol L^{-1} Cd decreased in 21, 20, 52, 30, 30 and 52% and these variables of the plants exposed to 0.5 mmol L^{-1} Cd decreased in 47, 48, 56, 63, 63 and 83% compared to plants grown without Cd, respectively.

Table 1. Tillers number (TN), tillering rate (TR, tiller per day), tillers dry mass production (TP, g), leaves number (LN), leaf appearance rate (LR, leaves per day) and leaves dry mass production (LP, g) by one plant of *Panicum maximum* cv. Massai grown with combinations of Cd and S rates.

Cd (mmol L^{-1})	S (mmol L^{-1})	TN	TR	TP	LN	LR	LP
0.0	0.1	12.75±0.94ab*	0.23±0.02ab	1.02±0.07b	36.00±2.48bc	0.67±0.05bc	1.58±0.09b
	1.9	15.00±0.41a	0.28±0.01a	1.62±0.03a	54.25±0.62a	1.02±0.01a	2.53±0.08a
	3.7	13.00±0.41ab	0.24±0.01ab	0.98±0.07b	41.00±1.78b	0.77±0.03b	1.62±0.07b
0.1	0.1	11.00±0.41b	0.21±0.01b	0.76±0.03bc	28.00±0.71c	0.53±0.01cd	0.91±0.02c
	1.9	10.25±0.85bcd	0.19±0.02bcd	0.46±0.04cd	33.00±3.24bc	0.62±0.06bc	0.89±0.17c
	3.7	10.75±0.47bc	0.20±0.01bc	0.51±0.10cd	30.25±3.17c	0.57±0.06c	0.96±0.14c
0.5	0.1	7.75±0.62de	0.14±0.01de	0.50±0.02cd	16.00±0.00d	0.30±0.00e	0.31±0.01de
	1.9	8.00±0.71cde	0.15±0.01cde	0.75±0.10bc	18.25±2.25d	0.35±0.04de	0.48±0.05d
	3.7	5.75±0.24e	0.10±0.00e	0.36±0.04d	14.00±1.08d	0.26±0.02e	0.18±0.03e
LSD 0.05		2.88	0.05	0.29	9.65	0.18	0.42

*** Mean ± standard error (*n* = 4) followed by different letters in the column differ by Tukey test (*p*<0.05).**

A large amount of Cd absorbed by the grasses was allocated in the basis of plant, more specifically in buds which originate new tillers (Fujimaki et al., 2010), decreasing the TN, TR and TP (Table 1). When the Cd is transported to leaves, the photosynthetic process is compromised due to chlorophyll degradation, changes in electron transport between photosystems I and II, and inactivation of enzymes involved in carbon fixation (Benavides et al., 2005), which results in lower LN, LR and LP.

Conclusion

The S supply (1.9 mmol L^{-1}) attenuates the damage caused by Cd and the Massai grass shows potential for phytoextraction of environments contaminated with Cd.

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