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Soil Flood Tolerance of Seven Genotypes of *Panicum maximum* Jacq.

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ABSTRACT

The soil flood tolerance of seven genotypes of Panicum maximum *Jacq. (PM11, PM34, PM40 and PM45, and the commercial cultivars Massai, Mombaça and Tanzânia) was evaluated in plants subjected to two conditions: flooded and not flooded, during a period of 14 days. Flooding significantly decreased the total and above ground biomass of PM40 and PM45. For cultivar Tanzânia, flooding decreased these two variables and also root biomass. The root, total and above ground relative growth rates were significantly reduced by flooding in cultivar Tanzânia, while in PM45 only the above ground relative growth rate was reduced. Cultivar Tanzânia showed significant differences for all variables analyzed, thus was not flood tolerant, as well as PM40 and PM45. It could be concluded that Massai, PM34, Mombaça and PM11 were the most flood tolerant genotypes.*

Key words: Anoxia, flooding, forage grass

INTRODUCTION

Mechanisms of tolerance to stress factors, as soil flooding, are found in many plant species and may be based on adaptation strategies to improve gaseous exchanges and maintain the energy production (Armstrong et al., 1994).

The capacity and response to adaptation differ among the species or even within a species, due to species diversity, and should, therefore, be investigated (Andrade et al., 1999; Dias-Filho and Carvalho, 2000; Dias-Filho, 2002; Queiroz and Dias-Filho, 2003; Gontijo Neto et al., 2004; Dias-Filho, 2006).

An organism may be considered susceptible to a given stress when it suffers aberrant alterations in its metabolism, which are translated as a form of reasonably important injuries (Giaveno and Oliveira, 2003). On the other hand, if the organism does not present stress injury symptoms, it should be considered resistant.

Plants susceptible to water stress show changes in metabolic and physiological processes. Factors as decrease in root conductance and photosynthetic rate are among the first responses to flooding (Baruch, 1994; Costa, 2004). Other changes, in sequence, include decrease in root permeability, alteration in the balance of growth hormones, epinasty of the leaves, chlorosis and abscission, leading to an interruption of the vegetative and reproductive growth (Moura et al., 2008), reducing relative growth rates (RGR).

When plants are subjected to soil flooding, many physiological functions are affected, amongst them; generally an immediate decrease in gaseous exchange with the environment is observed (Queiroz and Dias-Filho, 2003). Hypoxia or anoxia are the main limiting factors which

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decrease aerobic respiration and the absorption of minerals and water through the roots (Costa, 2004). However, plants under natural or experimental conditions may be submitted to great variations in the availability of oxygen, from normal levels to deficiency (hypoxia) and total absence (anoxia). The deficiency of oxygen may occur when the soil becomes flooded for a period of time (long or short) depending on its drainage capacity, or due to the anatomical structure of some tissues, which prevent gaseous exchanges. Nevertheless, the majority of the plant tissues may tolerate oxygen deficiency for short periods of time before suffering irreversible damage.

According to Humphreys (1981), flooding or poor drainage of soils covered by forage species which are susceptible to flooding, are factors which act directly upon the deficiency of oxygen for the root development, and are, therefore, the cause of death of these forages, due to the reduction in root respiration, and decrease in energy availability and nutrient absorption.

Crawford (1993), reviewing plant responses to flooding described the ability of species to reduce the impact caused by the stress, to different survival strategies concerning mechanisms of tolerance and avoidance as a means to avoid or escape from anoxic environments. According to the author, tolerance involves metabolic adaptations depending on the species, plants and tissues and consists of the regulation of respiration, energy storage, lipid metabolism and mitochondrial activity in the synthesis of ethylene and photosynthetic adaptations. The consequence of these adaptations of anaerobic respiration in the cellular metabolism is one of the factors that most interfere in the physiological processes.

The mechanisms of adaptation assure the renovation of oxygen supply to submerged roots and consist in developing channels filled up with gases, called aerenchyma, which permit the movement of oxygen of the aerial part to the roots under anoxia conditions (Jackson, 1989).

Another mechanism of adaptation, in which the plant "avoids" the injuries caused by flooding, is the formation of adventitious roots, as an alternative to reduce the impact. In species adapted to flooded soils, normally stomata do not close and the root metabolism is not much altered by anoxia due to the efficient transport system and oxygen diffusion in the roots of these species (Jackson and Drew, 1984; Costa, 2004).

In the absence of O_2, electron transport and oxidative phosphorylation in the mitochondria cease, the cycle of tricarboxylic acid cannot operate and ATP may only be produced by fermentation. Thus, damage to the root metabolism due to O_2 deficiency originates, partly, from the lack of ATP to guide essential metabolic processes (Drew, 1997; Taiz and Zeiger, 2004). The citosolic acidosis irreversibly breaks the metabolism in the cytoplasm of the cells of superior plants, as well as anoxic cells in animals. The rhythm and degree to which the citosolic acidosis is limited are primary factors that distinguish the flood sensitive from tolerant species (Taiz and Zeiger, 2004).

Flooding is related to the pluviometric system, local topography, soil type and river courses (Bianchini et al., 2001). Temporary or continuous flooding of the soils occurs as a result of storms, overflowing of rivers or inadequate drainage of the soils (Dias-Filho and Carvalho, 2000).

Overflowing or temporary or continuous flooding of the soils are common events, being limiting factors in the use of these areas for agricultural and animal husbandry purposes. In Brazil, usually many of these areas are used as pastures because they are inadequate for other agricultural activities (Dias-Filho, 2003). During the last few years the syndrome of death *Brachiaria brizantha* cv. Marandu is becoming one of the major causes of pasture degradation in the Brazilian Amazonia; this syndrome is likely to be caused by the low tolerance of this cultivar to waterlogging that adversely affects the plant physiology, resulting in predisposition to biotic stresses like fungal infection (Dias-Filho, 2006).

The occurrence of the syndrome of death in most of *B. brizantha* accessions suggests that the problem is not specific of the cultivar Marandu, but that the species has low adaptability to waterlogging (Andrade et al., 2003).

Presently, the only alternative to mitigate the problem of the death of *B. brizantha* is the diversification of the pastures, using grasses more tolerant to soils with deficient draining (Dias-Filho, 2005a).

The objective of this study was to evaluate three cultivars and four accessions of *Panicum maximum* Jacq., of the Poaceae family, under temporary flooding, during two weeks, and identify the most tolerant to soil flooding. It was hypothesized that the accessions and cultivars of

P. maximum would show differential ability to tolerance to soil flooding.

MATERIAL AND METHODS

The experiment was carried out in a greenhouse at Embrapa Beef Cattle in Campo Grande, Mato Grosso do Sul (Brazil). Seven genotypes of *P. maximum* were evaluated: four accessions (PM11, PM34, PM40 and PM45), and three commercial cultivars (Massai, Mombaça and Tanzânia). These were pre-selected by Gontijo Neto et al. (2004), from 24 genotypes, as possible forage options for pasture areas for low permeability soils subject to temporary flooding.

Seeds of the genotypes were germinated in gerbox filled with the commercial substrate Plant Max HA® and watered daily. After 20 days of sowing, the grass seedlings were transplanted to pots of 6.0 L capacity (two plants/pot). As substrate, sieved Red Latosol (Oxisol) and sand (3:1 respectively) were used. After 21 days, each pot received 50 mL of nutritive solution of Hoagland and Arnon (1950); 15 days later, the plants were cut to a uniform height of 0.10 m and seven days later, the plants were subjected to the treatments: flooding and non flooding (control). Non flooded plants (soil close to field capacity) were watered daily and excess water drained from the holes at the bottom of the pots. Flooded plants had their pots inundated to around 0.05 m above the soil level during 14 days.

A completely randomized design was used, with three replications for each genotype under two conditions (flooded and non flooded), evaluated during 14 days (flooding period). After the flooding period, for each flooded and non flooded pot, an evaluation harvest was carried out by cutting the plants close to the soil level to determine above ground biomass. The substrate of the pots was removed and the roots were washed to determine dry roots biomass. Dry roots biomass was determined in a digital analytical balance after being forced-air dried at 65ºC for 72 h.

Dry biomass and the weekly relative growth rate (RGR) of the roots, above ground and total material of flooded and non flooded plants (control) were determined by the formula: RGR = $(\ln_{xf} - \ln_{xi})/\Delta t$, where: $\ln_{xf}$ is the neperian logarithm of the parameter “x” (root, above ground, total) at the end of the experiment (two weeks), $\ln_{xi}$ is the neperian logarithm of the parameter “x” at time zero (beginning of the experiment) and Δt is the interval of time (in weeks). For each variable and genotype, an analyses of variance was done, between flooded and non flooded (F test, at 5% and 1% level probability) and the mean and mean confidence interval was calculated (IC 90%) using the statistical program Minitab for Windows version 12.1 (Minitab Inc., USA).

RESULTS AND DISCUSSION

Root biomass (RB)

There is a great variety of morphological, anatomical and physiological characteristics of adaptation or that act as a buffer against the negative stress effects (Sena et al., 2007).

In this work, only cv. Tanzânia differed statistically ($p < 1\%$) in RB under flooding (Fig. 1). The accession PM34 was the only one that increased RB (24.6%) under flooding (Fig. 1). After PM34, the most flood tolerant genotypes with lower decreases in RB were: cv. Massai with 17.1%, followed by cv. Mombaça (25.2%), PM40 (27.2%) and PM11 (29.5%). The maximum decreases in RB were found in cv. Tanzânia (52.9%) and PM45 (71.3%). In *Panicum*, Anderson (1972) recorded a positive relationship of higher flooding tolerance and the ability to produce adventitious roots; however, this was not observed in the present research.

Above ground biomass (AGB)

Flooding caused a significant ($p < 5\%$) decrease in AGB for genotypes PM40 and PM45 and for cv. Tanzânia ($p < 1\%$, Fig. 2). Genotypes PM34, cv. Mombaça, PM11, cv. Tanzânia, PM40 and PM45 showed a decrease in AGB under flooding of 15.5, 25.6, 31.1, 44.1, 47.4 and 73.4%, respectively (Fig. 2). Interestingly, cultivar Massai showed a 9.8% increase in AGB under flooding.

Total biomass (TB)

Anderson (1972) evaluating five *Panicum coloratum* cultivars and one cultivar of *P. maximum* under five flooding periods, found a slight reduction in weight at the 30 and 40-day period for four cultivars. However, one cultivar (Kabulabula 14375) produced more dry matter than any other cultivar in any flooding period. Willis and Hester (2004) evaluating *P. hemitomon* found that moderate flooding tended to increase the productivity, although this relationship was not statistically significant.

In the present work, flooding decreased the TB of genotypes PM40, PM45 and cv. Tanzânia (Fig. 3). The accessions that had the largest decrease in TB were PM45 (72.9%) and cv. Tanzânia (46.8%). Cultivar Massai with an increase of 2.5%, and PM34 with a decrease of only 8.7% under flooding were the least affected genotypes.

Weekly relative growth rate of roots (RGRr)

Plant biomass production is in part resultant of the photosynthetic rate, and therefore, the relative growth rate (RGR) also decreases under flooding (Dias Filho, 2005b).

RGRr of PM40 and cv. Tanzânia was significantly reduced by flooding (Fig. 4). Genotype PM34 and cv. Massai showed an increase in RGRr of 17.4% and 1.4% in flooded plants; PM45 and cultivars Tanzânia and Mombaça were less tolerant (Fig. 4).

Weekly above ground relative growth rate (RGRa)

Flooding showed a tendency to reduce the RGRa of all genotypes, except for cv. Massai (24% higher under flooding). The reduction in RGRa due to flooding was statistically significant only for genotype PM45 (p < 5%) and for cv. Tanzânia (p < 1%) (Fig. 5). The reduction tendency in RGRa was less for cv. Mombaça and PM11, PM34 and PM40 (16.6, 17.5, 19.2 and 22.5%, respectively). Cultivar Tanzânia and genotype PM45 showed the highest decrease in RGRa due to flooding (30.4 and 63.5%, respectively).

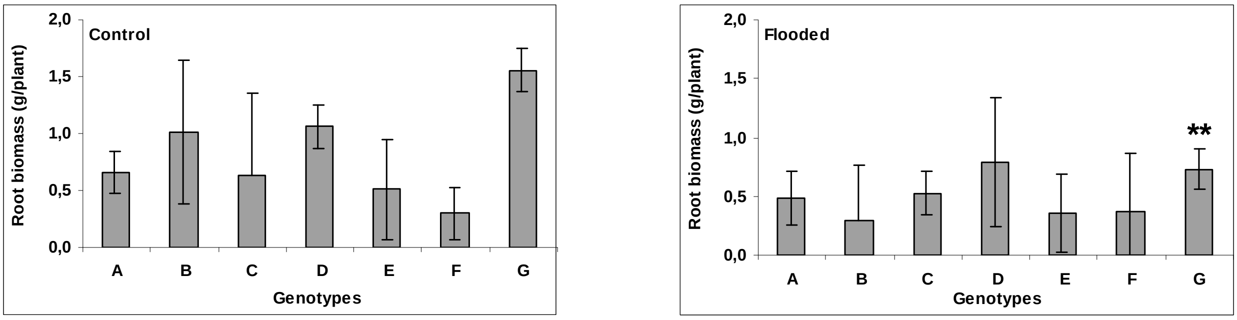

Figure 1 - Root biomass of *Panicum maximum* genotypes PM40 (A), PM45 (B), cv. Massai (C), cv. Mombaça (D), PM11 (E), PM34 (F) and cv. Tanzânia (G). An asterisk indicates that for the same accession, the difference between treatments was statistically significant at 5% level and two asterisks, significant at 1% level. Whiskers indicate the lower and upper confidence interval (90%) for each genotype.

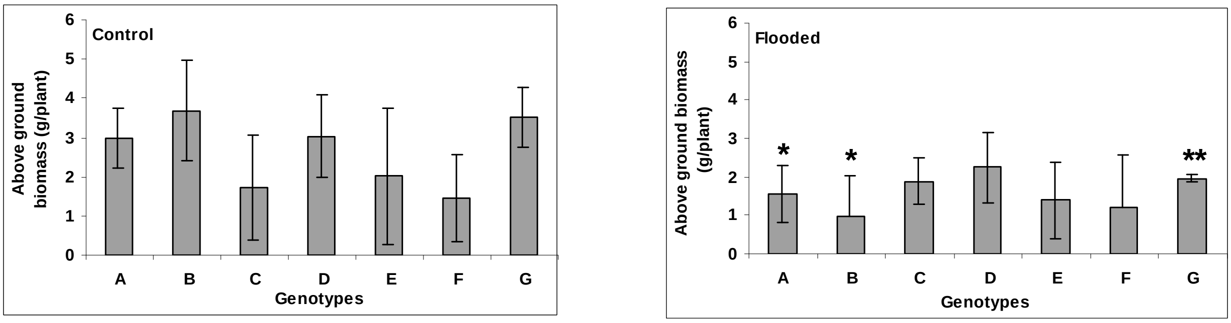

Figure 2 - Aboveground biomass of *Panicum maximum* genotypes PM40 (A), PM45 (B), cv. Massai (C), cv. Mombaça (D), PM11 (E), PM34 (F) and cv. Tanzânia (G). An asterisk indicates that for the same accession, the difference between treatments was statistically significant at 5% level and two asterisks, significant at 1% level. Whiskers indicate the lower and upper confidence interval (90%) for each genotype.

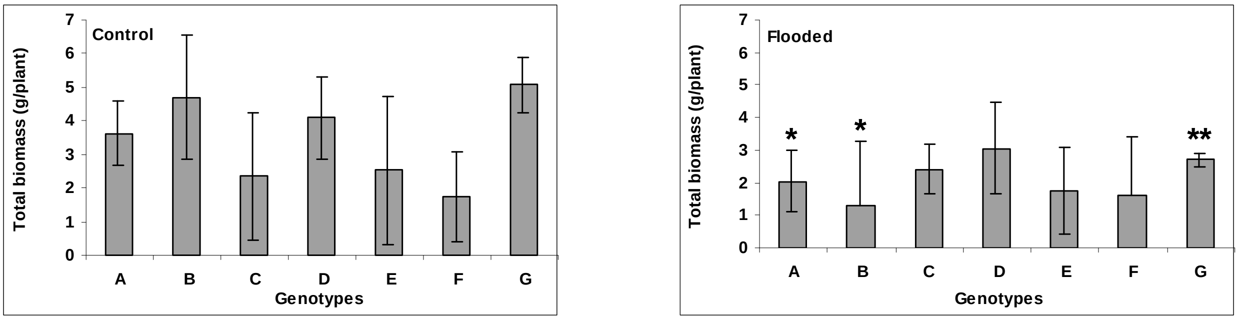

Figure 3 - Total biomass of *Panicum maximum* genotypes PM40 (A), PM45 (B), cv. Massai (C), cv. Mombaça (D), PM11 (E), PM34 (F) and cv. Tanzânia (G). An asterisk indicates that for the same accession, the difference between treatments was statistically significant at 5% level and two asterisks, significant at 1% level. Whiskers indicate the lower and upper confidence interval (90%) for each genotype.

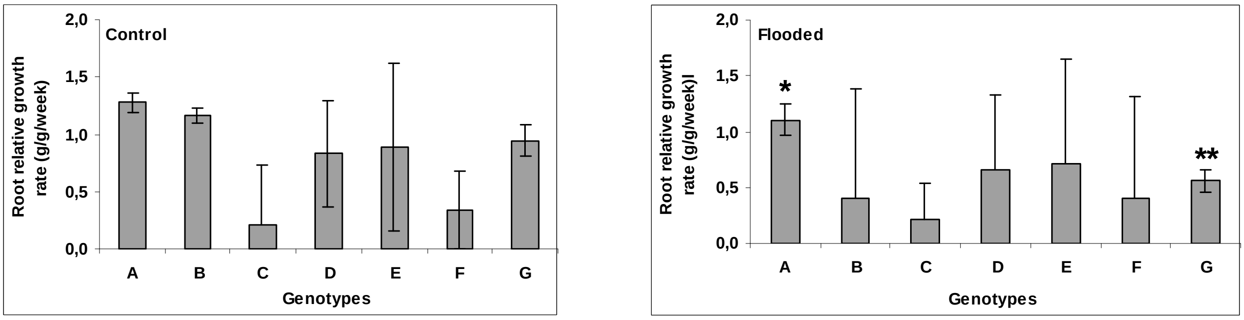

Figure 4 - Root relative growth rate of *Panicum maximum* genotypes PM40 (A), PM45 (B), cv. Massai (C), cv. Mombaça (D), PM11 (E), PM34 (F) and cv. Tanzânia (G). An asterisk indicates that for the same accession, the difference between treatments was statistically significant at 5% level and two asterisks, significant at 1% level. Whiskers indicate the lower and upper confidence interval (90%) for each genotype.

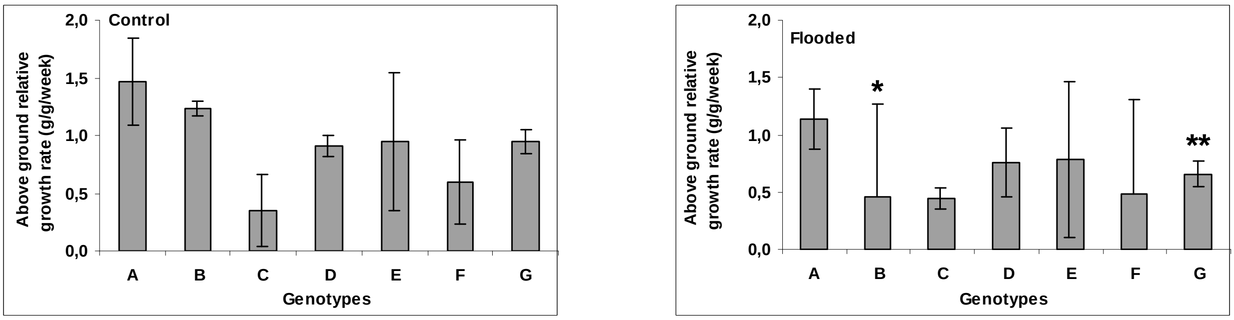

Figure 5 - Above ground relative growth rate of *Panicum maximum* genotypes PM40 (A), PM45 (B), cv. Massai (C), cv. Mombaça (D), PM11 (E), PM34 (F) and cv. Tanzânia (G). An asterisk indicates that for the same accession, the difference between treatments was statistically significant at 5% level and two asterisks, significant at 1% level. Whiskers indicate the lower and upper confidence interval (90%) for each genotype

Total relative growth rate (RGRt)

Only cv. Tanzânia showed a significant decrease (p < 1%) in RGRt due to flooding (Fig. 6). The RGRt of cv. Massai under flooding was 18.5% higher. In PM34, cv. Mombaça and PM11 flooding caused an average decrease in RGRt of 14.3, 17.4 and 17.8%, respectively. Genotype PM45, cv. Tanzânia and PM40 suffered the highest RGRt decrease under flooding (63.9, 33.3 and 20.9%, respectively).

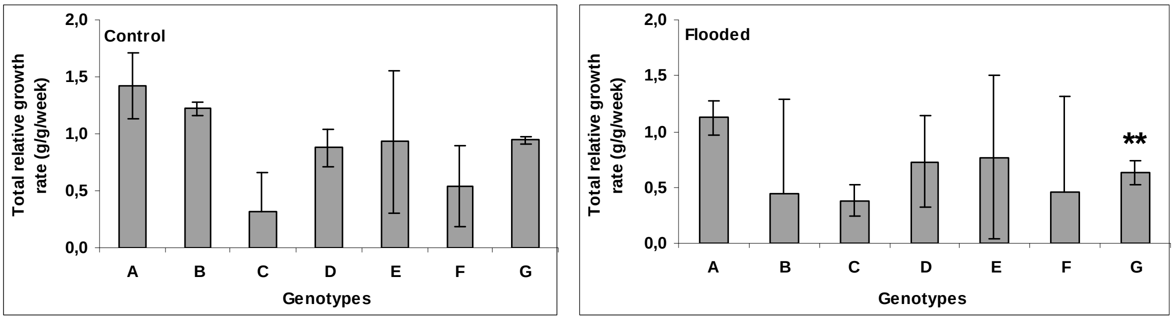

Figure 6 - Total relative growth rate of *Panicum maximum* genotypes PM40 (A), PM45 (B), cv. Massai (C), cv. Mombaça (D), PM11 (E), PM34 (F) and cv. Tanzânia (G). An asterisk indicates that for the same accession, the difference between treatments was statistically significant at 5% level and two asterisks, significant at 1% level. Whiskers indicate the lower and upper confidence interval (90%) for each genotype.

CONCLUSIONS

Variability among *P. maximum* accessions and cultivars to soil flood tolerance was found. Cultivar Massai was the most appropriate *P. maximum* cultivar for low permeability soils subject to temporary flooding, and accession PM34 was promising for these conditions. The most flood sensitive genotypes were cv. Tanzânia and PM45.

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RESUMO

Avaliou-se a tolerância ao alagamento do solo em sete genótipos de *Panicum maximum* Jacq. As plantas foram submetidas a duas condições: alagado e não alagado, avaliadas por um período de 14 dias. O alagamento reduziu a produção de biomassa seca da parte aérea e total (para PM40, PM45, p < 5%). Para a cv. Tanzânia (p < 1%), além destas variáveis, reduziu a biomassa da raiz. Quanto à taxa de crescimento relativo total sob alagamento em relação à testemunha foi significativa apenas para PM45 (p < 5%), na parte aérea e para a cv. Tanzânia (p < 1%) na taxa de crescimento relativo da raiz, parte aérea e total; a cv. Tanzânia apresentou diferenças significativas em todas as variáveis analisadas, não sendo tolerante ao alagamento, assim como PM40 e PM45; Massai, Mombaça, PM11 e PM34 são tolerantes ao alagamento, sendo que o mais tolerante foi a cv. Massai.

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