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Evaluation of *Megathyrsus maximus* genotypes under water stress conditions

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ABSTRACT. The objective was to evaluate the production of *Megathyrsus maximus* genotypes (Syn. *Panicum maximum*), under different levels of water in the soil. This was a 5x5 factorial completely randomized design conducted in a greenhouse, combining five genotypes of *M. maximus* (B55, C10 and PM30, cv. Massai and cv. BRS Tamani) and five levels of soil field capacities (20%, 40%, 60%, 100% and 140%), with three replications. Dry matter production was evaluated: leaf, stem, dead material, root, shoot and total dry matters, as well as the number of tillers and leaf:stem and aboveground:root ratios. The qualitative factor (genotypes) was subjected to Duncan test at 5% probability. The quantitative factor (% field capacity) was subjected to regression, adopting 5% as a critical level of probability. There was no interaction between the factors for any of the evaluated characteristics. Significant differences among the genotypes were detected for tiller number, dead material dry mass, root and total dry mass and leaf:stem ratio. There was no significant effect of the percentage of field capacity on most of the characteristics, except for leaf:stem and aboveground:root ratios. Cultivar Massai showed the best forage production compared to the other genotypes, regardless of the percentage of field capacity evaluated. In general, the evaluated genotypes were more tolerant to excess water stress than to water deficit.

Keywords: Flooding; forage; water deficit; field capacity.

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Introduction

Brazil has a huge territorial extension, of which more than 111 million hectares is represented by cultivated pastures (Brasil, 2018). This area comprises ecosystems with varied soil and climate conditions. Despite the abundance of pastures, forage production is not uniform throughout the year (Euclides, Flores, Medeiros, & Oliveira, 2007), due to a period in which the forages are subjected to water deficit, low temperatures and low luminosity. In addition, most pastures occupy areas with wide restriction for cultivation, which includes soils with high declivity, sandy or poorly drained soils.

Water is a major determining factor for the full development and functioning of plants, and at the same time one of the most limiting (Araújo Júnior et al., 2019). Thus, one of the main causes of stress in plants is the availability of water in the soil. Water deficiency and excess can directly interfere with the root and aboveground development of the plants. Pastures in the Northern region of Brazil, mainly formed by Marandu grass, have been and are being degraded due to excess water in the soil (Andrade & Valentim, 2007). In *M. maximus*, cultivars BRS Tamani and BRS Quênia, recently released hybrids (Embrapa Gado de Corte, 2015; Jank et al., 2017), are susceptible to excess water in the soil, however, cultivars such as Mombaça, BRS Zuri and Massai (Schiavo, Laura, & Jank, 2009; Mass Junior, Domiciano, Ribeiro, & Pedreira, 2016; Ribeiro-Júnior et al., 2017) have been indicated to increase pasture persistence in poorly drained sites. Pasture death has also been observed after recurrent years of water deficit, mainly in transition areas with the Caatinga Biome, and *M. maximus* cultivars such as Massai and others (Veras et al., 2020) have been used as alternatives. Thus, *M. maximus* represents a good option to increase the persistence of pastures in regions under water stress.

The evaluation of these stress factors in forages allows to know the effect of water on the pattern of tissue deposition among the different components of the plants. The study and development of forages that perform well under adverse environmental conditions is essential, in order to optimize animal production on pasture and improve the use of these areas, since there is a predominance of the use of pastures as the main source of feed for Brazilian herds (Euclides et al., 2010).

Megathyrsus maximus cultivars are of great importance in Brazil, not only because the species is widely used in the constitution of pastures for ruminants, due to its high nutritional value and good productivity (Jank, Martuscello, Euclides, Valle, & Resende, 2022), but also due to the country's prominence in the production and export of forage seeds (Jank, Barrios, Valle, Simeão, & Alves, 2014). In addition, with the need to intensify livestock production and increase productivity under increasingly challenging environments, *M. maximus* becomes an important forage resource due to its high diversity and adaptability to environments under water stress.

The objective of this study was to evaluate the production of *M. maximus* genotypes (B55, C10, PM30, cv. Massai and cv. BRS Tamani) under different soil water levels.

Material and methods

The experiment was conducted in a greenhouse at the Federal University of São João del-Rei, in the municipality of São João del-Rei, state of Minas Gerais, Brazil. The municipality is at an altitude of 904 m and at geographic coordinates 21° 08' 11" South latitude and 44° 15' 43" West longitude. The climate of the region, according to the Köppen classification, is Cwa, subtropical with dry winter and hot summer.

Two cultivars of *M. maximus* (BRS Tamani and Massai), and three genotypes (B55, C10 and PM30) were evaluated in pots with a capacity of 5.8 dm^3 in volume. A soil sample was used, which was collected, at a depth of 0 to 20 cm, in the municipality of São João del-Rei. After drying and sieving, the sample was subjected to chemical analysis (Table 1).

The maximum and minimum temperatures inside the greenhouse were measured daily, with averages of 37.4 and 16.7°C, respectively.

Table 1. Chemical characteristics of the soil in the 0-20 cm layer.

P	K	pH	Ca	Mg	Al	H+Al	S.B.	t	T	V%	m%
mg dm^{-3}			cmol$_C$ dm^{-3}								
1.80	26.0	5.42	0.58	0.07	0.15	1.83	0.72	0.87	2.55	28.2	17.2

S.B. = Sum of exchangeable bases; t = Effective cation exchange capacity; T = Cation exchange capacity at pH 7.0; V% = Base saturation; m% = Percentage of aluminum saturation.

Soil sample preparation operations, for acidity correction, were done 60 days before sowing, applying 15 g lime per pot. Phosphate fertilization was carried out at the time of sowing and 2 g simple superphosphate was used per pot (equivalent to 120 kg ha^{-1} P_2O_5). Sowing was done directly in the pots. After the establishment of the forages, plants were thinned, leaving the three most vigorous plants in each pot. Thirteen days after thinning, plants were cut at 10 cm from the ground.

Thirty days after sowing and after each cut, plants were fertilized with 1 g ammonium sulphate per pot (equivalent to 70 kg N ha^{-1}) and 0.2 g potassium chloride per pot (equivalent to 41 kg K2O ha^{-1}). Three harvests were performed at an interval of 28 days.

The experimental design was a completely randomized design in a factorial arrangement (5x5), combining five genotypes of *M. maximus* (Massai, BRS Tamani, B55, C10 and PM30), five water levels (20%, 40%, 60%, 100% and 140% soil field capacity), with three replications.

Pots were weighed daily to control water availability. The treatment with 100% field capacity was considered a control, with the weight of the pot + soil in the field capacity of 6.5 Kg. For treatments 20, 40, 60 and 140% field capacity, the weight of the pot + soil was 5.5, 5.7, 5.9 and 7.1 kg, respectively.

Plants were subjected to three harvests every 28 days, 5 cm from the ground. Before each harvest, the number of tillers in each pot was counted. In the last harvest, aboveground and root parts were collected. The aboveground part of the plant, in all cuts, was separated into leaf, stem + sheath and dead material. All samples were dried in an air-forced oven at 55°C for 72 hours. From these dry weights, the production of leaf, stem, dead material, root, aboveground and total DM were estimated, as well as the leaf:stem and aboveground:root ratios.

Data of harvests were tested by analysis of variance. The qualitative factor (genotypes) was subjected to Duncan test at 5% probability. The quantitative factor (%field capacity) was subjected to regression, adopting 5% as a critical level of probability, with the models chosen by means of the level of significance of the parameters according to the t-test and by the coefficient of determination (R^2). All statistical analysis were performed using the MIXED procedure of SAS 9.4 (Littell, Milliken, Stroup, Wolfinger, & Schabenberger, 2006).

Results and discussion

The analysis of variance (Table 2) evidenced significant differences between genotypes and levels of field capacity for most characteristics, while the interaction between these factors was not significant for any of the characteristics evaluated. The genotypes differed significantly only for number of tillers, DM of dead material, root, total (aboveground + root) DM and leaf:stem ratio, indicating that there was variation between the genotypes evaluated for these characteristics regardless of the level of field capacity. The level of field capacity significantly affected most of the characteristics, except leaf:stem and aboveground:root ratios, indicating that there was an influence of the soil water level on the performance of most of the characteristics.

Table 2. Effects of genotype, field capacity percentage, interaction between factors and coefficient of variation for production characteristics in *Megathyrsus maximus*.

Characteristic	P value			CV
	Genotype	% field capacity	Interaction	
Number of tillers	<0.0001	<0.0001	0.0546	22.8
Leaf dry mass[1]	0.0774	<0.0001	0.6962	32.5
Stem dry mass[1]	0.2045	0.0010	0.5531	43.9
Dead material dry mass[1]	0.0135	0.0033	0.6475	85.6
Aboveground dry mass[1]	0.1877	<0.0001	0.8386	36.0
Root dry mass[1]	0.0204	0.0004	0.1026	45.6
Total dry mass (aboveground + root)[1]	0.0289	<0.0001	0.1462	40.6
Leaf:stem ratio	<0.0001	0.1142	0.5633	34.1
Aboveground:root ratio	0.1341	0.8709	0.6502	45.3

[1] (g pot^{-1}), CV= coefficient of variation.

The cultivar Massai stood out in number of tillers, regardless of the field capacity evaluated (Table 3), with tiller number of 65.3; 255.9; 309.2 and 415.3% greater than the genotypes BRS Tamani, C10, B55 and PM30, respectively. Massai grass is known for its high tillering capacity, an important characteristic for the longevity of the grass (Alexandrino, Candido, & Gomide, 2011). Luna et al. (2016) evaluated the tillering dynamics, tiller density and structural characteristics of *Brachiaria brizantha*, *M. maximus* and *Cenchrus ciliares* under a cutting regime, and observed the highest tiller population density in the Massai cultivar.

Table 3. Characteristics of production of genotypes of *Megathyrsus maximus* subjected to water stress.

Characteristic	Massai	Tamani	C10	B55	PM30
Number of tillers	106.845[a]	64.622[b]	30.023[c]	26.112[cd]	20.733[d]
Dead material dry mass[1]	1.400[a]	1.467[a]	0.733[b]	0.867[ab]	0.533[b]
Root dry mass[1]	36.704[a]	21.947[b]	23.932[b]	26.583[b]	26.193[b]
Total dry mass[1]	46.326[a]	30.703[b]	31.109[b]	35.229[b]	33.750[b]
Leaf:stem ratio	4.949[a]	3.872[b]	2.890[c]	2.903[c]	3.061[bc]

[1] (g pot^{-1}). Means followed by different letters, in the same row, are statistically different by Duncan test at 5% probability.

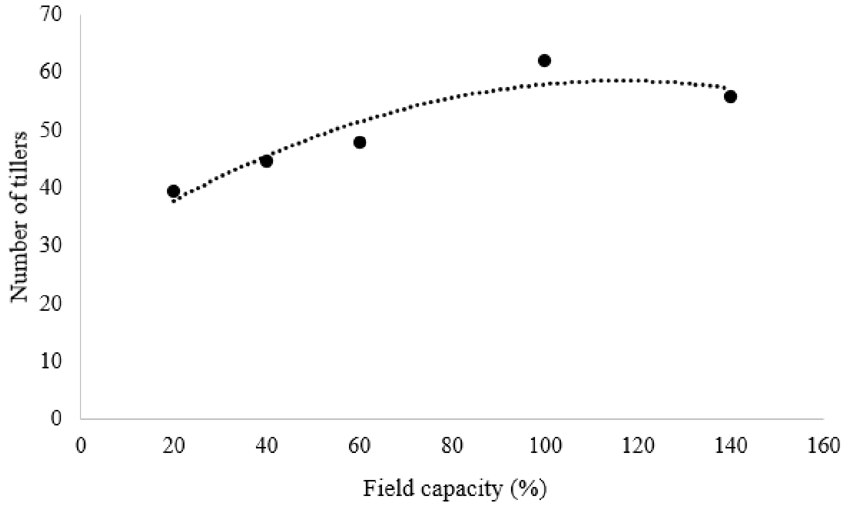
Genotypes Massai, BRS Tamani and B55 did not differ as to dead material dry mass (DMDM). Genotype B55 showed an intermediate production. The lowest yields were observed for C10 and PM30 genotypes. The DMDM is directly related to the forage quality, because the greater its participation in the forage mass, the worse the forage quality, thus influencing the intake and consequently the habit of grazing animals.

Massai cultivar presented a higher production of dry root mass (RDM), indicating that its root system was less affected when compared to the other genotypes, regardless of the soil water levels.

In addition, Massai had the highest total dry mass (TDM). Probably, the large number of tillers was the factor of greatest influence in the forage production of this cultivar, with regard to TDM, since the number of tillers can increase biomass accumulation.

Among the genotypes, Massai showed the best leaf:stem ratio. The positive response of this grass to this characteristic may be associated with its morphology composed of thin stems. The leaf:stem ratio is an important characteristic used in the evaluation of forage plants, as it represents changes in plant components in case of stress. Thus, when a given treatment favours or impairs the production of leaf dry mass, it is expected that the production of stem dry mass is influenced in the same proportion so that the relationship between these two components is not impaired. Bauer, Pacheco, Chichorro, Vasconcelos, and Pereira (2011) points out that the high leaf:stem ratio represents forage with a higher protein content and digestibility, easier to be grasped by the animals and, consequently, greater animal intake.

The number of tillers showed a significant and quadratic response to the percentage of field capacity (Figure 1). It was observed that the number of tillers was 37.79 and 57.72 for plants cultivated with 20% and 140% field capacity, respectively. The best tiller production was for plants cultivated in irrigated soil at 100% field capacity (58.12). Tillering is an indicator of vigor and persistence of forage plants and can be affected by a number of environmental factors (Matthew, Lemaire, Hamilton, & Hernandez-Garay, 1995), as observed under water stress conditions. In addition, the tiller demography can vary considerably among grasses.

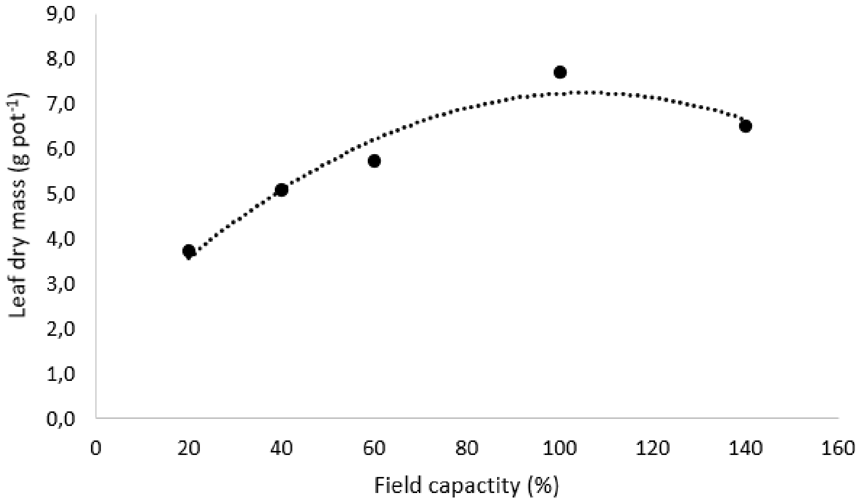


$$Y = 28.31 + 0.5181x - 0.0022x^2 \quad R^2 = 0.8913$$

**Significant at 1% probability

Figure 1. Number of tillers of *Megathyrsus maximus* genotypes subjected to different percentages of field capacity.

Leaf dry mass (LDM) responded quadratically to field capacity percentage (Figure 2). The treatment with 100% field capacity showed the highest LDM production (7.21 g pot^{-1}). Productions of 3.57 g pot^{-1} and 6.22 g pot^{-1} were observed for this characteristic for 20 and 140%, respectively. The lower production of LDM for the treatment with less water availability (20%) may impair forage production of the evaluated genotypes. Mattos, Gomide, and Huaman, (2005b) observed that water deficit also affected the production of leaf dry mass in different species of *Brachiaria*.



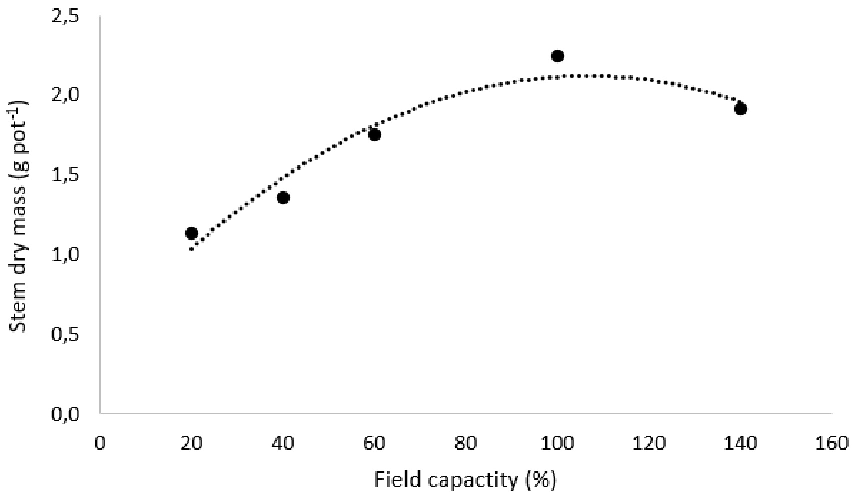
$$Y = 1.6594 + 0.1055x - 0.0005x^2 \quad R^2 = 0.9452$$

**Significant at 1% probability

Figure 2. Leaf dry mass (LDM) in *Megathyrsus maximus* genotypes subjected to different percentages of field capacity.

Leaf dry mass plays a key role in the growth of forages, since the leaf is the photosynthetically most active component in the plant (Parsons, Leafe, Collet, & Stiles, 1983). Martuscello et al. (2006) observed a high correlation between greater leaf production and larger leaf area of plants. In this way, leaf is a fundamental vegetative component of forage plants with regard to animal nutrition, since it presents greater digestibility compared to the stem.

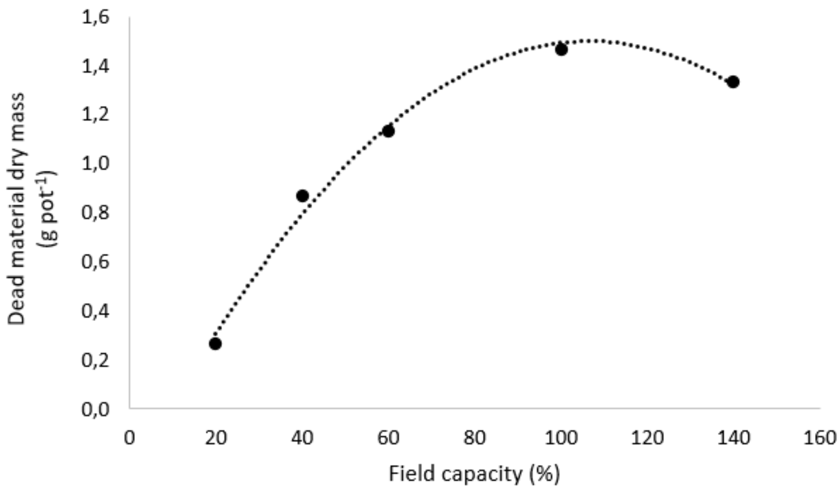
Stem dry mass (SDM) in plants subjected to different percentages of field capacity, responded in a quadratic manner (Figure 3). It was observed that the SDM was 1.04 g pot^{-1} and 1.97 g pot^{-1}, for 20 and 140% of field capacity, respectively. The highest production for this characteristic was for plants subjected to irrigated soil up to 100% field capacity (2.09 g pot^{-1}). A higher production of SDM is not advantageous for genotype selection process, since large proportions of stem can reduce the nutritive value of forage, as a result of the reduction in the leaf:stem ratio.



$$Y = 0.5038088131 + 0.0293412758x - 0.0001348836x^2 \quad R^2 = 0.9404$$
*Significant at 5% probability

Figure 3. Stem dry mass (SDM) in *Megathyrsus maximus* genotypes subjected to different percentage of field capacity.

In Figure 4, the dead material dry mass (DMDM) responded in a quadratic way to the different percentages of field capacity. For plants subjected to water deficit conditions, DMDM production was lower. Lima et al. (2018), evaluating the morphological characteristics of *M. maximus* clones during the regrowth period, after the interruption of irrigation, reported that after one and three weeks there was a tendency to decrease the number of dead leaves.

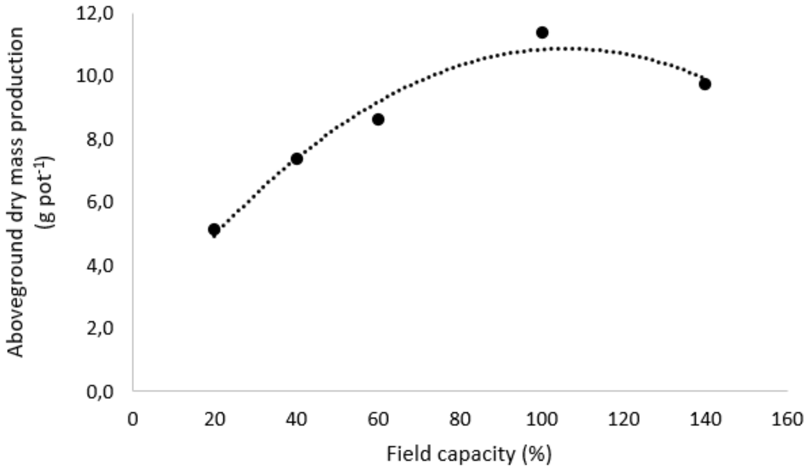


$$Y = -0.2842928216 + 0.0324484719x - 0.0001494314x^2 \quad R^2 = 0.991$$
*Significant at 5% probability

Figure 4. Dead material dry mass (DMDM) in *Megathyrsus maximus* genotypes subjected to different field capacity percentages.

The highest DMDM production was for plants subjected to irrigated soil up to 100% field capacity (1.47 g pot^{-1}). Due to the fact that genotypes were submitted to ideal water availability conditions, the flow of tissues was probably intensified, accelerating the senescence of the genotypes, thus generating a greater accumulation of dead material, since the treatment of 100% field capacity also showed higher production of aboveground DM (Figure 5).

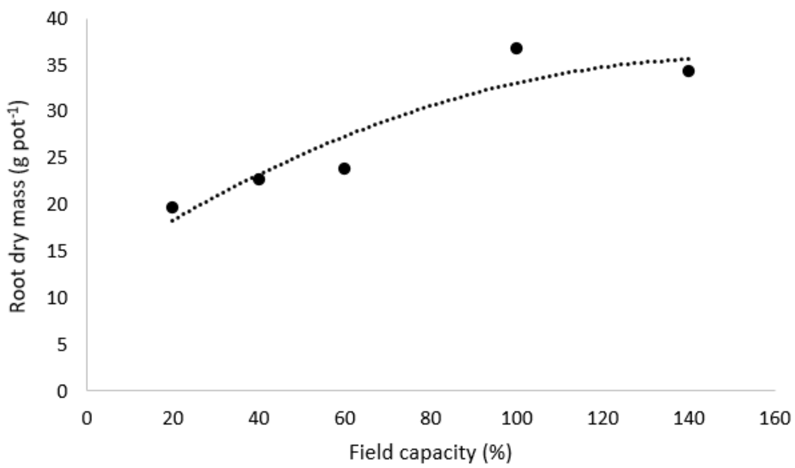
As for the aboveground dry mass production (LDM + SDM + DMDM), the genotypes responded significantly and quadratically to the percentage of field capacity (Figure 5). The aboveground dry mass production (ADM) was 4.95 g pot^{-1} and 10.02 g pot^{-1}, for 20 and 140% field capacity, respectively. The best production for this characteristic was for plants subjected to irrigated soil at 100% field capacity (10.89 g pot^{-1}). Since forage grasses have a high demand for water (Staniak, 2016), genotypes subjected to low water levels in the soil had the most impaired production of ADM.



$$Y = 1.8604 + 0.1703x - 0.0008x^2 \quad R^2 = 0.9691$$
*Significant at 1% probability

Figure 5. Aboveground dry mass (ADM) in *Megathyrsus maximus* genotypes subjected to different field capacity percentages.

Root dry mass (RDM) responded in a quadratic way to the percentage of field capacity (Figure 6). There was a greater DM accumulation of the root system for plants irrigated with 140% field capacity (35.89 g pot^{-1}). When plants are subjected to soil flooding or an anaerobic condition, a variety of morphological and anatomical changes develop in the root system (Liao & Lin, 2001). The plant can develop adventitious roots (Armstrong, Brändle, & Jackson, 1994; Mattos, Gomide, & Huaman, 2005a) that promote an increase in the contact surface between the roots and the environment, which may explain the greater production of dry root mass in excess water conditions in the soil. Although Dias-Filho (2005) points out that such a mechanism, by itself, may not necessarily guarantee the plant's full tolerance to this stress.

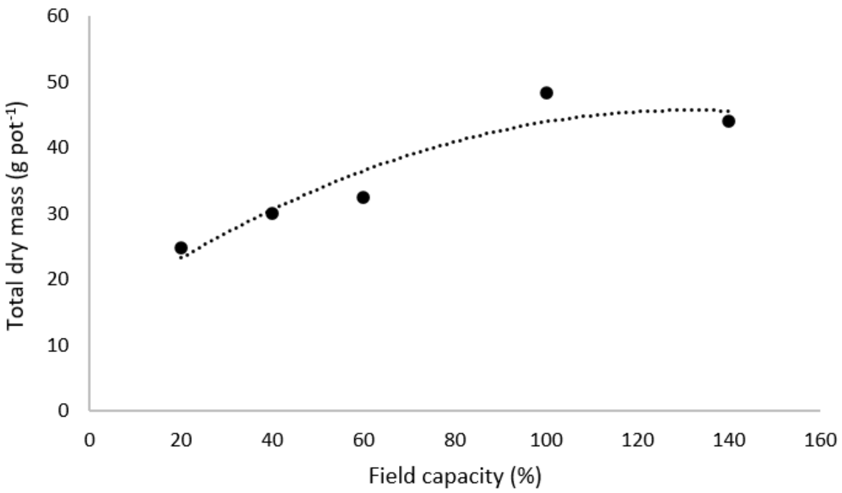


$$Y = 12.591 + 0.3064x - 0.001x^2 \quad R^2 = 0.8697$$
*Significant at 5% probability

Figure 6. Root dry mass (RDM) in *Megathyrsus maximus* genotypes subjected to different percentages of field capacity.

In the present study, the lowest root production was observed in soil with 20% field capacity (18.32 g pot^{-1}). The control treatment (100% field capacity) showed a production of 33.23 g pot^{-1} of root DM. Root production is extremely important in the evaluation of forage plants, as it influences their capacity to exploit nutrients in the soil.

For total dry mass (ADM + RDM), differences with a quadratic response for percentage field capacity were observed (Figure 7). The best DM production was found for plants subjected to irrigated soil at 140% field capacity (45.88 g pot^{-1}), demonstrating that, in general, this water level caused no damage to production. Soils irrigated with 100% field capacity showed 44.09 g pot^{-1} total dry matter. Soils with water deficiency (60, 40 and 20% field capacity) showed lower values, 36.54 g pot^{-1}, 30.61 g pot^{-1} and 23.23 g pot^{-1}, respectively. As with most of the characteristics evaluated in this study, the total dry mass is more negatively influenced by water scarcity than by excess water in the soil.



$$Y = 14.421 + 0.4767x - 0.0018x^2 \quad R^2 = 0.8969$$

**Significant at 1% probability

Figure 7. Total dry mass (TDM) in *Megathyrsus maximus* genotypes subjected to different percentages of field capacity.

In general, all characteristics were more affected by water deficit than by excess water. As an example, the most severe level of water deficit reduced the number of tillers by 35% compared to the most severe level of water excess (140% field capacity). Genotypes like Massai with better population dynamics of tillers favor tolerance to stress due to water deficit (Veras et al., 2020). For the aboveground dry mass, which represents the sum of dry matter production of all components, this reduction was even more drastic (50.6%).

Conclusion

The cultivar Massai showed better forage production compared to the other genotypes, regardless of the field capacity percentage evaluated.

The evaluated genotypes were, in general, more tolerant to water stress due to flooding than to water deficit.

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