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RESEARCH ARTICLE

# INITIAL GROWTH OF MILLET UNDER BULK DENSITY LEVELS IN OXISOL OF THE CERRADO

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ABSTRACT

The millet (*Pennisetum americanum*) is an annual cover crop in increasing use in the Cerrado region. Excessive use of agricultural machinery and inadequate management has caused losses in soil physical quality. Research has shown that besides being effective as ground cover, millet has shown ability to break through compacted layers. This study aimed to evaluate the growth and yield of millet plants subjected to levels of soil compaction. The experiment was carried out in a greenhouse using a completely randomized design. The treatments consisted of five levels of soil densities: 1.0, 1.2, 1.4, 1.6, 1.8 Mg $m^{-3}$ with four replications. The recipients were built with PVC pipes of 200 mm diameter. The collection of the experiment was performed at 34 days after sowing and the variables analysed were: chlorophyll index, plant height, number of leaves and tillers, length and stem diameter, dry mass of leaves, stems and roots. All variables were subjected to analysis of variance and regression test at 0.05 probability. The bulk density of the Oxisol that provided the best development of millet plants varied between 1.0 to 1.4 Mg $m^{-3}$.



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## INTRODUCTION

Millet (*Pennisetum americanum*) is an annual summer crop, used for forage production and yield of grains (Gonçalves *et al*., 2006). Pearl millet is grown in the offseason because of their rapid growth, elevated biomass production and nutrient cycling, even under conditions of water deficit (Pacheco *et al*., 2011). The area planted with millet has increased, mainly in Cerrado region, due to the high potential for soil coverage offered for the practice of tillage as well as for use as in livestock forage (Pereira Filho *et al*., 2003). While cover crop, millet provides erosion control, reduces weed infestation, soil temperature attenuates and maintains moisture of that (Netto *et al*., 2008). The mechanization and intensification of productive processes in the agricultural sector, due to technological advances, promoted, in many cases, a worsening in the degradation of the physical quality of soils, commonly diagnosed as an increase in the degree of compaction of the soil layers (Piffer and Benez, 2005, Bergamin *et al*., 2010), these hardened and impervious layers that are situated generally between 5 and 30 cm deep, with a thickness between 5 and 15 cm (Nascimento *et al*., 2010). Inadequate soil cultivation alters the physical attributes in relation to unimproved land, which justifies the need to quantify and qualify the structural conditions of soil, for in this manner, get up information on the effectiveness of soil management and their influence on the productivity of crop (Rossetti and Centurion, 2013). Layers of compacted soil reduces infiltration rate of the soil water, which according to Zwirtes *et al*. (2011), saturate with water, even with little amount of pluvial precipitation, causing the occurrence of surface runoff losses with solid soil particles and nutrients. The growth of root system and aerial part of plants is influenced by several soil physical attributes (Freddi *et al*., 2008). The determination of critical values for soil density has countless obstacles because they are not direct determinants of plant growth (Bonini *et al*., 2011). According to Pereira Filho *et al*. (2003) when the millet is used as a ground cover plant, plays the role of a "bomb" recycler of nutrients and, depending on the level of soil fertility, can even dispense fertilizing to their full growth and development taking advantage of the residual fertilizer from the previous crop, usually corn or soybeans. On the other hand, papers in the literature have pointed out that depending on levels of soil compaction, nutrients may be present in the system in ways unavailable due

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to reduced aeration and the availability of water (Tormena *et al*., 2002; Medeiros *et al*., 2005; Bonfim-Silva *et al*., 2011). Thus, the objective of the present study was to evaluate the growth the initial development of millet plants subjected to compression levels in a typical Cerrado Oxisol.

## MATERIALS AND METHODS

The experiment was conducted in a greenhouse the period of March to June 2011. The culture was used to cultivate millet ADR 300. The experimental design was completely randomized with four replications and five levels of soil compaction, bulk density, corresponding to: 1.0; 1.2; 1.4; 1.6 e 1.8 Mg m$^{-3}$. The soil used was typical Oxisol, collected at 0-20 cm depth in the area of the Cerrado region of Rondonópolis-MT. The chemical and granulometric analyzes were performed according to EMBRAPA (1997) (Table 1).

The fertilizers were incorporated into the soil to form homogeneous. Up to 10 days after sowing, the soil moisture was maintained by surface irrigation; from this moment the water supply to the system is given by adding him water in plastic dishes placed under the pots. The supply of water by capillarity had the objective provide the plants, the need to break up the compacted layer in search of water in depth. The fertilization with nitrogen was 200 mg dm$^{-3}$, split in three applications at 10, 17 and 25 days after seedling emergence, respectively.

The nitrogen source used was urea. This fertilizer was taken on the soil surface in solutions with a volume of 100 m L in each application. Seven days after plant emergence, there were thinning leaving five plants per pot. The chlorophyll index were determined 22 days after emergence of the plants being performed in diagnostic leaves (leaves +1 and +2).

**Table 1. Chemical analysis and granulometric of the sample Oxisol in the 0-20 cm layer**

| pH | P | K | Ca | Mg | H | Al | SB | CTC | V | OM* | Sand | Silt | Clay |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $CaCl_2$ | mg dm$^{-3}$ | | --------------- cmol$_c$ dm$^{-3}$ -------------- | | | | | | % | g dm$^{-3}$ | ------- g kg$^{-1}$ ------- | | |
| 4.1 | 2.4 | 28 | 0.3 | 0.2 | 4.2 | 1.1 | 0.6 | 5.9 | 9.8 | 22.7 | 549 | 84 | 367 |

*organic matter

The soil was corrected to elevation the base saturation to 60%. After liming, the soil was moistened to field capacity, stored in plastic bags and incubated for 30 days. Simultaneously, were made vessels with pipes PVC (polyvinyl polyvinyl) of 200 mm in diameter, superimposed by two rings of 10 cm each, reaching a height of 20 cm. At the bottom of each plot one antiafideos screen with the aid of air of motor chamber was fixed. For the union of the two rings tape duct tape was used. Plastic dishes were placed at the bottom of the vases to provide irrigation by capillarity. For the realization of soil compaction soil samples were collected and taken to the greenhouse for a period of 24 h at 105 ° C to determination of moisture, this moisture through a correction was carried out to obtain the optimum moisture for compaction. The rings the bottom of were filled with soil at a density of 1.0 Mg m$^{-3}$, while the upper rings were filled with two separate layers, one layer of 5 cm compacted soil in density levels in treatments applied at the bottom of ring and another layer also 5 cm of soil with 1.0 mg m$^{-3}$ at the top. The soil compaction was carried out with the aid of a hydraulic press P15 ST mark Bovenau®. The of soil density was used as a parameter to represent the levels of soil compaction. To determine the mass corresponding to each level of soil compaction is used Eq. 1.

$Ds = Ms/V$(1)

where:

Ds - soil density, Mg m$^{-3}$
Ms - mass of dry soil, Mg
V - volume, m$^3$

The moisture for compaction was defined based on the Proctor test, where moisture of 16% as optimum moisture for compaction was determined. Before assembling the vases with each respective treatments and sowing millet, held fertilization with phosphorus ($P_2O_5$) and potassium ($K_2O$) in quantities of 150 and 80 mg dm$^{-3}$, respectively.

After 34 days of plant emergence to was performed harvest, where the material collected was separated, weighed and sent to oven forced air circulation at 65 ° C for a period of 72 h to obtain constant mass. The variables studied were plant height, stem length and diameter, number of tillers, dry mass of shoots, leaves and roots and chlorophyll index. The results were subjected to analysis of variance and significant test when applied regression testing, both at the 0.05 level of probability by Software SISVAR (Ferreira, 2011).

## RESULTS AND DISCUSSION

The variables plant height and stem length set to the quadratic regression model, with higher results observed in soil density of 1.31 and 1.41 Mg m$^{-3}$, respectively (Figures 1 and 2). These results corroborate with those observed by Freddi *et al*. (2009a) verified that, in the corn crop, that with increasing soil compaction, decreased the plant height. Similarly, Foloni *et al*. (2003) observed after 40 days of cultivation of corn, reduced shoot growth of two cultivars in soil density corresponding to 1.69 Mg m$^{-3}$. Piffer and Benez (2005) also observed a decrease in length of millet plants with increasing soil compaction. Dezordi *et al*. (2013) working with three different vegetable species (millet, *Brachiaria brizanth*a and *Crotalaria spectabilis*), and levels of soil compaction densities from 1,0 to 1,4 Mg m$^{-3}$, observed higher tolerance of millet and brachiaria to different soil compaction, with regard to plant height. The same authors verified that soil density of 1.4 Mg dm$^{-3}$ lower to medium high, with reduction greater than 20% for millet in relation to the lower density of soil at 45 days after sowing. Guimarães and Moreira (2001) working with dryland rice that also observed a decrease in plant height and stem length with increasing soil density. The results of this work confirm that soil compaction is a limiting factor in the growth of shoots of grasses, as observed in the present study. Stem diameter was adjusted to the linear regression model with decreased due to the increased density of soil (Figure 3).

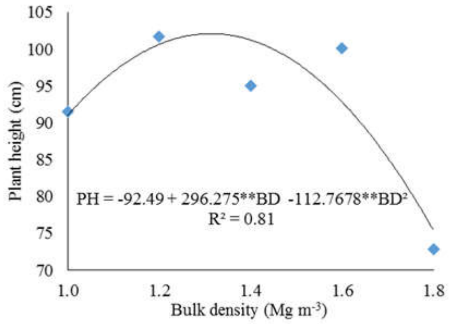


**Figure 1. Plant height of millet plants according to the levels of bulk density in Oxisol. PH - Plant height; BD - Bulk density. ** significant at 0.01**

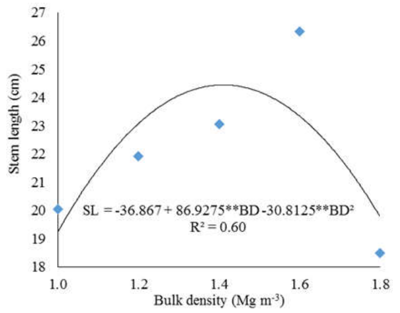


**Figure 2. Stem length of millet plants according to the levels of bulk density in Oxisol. LS - Stem length; BD - Bulk density. ** significant at 0.01**

By comparing the stem diameter of the soil density 1.0 mg $m^{-3}$ with the soil density 1.8 mg $m^{-3}$, it can be observed that there was a reduction of 30% in diameter.

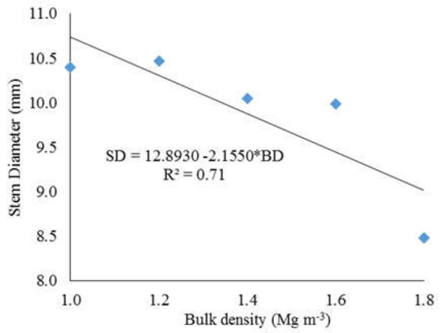


**Figure 3. Stem diameter of millet plants according to the levels of bulk density in Oxisol. SD - Stem diameter; BD - bulk density. * significant at 0.05**

The stem performs an important role in the evaluation of morphological and structural characteristics of plants having sustain function and too the organs of carbohydrate reserves. Thus, plants with stems of greater diameter, in general, are more resistant to lodging. The results of this study are in agreement with those observed by Freddi *et al*. (2009a), in a study with the corn crop where the authors observed that there is linear reduction of 13% in stem diameter with the increase of resistance soil to penetration. It is worth mentioning that resistance to penetration is directly related to soil density.

The compaction levels contribute to soil nutrients remain available to plant roots can absorb them and that soil compaction can cause stress and that depending on the compaction level can be no physical soil limitations that are too related with the dynamics and uptake of nutrients by plants (Bonfim-Silva *et al*., 2011). For number of tillers of millet plants was adjusted to the linear regression model to decrease with the increase of soil density. Comparing tillering in soil density of 1.0 Mg $dm^{-3}$ with soil density of 1.8 Mg $dm^{-3}$ was reduced by 46.3% (Figure 4).

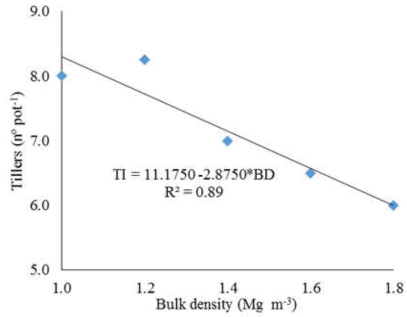


**Figure 4. Number of tillers of millet plants according to the levels of bulk density in Oxisol. TI - Tillers; BD - Bulk density. * and ** significant at 0.01 and 0.05, respectively**

This possibly occurred by reducing the pore space of soil and consequently lower soil exploitation by roots and nutrient uptake by roots which directly influenced the production of grass. These results are in agreement with those observed by Medeiros *et al*. (2005), in which both tillering cultivar of dryland rice that BRS Liderança on a Fluvic Entisol was also negatively influenced by increased soil densities in the interval 1.11 to 1.31 Mg $m^{-3}$, the result of which was also described by linear regression model. Bonfim-Silva *et al*. (2011) studying the culture of wheat under compaction levels found fits the quadratic regression model, with greater tillering in density 1.32 Mg $m^{-3}$. The dry mass of shoot (leaves + stem) and leaves of millet was adjusted to the quadratic regression model (Figures 5 and 6). It can be observed that the highest yields were at densities of 1.31 and 1.28 Mg $m^{-3}$, respectively.

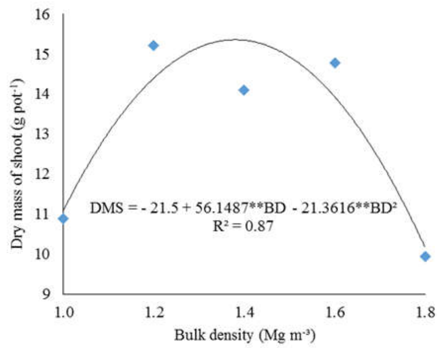


**Figure 5. Dry mass of shoot of millet plants according to the levels of bulk density in Oxisol. DMS - Dry mass of shoot; BD - Bulk density. ** significant at 0.01**

These results corroborate those Bonfim-Silva *et al*. (2011), who reported that in compacted soils a lot can occur quickly depletion of water and nutrients available to the root system that exploits a small volume of soil, reflecting the production of the aerial part.

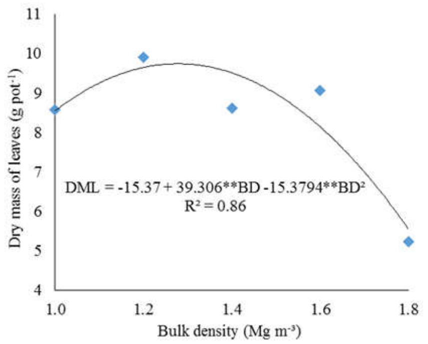


**Figure 6. Dry mass of leaves of millet plants according to the levels of bulk density in Oxisol. DML - Dry mass of leaves; BD - Bulk density. ** significant at 0.01**

These authors also concluded that the limitation on structural development and production of wheat plants in the Cerrado Oxisol under compaction levels takes place from the soil density of 1.3 Mg $m^{-3}$. Guimarães and Moreira (2001) working with dryland rice that consisted 35% reduction in dry mass of shoots with increasing soil density. Bonfim-Silva *et al.* (2012) observed that compaction negatively influenced the dry matter production of shoots of grass Marandu, thus having a downward adjustment of the linear regression model. The dry mass of roots of millet was adjusted to the quadratic regression model, with lower production observed in the soil with a density of 1.33 Mg $m^{-3}$ (Figure 7).

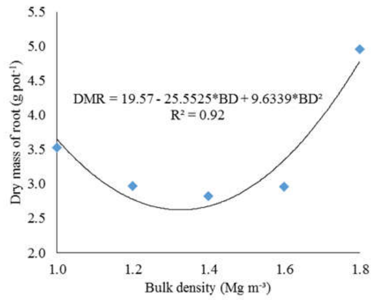


**Figure 7. Dry mass of root of millet plants according to the levels of bulk density in Oxisol. DMR - Dry mass of root; BD - Bulk density. * significant at 0.05**

In the present study, we observed that, in a general way, soil compaction provided larger volume of millet roots near the soil surface due to restriction on root growth in depth. These results are different from observed by Medeiros *et al.* (2005), which have reported that the production of roots by the rice crop due to the interaction of compaction levels and the management of water in the soil resulted in a decreasing linear function, except in saturated soil conditions, where the dry mass roots provided a quadratic regression model, being 1.17 Mg $dm^{-3}$ the critical density for the production of this variable. On the other hand, Nunes *et al.* (2016) did not observe the interaction between water management and soil density levels on dry matter production of roots of maize culture and increasing levels of soil density was a limiting factor for the root development of the culture of corn, differing of the results found in this study.

In this context, Rosolem *et al.* (2002) found that species of millet and sorghum demonstrated the greatest potential for use as cover crops in compacted soils, because of higher root length than other species. However, these same authors found that the root development of these species is impaired with increased resistance to soil penetration. According to Jimenez *et al.* (2008), in compacted soil macropore volume is reduced by increasing the physical strength the penetration of roots. Gonçalves *et al.* (2006) evaluated four species of grasses observed that millet stood out among the studied species how much the accumulation of root dry weight, in the compacted layer at the bottom, the highest level of compaction. These results highlight the potential growth of millet in compacted soils. Miransari *et al.* (2009) found limitations in the nutrition of corn in compacted soil. On the other side of Freddi *et al.* (2009b) observed a positive linear correlation between resistance to penetration and the dry mass matter of corn roots at a depth of 10-20 cm. According Dezordi *et al.* (2013) the millet can provide in the soil in these conditions greater lengths of pores after the decomposition process. These pores are important for water infiltration and diffusion of gases, contributing to the improvement of soil physical conditions and to better root growth of the species in sequence.

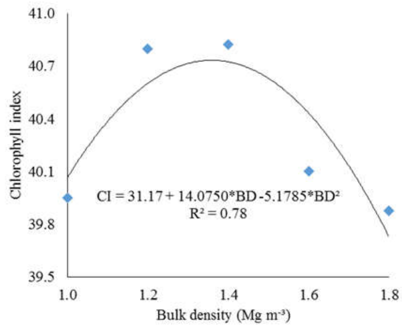


**Figure 8. Chlorophyll index of millet plants according to the levels of bulk density in Oxisol. CI - Chlorophyll index; BD - Bulk density. * significant at 0.05**

For the results of the chlorophyll index was adjusted to quadratic regression model with higher reading observed in density 1.36 Mg $m^{-3}$ (Figure 8), considering that upper and lower soil densities indicate content less chlorophyll. Thus, the density of 1.36 Mg $m^{-3}$ can be considered as critical point, the compaction with higher or lesser intensity may be limiting for nitrogen absorption, by be the chlorophyll index has a high correlation with the concentration nitrogen in plants. This happens because the reduction of the pore diameter of the soil results in increased soil hydraulic conductivity, thus affecting the water retention in the soil and as a consequence the soil-plant interaction (Tavares *et al.*, 2008). Medeiros *et al.* (2005) found that there was reduction in the accumulation of nitrogen in the aerial part of the dryland rice that BRS Liderança with increasing levels of soil compaction, reporting that this is due to the reduction of total porosity limiting soil aeration, decreased infiltration rates that are essential for uptake of water and nutrients to the roots, particularly with respect to nitrogen, wherein the ion-root contact occurs predominantly through mass flow. However, Binghan *et al.* (2010) observed reduction in nitrogen absorption, by barley in density of 1.1 Mg $m^{-3}$; however, when the dose of nitrogen increased, this effect disappeared, demonstrating that the increased fertilization mitigated the consequences of compaction and the need for nitrogen supplied the plant.

## Conclusion

The initial growth of millet plants is influenced by the levels of bulk density. The tiller number and stem diameter showed decreasing linear effect due to increased levels of soil compaction. The values of densities in Oxisol that provided the best growth of plants of millet are amongst 1.0 to 1.41 Mg $m^{-3}$.

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