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Subsurface Soil Compaction and its Effect on the Morphophysiological Characteristics of Maize Plants, *Urochloa ruziziensis* and *Panicum maximum*

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HIGHLIGHTS

- Cover crops benefit soil descompaction.
- *Panicum maximum* is a promising species to be cultivated in compacted soils.
- The corn-*U. ruziziensis* intercrop minimizes the damage of soil compaction to maize plants.

Abstract: The use of cover crops has proved to be a promising strategy in soil decompaction. Thus, the objective was to evaluate the morphophysiological characteristics of maize plants (*Zea mays* L.), *Urochloa ruziziensis* and *Panicum maximum* growing in soil with or without subsurface compaction. The experiment was conducted in a greenhouse, adopting the factorial scheme 4 x 2, being three cover crops (single corn, *U. ruziziensis*, *P. maximum* – BRS Zuri) and a corn-*U. ruziziensis* intercrop grown in soil with and without compaction in the layer of 10-15 cm of depth, with four replications. Physiological and morphological variables and dry matter accumulation of roots and shoots were evaluated. Subsurface compaction reduced the shoot dry mass of *U. ruziziensis*, corn-*U. ruziziensis* and single corn. The *U. ruziziensis* and single corn plants had a reduction in the dry mass of roots in different layers of depth and in conditions of subsurface compaction. The *U. ruziziensis* and *P. maximum* grasses showed higher photosynthetic rate when growing in compacted soil. Corn was the species most sensitive to subsurface compaction, showing the greatest reduction in physiological parameters and biomass accumulation. The corn-*U. ruziziensis* intercrop minimizes the damage of soil compaction to maize plants. *P. maximum* grass is a promising species to be cultivated in compacted soils, as it demonstrates good adaptability and resistance to this condition; the *U. ruziziensis* is an efficient species in soils without subsurface compaction.

Keywords: conservative management; cover crops; biomass; photosynthetic and transpiration rates.

INTRODUCTION

Agriculture is one of the flagships of the world economy, being very developed in the Midwest region of Brazil with the cultivation, mainly, of soybean and corn. In view of the search for more sustainable agriculture, the adoption of conservation management has increased, mainly in areas with flat to slightly undulating relief, in soils with low natural fertility and acidic pH, as is the case of soils in the Brazilian Center-West region [1]. The adoption of soil conservative systems has increased the fertility of agricultural areas. In addition to the aspects related to fertility, the adoption of the no-tillage system has reduced the erosive processes frequently observed in areas under conventional soil tillage [2].

Although the no-tillage system mitigates the erosive effects caused by rains and winds, there is a recurring concern with the degree of soil compaction. The use of heavy machinery in planting and harvesting operations in moist soil may intensify soil compaction, compromising porosity, water infiltration in the soil profile and its surface runoff. These factors together can intensify soil erosion even in conservative systems [3]. This situation is further aggravated by intensive land use in the Brazilian Midwest region due to the regular distribution of rainfall only in the period between October and April, which restricts the successive cultivation of soybeans and corn in short time windows for planting and harvesting. This means that a large number of operations are carried out with large and heavy machines in a short space of time, which increases the pressure on the soil, resulting in its compaction [4].

The use of cover crops is an alternative to assist in soil decompaction, as the root system of plants can perform soil descompaction as they grow in search of nutrients and water in the deeper layers [5, 6]. In addition to the benefits on soil decompaction and structuring, the use of cover crops improves the chemical and biological attributes of the soil, as well as a less costly mechanism than mechanical decompaction. The contribution of organic carbon to the soil is another benefit, a recommended practice for greater sustainability of agricultural systems [7, 8, 9].

The choice of cover species adapted to the edaphoclimatic and agronomic system of each region is essential to ensure the desired environmental and economic returns, as the insertion of incompatible species might result in competition with the main crop [10, 11], reducing productivity and biomass accumulation. Another important factor is the choice for crops of rapid establishment and higher phytomass production, both for soil cover and for nutrient cycling taking into account the release of these for subsequent crops [12].

Genus *Urochloa* and *Panicum* have been evaluated for their potential use as cover crops [13, 14]. They are species with a C4 photosynthetic cycle, accumulating large amounts of carbon in their biomass in a short period of time. The C4 photosynthetic metabolism favors the growth and development of these plants in conditions of lower water availability [15], a frequent condition in the agricultural off-season of the Brazilian Midwest in which they are implemented (after summer cultivation). Another important characteristic of these species for carbon input in the agricultural system is the chemical shoot tissues composition, as they have a high C/N ratio in their leaves and stems, which provides a slow rate of decomposition of their plant remains, even in tropical climate conditions [16]. When grown in intercropping systems, the main strategy used is the maize cultivation (*Zea mays* L.) intercropped with cover crop, using either *Urochloa* or *Panicum*. The maize intercropped with any of these two species has already been evaluated for soil benefits, without compromising productivity of the main crop [17, 18].

The objective was to evaluate the morphophysiological characteristics of maize plants, *Urochloa ruziziensis* and *Panicum maximum* grown in soil with or without subsurface compaction in greenhouse.

MATERIAL AND METHODS

Location, design and development of the research

The experiment was installed and conducted in Rio Verde County – GO (Latitude: 17° 47' 53" and longitude: 51° 55' 53"), from December 2021 to May 2022. The experimental design was completely randomized, with 8 treatments, in a 4 x 2 factorial scheme, with four replications. The first factor consisted of species cultivation: *U. ruziziensis*, *P. maximum* - BRS Zuri, single maize and maize intercropped with *U. ruziziensis* (corn-*U. ruziziensis*). The second factor was constituted by the presence or absence of compacted layer between 10 and 15 cm deep.

Rigid PVC pipes of 200 mm with a volume of 16 liters were filled with soil, and then three seeds of each species were sown. Ten days after emergence, only the most vigorous seedling was maintained, and the others were eliminated, except for the intercropped in which was kept one seedling of each species, remaining in a greenhouse for 52 days. The tubes were divided into three sections, with the following

dimensions: 0 to 15, 15 to 30 and 30 to 50 cm deep. The tubes were filled with soil from the forest area located at the University of Rio Verde, from horizon A of a dystroferic Red Latosol (Oxisol) of clayey texture, collected in the 0-20 cm layer. The chosen soil presented adequate drainage and never had human intervention.

The soil was air-dried and sieved in 2 mm mesh sieves for chemical and textural characterization [19]. Based on the result of the analysis: $\text{Ca} = 0.39 \text{ cmol}_c \text{ dm}^{-3}$, $\text{K} = 0.20 \text{ cmol}_c \text{ dm}^{-3}$, $\text{Mg} = 0.22 \text{ cmol}_c \text{ dm}^{-3}$, $\text{P} = 0.76 \text{ mg dm}^{-3}$, $\text{Al} = 1.00 \text{ cmol}_c \text{ dm}^{-3}$, $\text{H} + \text{Al} = 9.41 \text{ cmol}_c \text{ dm}^{-3}$, $\text{M.O} = 28.59 \text{ g kg}^{-1}$, $\text{pH CaCl}_2 = 4.08$, $\text{V}\% = 55.54$, $\text{m}\% = 6.57$, $\text{CEC} = 12.19 \text{ cmol}_c \text{ dm}^{-3}$, the used soil to fill up the pots was chemically corrected, raising base saturation to 60 %, using limestone with 24 % CaO , 11 % MgO and $\text{ECCE} = 100 \%$. After that, the soil was incubated for 30 days, with humidity preserved close to 60 % of the total pore volume (TPV). Then, the soil was fertilized with macro and micronutrients for pot assays [20]. Nutrients were added to the pots using a pipette. The nutrient requirements corresponded to: $\text{P} = 250 \text{ mg dm}^{-3}$, $\text{S} = 60 \text{ mg dm}^{-3}$, $\text{Cu} = 1.5 \text{ mg dm}^{-3}$, $\text{B} = 0.5 \text{ mg dm}^{-3}$, $\text{Mo} = 0.15 \text{ mg dm}^{-3}$, $\text{Zn} = 5 \text{ mg dm}^{-3}$, $\text{Mn} = 3.6 \text{ mg dm}^{-3}$, $\text{K} = 75 \text{ mg dm}^{-3}$. Side-dressing fertilization with N (200 kg ha^{-1}) was performed 20 days after emergence.

The compacted layer was established between 10 and 15 cm, with bulk density of 1.65 mg m^{-3} . These values were selected from the work developed by Guimarães and coauthors [21]. The chosen density is a critical density that indicates severe soil physical constraints. The soil was pressed with moisture of 18.13 % by means of a hydraulic press. A force equivalent to approximately 800 kg or 0.8 tons force was used.

To determine the amount of soil pressed at a depth of 10 to 15 cm, the equations $V = \pi \cdot r^2 \cdot h$ were used to calculate the volume of the pot, where: V = volume, r = radius; h = height. Then, the mass was calculated with the equation $d = m/v$, where: d = density, m = mass; v = volume. The value of 2.5 kg of soil was reached to be pressed in the layer of 10 to 15 cm.

After filling up the pots, the soil was irrigated daily to maintain humidity at 60 % of field capacity during the experiment. All treatments were irrigated with the same volume of water.

Gas exchange

Plant gas exchange was evaluated to record photosynthetic (A , $\mu\text{mol m}^{-2} \text{ s}^{-1}$) and transpiration (E , $\text{mmol m}^{-2} \text{ s}^{-1}$) rates, using a portable infrared gas analyzer (IRGA) model CI-340 (CID Biosciences Inc., Camas, WA, USA), at room temperature ($26 \pm 2 \text{ }^\circ\text{C}$), with photon flux density adjusted to $1500 \mu\text{mol m}^{-2} \text{ s}^{-1}$ in the leaf chamber. In addition, the instantaneous efficiency of water use was determined by calculating the A/E ratio.

Shoot dry biomass

The plants were cut close to the soil and the plant material was placed in a forced air circulation oven at $65 \text{ }^\circ\text{C}$, until it reached constant weight. Then, the dry mass of the shoot was weighed on an analytical and precision balance.

Root analysis

The soil containing the roots was removed from the pots and submerged in containers with water for at least 30 minutes to facilitate the process of washing the roots. The root system was washed in running water over a one-millimeter mesh sieve, and divided into three parts according to the layers of each pot. After the washing process the fresh mass of the root system was determined and then the roots were stored in plastic bags containing a solution of ethanol (350 mL of ethanol per liter of water), to avoid dehydration [22].

The analyses of length, density, volume and root area were achieved by using the Sapphire program coupled to a scanner of the Iphone 11 device. The representative subsamples of the root system were obtained by the following steps: (I) cutting the complete root system into pieces of 10 mm in length; (II) staining the root segments by soaking it into 0.1 % methylene blue solution for 15 minutes.; (III) the segments were placed in a mixture device filled with water of 18 L; and (IV) subsamples of 0.5 g of roots were collected and the remaining material was returned to the mixing system [22]. The subsampling process was repeated as many times as necessary to collect all subsamples from the root system. The root samples were placed in an acrylic tray (200 mm x 300 mm) with a 4 mm water slide and the roots were untangled in order to avoid overlapping. Subsequently, the tray was positioned in front of the scanner. The images were then digitized using the Sapphire program [22].

The plant material was dried in a forced air circulation oven at $65 \text{ }^\circ\text{C}$ to obtain the biomass of the dry matter of the roots.

Photosynthetic and transpiration rate

Photosynthetic and transpiration rates were analyzed only for plants of *U. ruziziensis*, maize and *P. maximum* grown in isolation (single). The photosynthetic and transpiratory rates of the intercropped treatment were not analyzed, since it is not ideal to use average data of the sum of two species as well for not having a treatment with corn intercropped with *P. maximum*, since maize is a commercial crop.

Statistical analysis

The obtained data were submitted to the t-test (SIGMAPLOT 14.5). Having significant differences, the means were compared by Tukey's test ($p < 0.05$) using statistical Sisvar software [23].

RESULTS

The shoot dry mass (SDM) of *U. ruziziensis* and maize plants, both in single and intercropping crops, had a significant reduction with subsurface soil compaction, while *P. maximum* plants had increased SDM (Figure 1A). Intercrop planting provided more biomass on the soil surface than plants in single cultivation. Among the species grown individually in the compacted soil, *P. maximum* showed the highest biomass accumulation, followed by *U. ruziziensis* and then maize (Figure 1A).

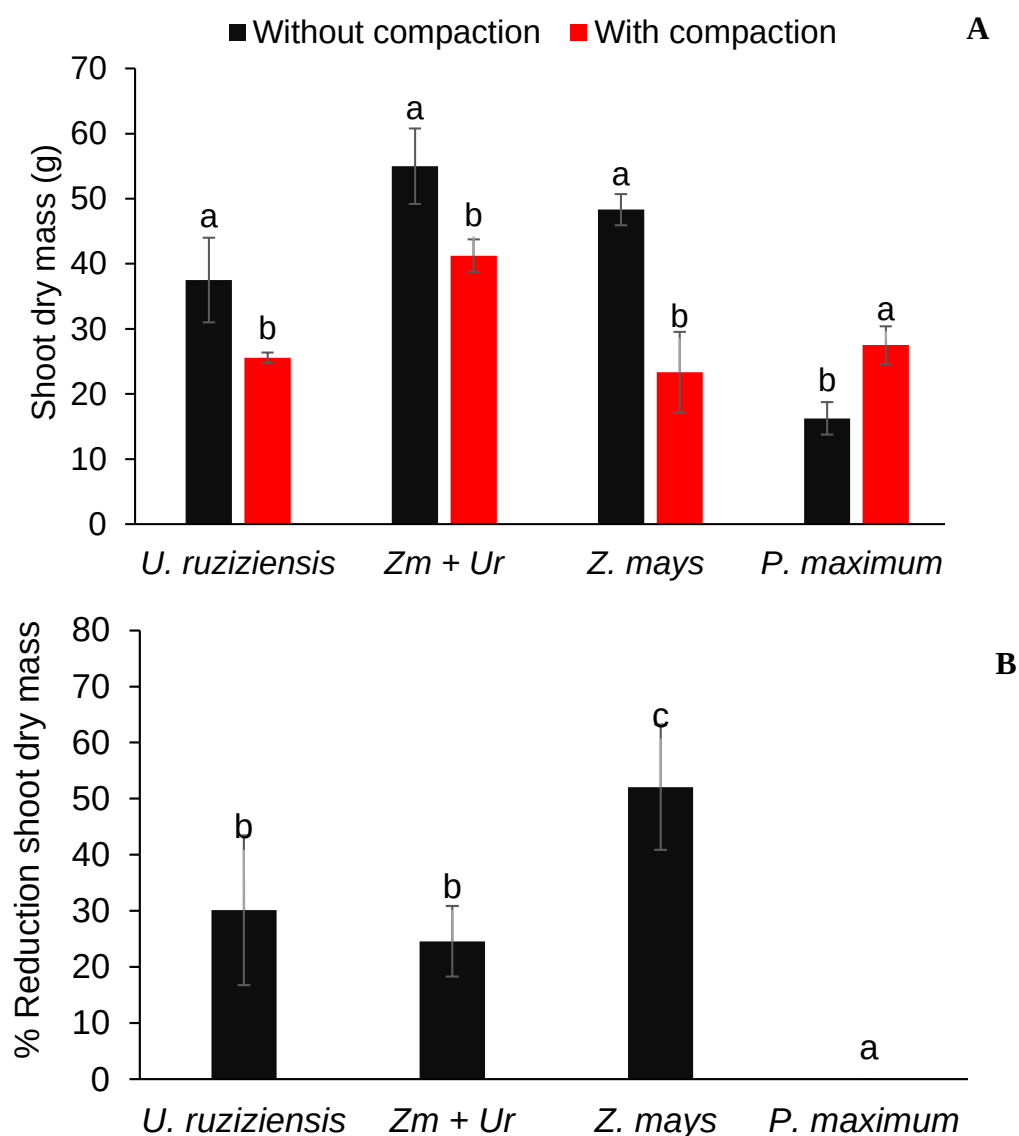


Figure 1. Shoot dry mass (A) and shoot dry mass reduction percentage (B) for maize and forage species as a function of soil without and with compaction. Different letters indicate statistical difference by Tukey test ($p \leq 0.05$). Bars indicate the standard deviation of the mean ($n=4$). *Zm + Ur*: Intercrop (*Z. mays* + *U. ruziziensis*).

The maize plants in single cultivation had the greatest reduction of SDM with soil compaction, with a reduction of 52.1%, followed by *U. ruziziensis* (30.2 %) and the intercropping system (27.5 %) (Figure 1B).

In plants of *U. ruziziensis* the subsurface compaction reduced the accumulation of root dry mass (RDM) in the layers of 0-15 (Figure 2A) and 15-30 cm (Figure 2B) depth, however there was no reduction in the layer of 30-50 cm (Figure 2C). For single maize there was no reduction of RDM in the most superficial layer (0- 15 cm, Figure 2A), but there was in the layers of 15-30 (Figure 2B) and 30-50 cm (Figure 2C). Maize plants intercropped with *U. ruziziensis* did not suffer reduction of RDM in any of the layers.

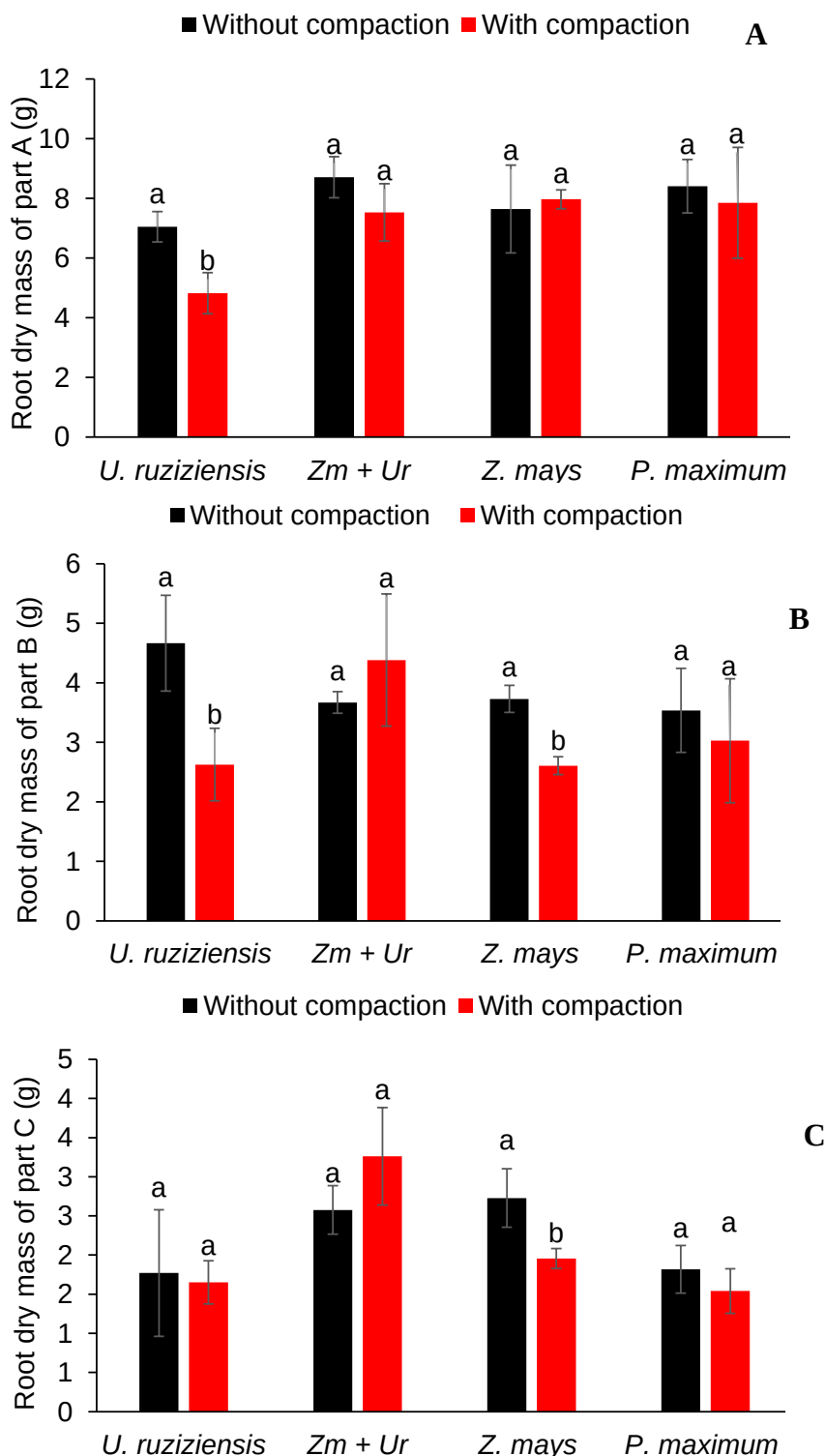


Figure 2. Root dry mass of part A (0-15 cm) (A), B (15-30 cm) (B) and C (30-50 cm) (C) for maize and forage species as a function of soil without and with compaction. Different letters indicate statistical difference by the t-test ($p \leq 0.05$). Bars indicate the standard deviation of the mean ($n=4$). *Zm + Ur*: Intercrop (*Z. mays* + *U. ruziziensis*).

Plants of *U. ruziziensis* had significant reduction of root length (RL) with soil compaction, presenting a reduction of 69 % in the 0-15 cm layer, 80 % in the 15-30 cm layer and 79 % in the 30-50 cm depth layer when compared to cultivation in soil without compaction (Figure 3A). When grown in soil without compaction, *U. ruziziensis* plants had higher RL than the other species, even when cultivated intercropped with *Z. mays* (Figure 3B).

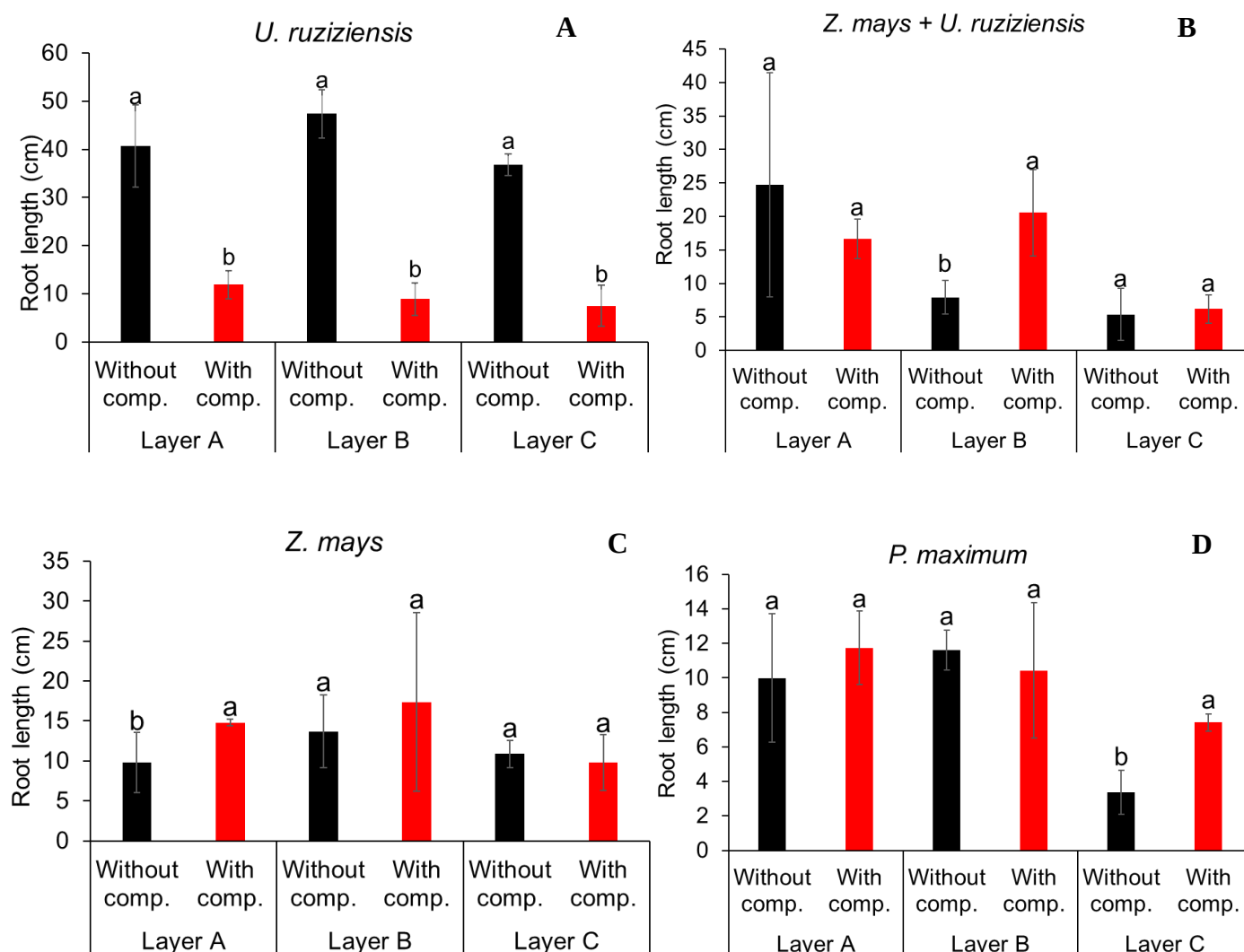


Figure 3. Root length of layers A (0-15 cm), B (15-30 cm) and C (30-50 cm) of maize and forage species as function of soil without and with compaction (comp.). ¹Different letters indicate statistical difference by the t-test ($p \leq 0.05$). Bars indicate the standard deviation of the mean ($n=4$). *Zm + Ur*: Intercrop (*Z. mays* + *U. ruziziensis*).

The RL of plants grown intercropped, in the 0-15 and 30-50 cm layers, had no differences regarding the presence or absence of soil compaction. In the 15-30 cm layer, the compacted environment stimulated the increase of RL (Figure 3B). Compaction favored the root system development of corn in the layer of 0-15 cm, promoting an increase of 69 % in relation to that of plants grown in soil without compaction, and in the other layers there was no difference (Figure 3C). *P. maximum* had its RL increased by soil compaction in the 30-50 cm layer (Figure 3D).

With soil compaction, *U. ruziziensis* roots were reduced in surface area by 93.5; 93.7 and 96.3 % in the 0-15, 15-30 and 30-50 cm layers, respectively (Figure 4A). The root area in intercropped plants, in the 0-15 cm layer, was reduced with soil compaction, while in the 15-30 cm layer the compaction stimulated the root area. In the 30-50 cm layer there was no difference between the root area of plants when grown in soil with or without compaction (Figure 4B). For maize and *Panicum* plants, there was no difference in root area in any layer regarding the presence or absence of soil compaction (Figure 4C and 4B, respectively).

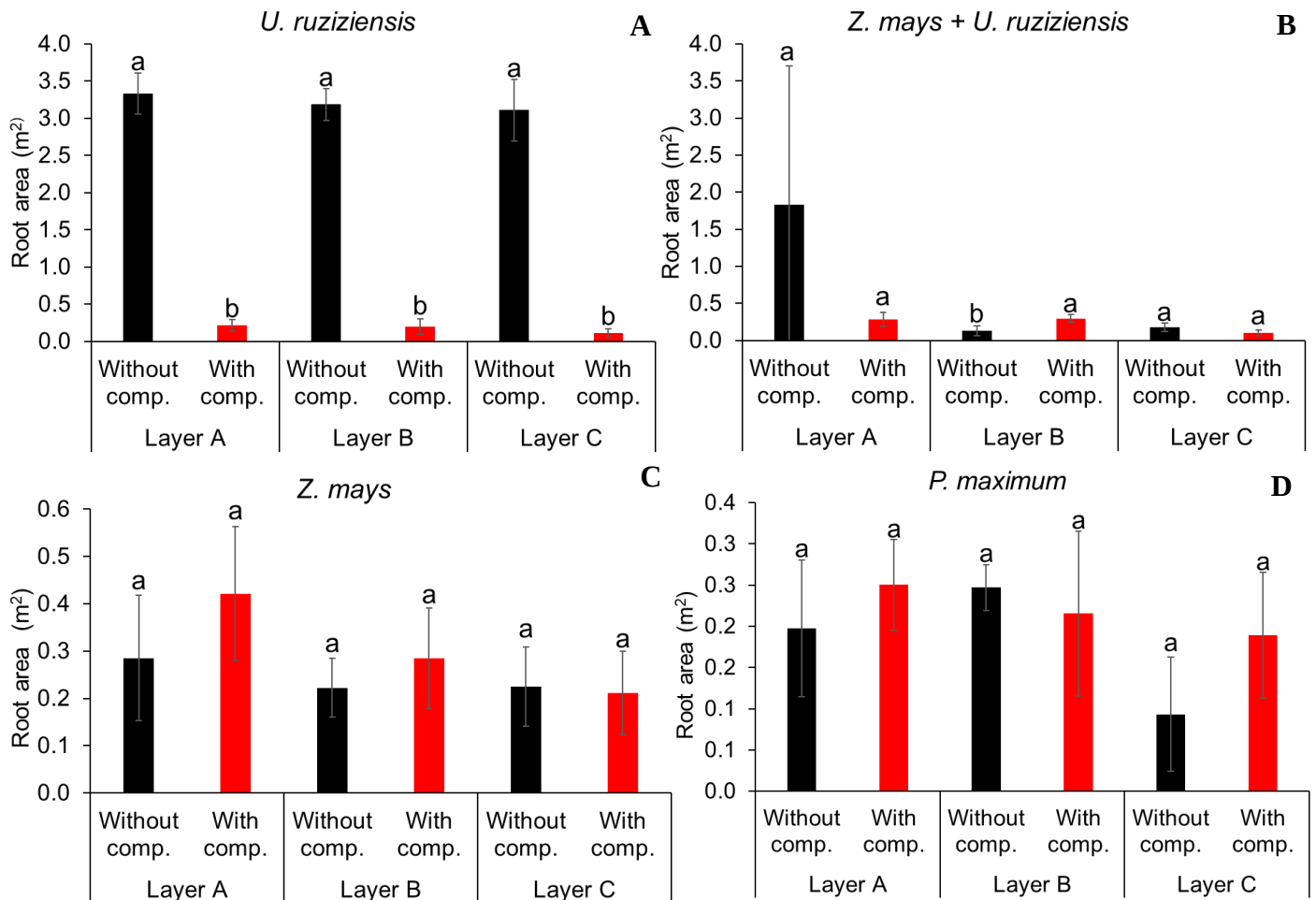
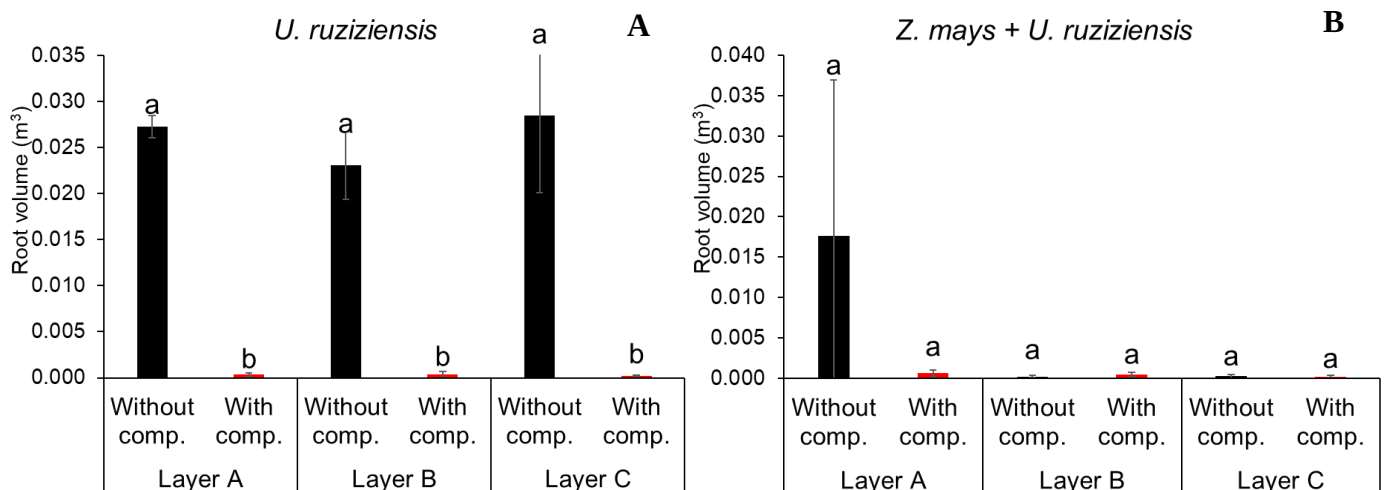


Figure 4. Root area of layers A (0-15 cm), B (15-30 cm) and C (30-50 cm) of maize and forage species as a function of soil without and with compaction (comp.). Different letters indicate statistical difference by the t-test ($p \leq 0.05$). Bars indicate the standard deviation of the mean ($n=4$).

Soil compaction promoted a reduction in root volume of *U. ruziziensis* plants of 98.7, 98.4 and 99.4 % in the 0-15, 15-30 and 30-50 cm layers, respectively (Figure 5A). For single maize (Figure 5C) and in intercropped with *U. ruziziensis* (Figure 5B) there was no effect of soil compaction on root volume. In *P. maximum* plants there was root volume reduction only in the layer of 15-30 cm, and this reduction occurred with plants grown in compacted soil (Figure 5D).



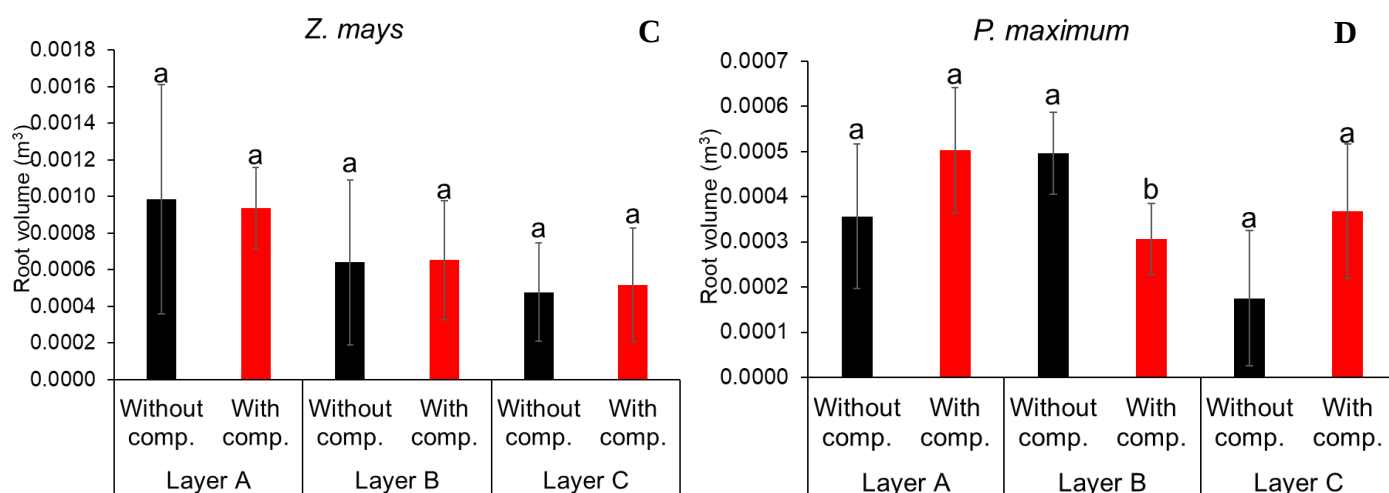


Figure 5. Root volume of parts A (0-15 cm), B (15-30 cm) and C (30-50 cm) of maize and forage species as function of soil without and with compaction (comp.). Different letters indicate statistical difference by the t-test ($p \leq 0.05$). Bars indicate the standard deviation of the mean ($n=4$).

The photosynthetic rates of *U. ruziziensis* and *P. maximum* plants were higher when cultivated in compacted soil. In maize plants, photosynthetic and transpiration rates were higher in soil without compaction (Figure 6).

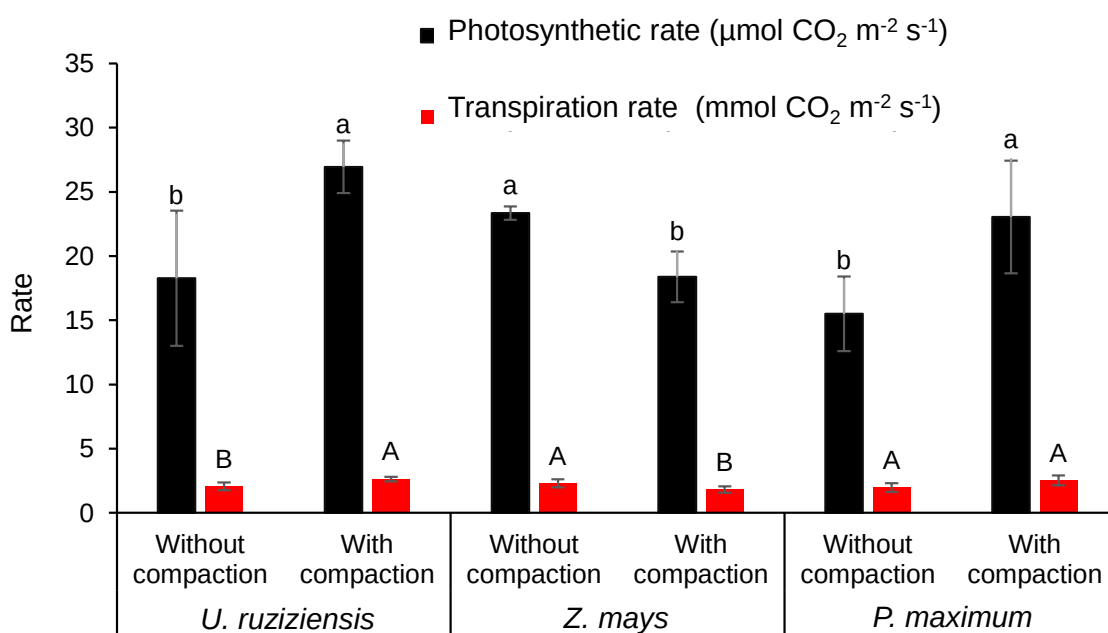


Figure 6. Photosynthetic and transpiration rates of maize and forage species as function of soil without and with compaction. Lowercase letters compare photosynthetic rate between compacted and uncompacted soil for the same species. Capital letters compare transpiration rate between compacted and uncompacted soil for the same species. Bars indicate the standard deviation of the mean ($n=4$).

The transpiration rate of *U. ruziziensis* plants was higher in compacted soil, while for *P. maximum* plants there was no difference between plants grown in soil without or with compaction (Figure 6).

DISCUSSION

Zea mays was the species most sensitive to soil compaction when compared to *U. ruziziensis* and *P. maximum*, presenting the greatest biomass reduction (Figure 1A and 1B). However, maize plants intercropped with *U. ruziziensis* were the ones that had the smallest shoot biomass reduction (Figure 1B) and did not have the root biomass reduced significantly at any depths evaluated (Figure 2). This shows that intercropped planting benefits the main crop development. The root system of *U. ruziziensis* plants is more aggressive in the soil than that of maize, so when growing intercropped, maize plants were benefited.

Cover crops with aggressive root systems benefit corn root growth, improving root activity and crop yield to some extent, confirming the results found in the present study [24]. The corn-*U. ruziziensis* intercrop improves the structural quality of the soil, probably due to the more abundant and aggressive root system of *U. ruziziensis* grass. Therefore, the implementation of this practice decreases soil-related problems [25].

For single maize there was no RDM reduction in the most superficial layer (0-15 cm, Figure 2A), but there was in the 15-30 and 30-50 cm layers (Figure 2B and 2C, respectively). Thus, it is assumed that corn roots spent more energy in breaking the compacted layers affecting the root mass at depth or they were confined in the first layer and did not properly deepen down along the soil profile [26].

P. maximum maintained shoot and root growth even in compacted soil (Figure 1 and 2, respectively). The RDM might be an indication of potential for root growth, so that the higher the RDM the more "aggressive" tends to be the plant root system. This results in opening of galleries in the soil and increases of organic matter content in depth. Roots also influence plant productivity, since they are the main form of nutrients and water supply to the aerial part. Cover crops assist in soil decompaction due to their root system performing soil descompaction in search of nutrients and water in the deeper layers [5, 6].

The fact that subsurface compaction reduced the accumulation of RDM of *U. ruziziensis* plants in the soil surface layers, it did not change these values in conditions of greater depth (30-50 cm). In maize plants the reduction was in the first two layers, hence it suggests that roots of *U. ruziziensis* possibly broke the subsurface compaction, allowing dry mass accumulation in the deeper soil layers. However, breaking the compacted layer required extra plant energy, limiting the accumulation of dry matter on the soil surface. Maize has not demonstrated this ability to overcome the subsurface compaction barrier. Even though both species have a fasciculated root system, the roots of *U. ruziziensis* are more "aggressive" than maize roots. It may be that maize, especially commercial varieties genetically improved for grain production, requires more energy for grain production than for root growth, even more so in an adverse (compacted) environment.

U. ruziziensis plants grown in compacted soil had a significant RL reduction in all evaluated layers. Fontes and coauthors [27] observed a linear reduction in root growth of *U. brizantha* cv. Marandu with the increase in bulk density. This behavior is probably due to increased resistance to soil penetration, promoting physical impediment and, thus, hindering root growth. But when grown in soil without compaction, *U. ruziziensis* is an appropriated choice for cultivation, having higher RL than the other cultivated species (Figure 3A). *U. ruziziensis* have a root system with good soil structuring capacity and good straw input to the system, consequently benefiting subsequent crops [28].

The RL of plants grown intercropped in the 0-15 and 30-50 cm layers had no differences regarding the presence or absence of soil compaction, and in the 15-30 cm layer the compacted environment stimulated the increase of the RL (Figure 3B). This may have occurred because the species were cultivated together, so they compete for resources such as water and nutrients in a limited area, resulting in architecture change of the root system in order to provide greater area of soil exploitation and advantage in competitiveness, because root anatomy has a fundamental role in the acquisition of soil resources [29].

Compaction favored corn root system development in the layer of 0-15 cm, having an increase of 69 % in relation to that of plants grown in soil without compaction, and in the other layers there was no difference (Figure 3C). The compaction in the layer of 10-15 cm depth, may have enforced corn roots take longer to break it, growing more in the most superficial layer. Rosolem and coauthors [30], reported that corn root growth was inhibited by the compacted layer, growing more in the superficial layers, presenting results similar to those of the present study. Maize had reduction of the RDM in the deeper layers (Figure 2C) and for RL the difference was in the most superficial layer (Figure 3C), in which there was RL increase in the most superficial layer under compaction conditions. This may demonstrate that there has been an anatomical change in the roots, making them thinner in the deeper layers.

P. maximum plants, on the other hand, had RL increased by soil compaction in the 30-50 cm layer (Figure 3D). According to Foloni and coauthors [31] the environment with subsurface compaction modifies the distribution of roots along the soil profile, but does not interfere in their production. This behavior is the same as those found in this study, in which plants of corn-*U. ruziziensis* intercropped and *P. maximum* the RDM had no difference between compacted and non-compacted environment. However, the in the layer of 15-30 cm for intercropped plants and layer of 30-50 cm for *P. maximum* plants RL were higher in the compacted environment.

Root area (Figure 4) and volume (Figure 5) tended to follow the root length behavior, in which plants of *U. ruziziensis* had root area and volume reduction in all soil layers after compaction. Maize plants had no reduction, plants intercropped had reduction only for root area in the layer of 15-30 cm (Figure 4B), in which there was an increase in the area with soil compaction, and *P. maximum* plants had only a reduction in root volume in the layer of 15-30 cm (Figure 5D), being impaired by soil compaction. The root area and volume

are important characteristics because they increase the ion-root contact, especially of immobile or poorly mobile elements in the soil [32], improving aggregates and biopores formation, helping both aeration and water storage in the soil.

The photosynthetic rates of *U. ruziziensis* and *P. maximum* plants were higher when grown in compacted soil (Figure 6). The compacted layer may have left the water available longer for the plants, since all treatments were irrigated with the same amount of water. And the treatments in which there was no soil compaction, the water was less available, since it might be drained more quickly along the profile. Thus, in addition to the higher photosynthetic rate, it is possible to analyze the transpiration rate, which for *U. ruziziensis* in compacted soil was higher than in non-compacted soil. For *P. maximum*, there was no difference between the transpiration rate in a compacted and non-compacted environment (Figure 6). Thus, it is believed that there was no occurrence of stomatal limitation.

Photosynthetic and transpiration rates depend on the stomatal opening and both share the same diffusive route [33]. The stomata are a multisensory hydraulic valve that responds greatly to the hydration status of tissues [34]. When water is available, solar radiation and adequate temperature, the stomata open and thus do not impose or impose little resistance to gas exchange – water output in the form of steam (transpiration) and CO₂ input to be fixed (photosynthesis) – process in which it can increase the biomass production of crops. Under conditions of water stress the stomata close making gas exchange and water loss difficult [35].

Maize in a compacted environment reduced its transpiration and photosynthetic rate when compared to the environment without compaction (Figure 6). This behavior was reflected in the shoot dry mass, being the culture that had the most reduction of this variable when compared to the other cultures (Figure 1B). According to Barbosa [36] maize is a crop that presents a high transpiration rate and when daytime temperatures increase its transpiration intensifies. Accordingly, the corn roots cannot immediately replenish the amount of water that their tissues need, causing stress in the hottest hours of the day. Stress may or may not be reversible, depending on the intensity [37].

In the face of stressful conditions, the hydration status of plants decreases, reducing stomatal opening and thus decreasing the diffusion of CO₂ into the tissues and directly affecting photosynthesis. With lower diffusive capacity, there was also a lower transpiration rate. Thus, several plant metabolic processes were affected, resulting in lower production of shoot dry matter (Figure 1A and Figure 6)

Based on the above, it can be inferred that *P. maximum* has a more efficient root system in the replacement of water to the leave tissues, since when cultivated in a compacted environment it presented a higher photosynthetic rate and increased the production of dry mass of shoots (Figure 1A).

CONCLUSIONS

Maize plants intended for grain production are more sensitive to soil compaction than *U. ruziziensis* and *P. maximum*. The corn-*U. ruziziensis* intercrop minimizes the damage of soil compaction to maize plants.

P. maximum is a promising species to be cultivated in compacted soils, demonstrating appropriated adaptability and resistance to this condition. *U. ruziziensis* is a species for cultivation in soils without subsurface compaction, as it has a low capacity to develop in compacted soils.

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