Original Research Article

Soil management in the physical attributes and the wheat crop irrigated productivity

ABSTRACT

The objetive of this work was to evaluate the influence of different soil tillage systems on soil physical properties and the productivity of wheat crop irrigated in the Tangará da Serra-MT. The experimental design was a randomized block split plot with 8 repetitions being considered the treatments 3 kinds of soil tillage system: conventional tillage with 2 disking (1 heavy and light); minimum tillage with a light disking and no-tillage, with two sampling depths (0 - 0,10 and 0,10 – 0,20 m) being at 42 and 97 days after wheat sowing. The soil physical properties were: macro and micro, total porosity, density and resistance to penetration. We also analyzed the productivity of the crop. The soil minimum tillage and the conventional tillage had an increase in the soil macroporosity at 42 days after sowing, when compared to no-tillage. At 97 days after sowing there was no effect of soil tillage and the microporosity keep different in both depths. In depths 0,10 at 0,20 m the soil tillage increase the macroporosity, total porosity and decrease the microporosity at 42 days due the tillage. The resistance to penetration between the conventional and minimum tillage did not differ in depth and both resistance values always remained below to 2 MPa. The productivity of wheat crop showed no difference between soil tillage evaluated.

Keywords: soil physical, soil resistance to penetration, Triticum aestivum.

1. INTRODUCTION

With the increasing demand for an increasing food production being necessary that the soil offers the physical, chemical and natural conditions to express its productive potentialities. Soil management systems can play an important role in the process, as they can influence the physical properties and the development of the crops.

The implantation of irrigated wheat in Mato Grosso, where soybean, cotton and maize predominates, may be an option in the short term to diversify production. According to [1], the wheat presents sensitivity to the structural state of the soil, and the soil preparation should be defined as the most suitable for the establishment of the crop. For [2], the establishment of management practices that optimize the applied inputs and the implantation of the crop can contribute to the increase of the yield of wheat in Brazil.

Changes in physical attributes by soil preparation may lead to changes in crop development and for this reason it is important to study the behavior of each soil management under cerrado conditions. According to [3], some physical attributes linked to the soil structural form and stability, such as density, soil penetration resistance and porosity are used to study the impacts of the use and management on soil physical quality.

The present work was developed with the objective of evaluating the influence of three management systems on the physical attributes and productivity of irrigated wheat, cultivar BRS-254, in the city of Tangará da Serra, MT.

2. MATERIAL AND METHODS

The experiment was carried out in the experimental field of the Mato Grosso Research, Assistance and Rural Extension Company (EMPAER), in the municipality of Tangará da Serra, located southwest of the state of Mato Grosso, in the geographical coordinates, 14º 04 '38 "latitude South, 57º 03 '45 "west longitude and 427m altitude.

The climate of the region, according to the Köppen classification, is predominantly tropical - Awi, with two well-defined periods, that of the rains, which runs from November to March, with the highest index in December and January, and the dry season, which goes from April to October. Rainfall and annual mean temperature are 1,348 mm and 25.2 ° C, respectively.

The soil was characterized as a Red Latosol Distroferric according to the Brazilian System of Classification of Soil-SBCS [4], with clay texture.

The experimental area was kept fallow for approximately one year after the cultivation of the wheat in the previous harvest, so that during the implantation of the management systems there was a large amount of organic matter on the surface.

The wheat crop was sown on June 4 and harvested on September 9, 2011. Seeding was carried out on 15 sow lines with spacing of 0.17 m between rows and 0.05 m between plants. The sowing strips had 6 x 18 m, totaling 108 m2 of area in each treatment. The cultivar BRS-254, of medium cycle (115-125 days) with seed density of 120 seeds.m-1 was used.

Three types of soil management were considered as plot: conventional management (MC) with two gradations (one heavy and one leve) regulated to a depth of 0.17 m; minimum management (MM) with a light harrow regulated to 0.075 m depth; and direct seeding (SD). As a subplot, two soil layers (0 to 0.10 m and 0 to 0.20 m) and two seasons were considered, being at 42 and 97 DAS.

The 6 x 18 m sowing strips presented two passes of the sowing machine, being considered as repetitions of the treatments within each plot. This was done so that the experiment reached the minimum degree of freedom required, following the statistics proposed by [5].

The culture was maintained under irrigation by spraying, with uniform distribution of water over the area, up to 30 DAS to ensure uniform germination and emergence. After 30 DAS, irrigation was made by only one central line, a system known as a line source, which promotes a decreasing gradient of the irrigated blade along the perpendicular distance from the irrigation center line.

With the objective of applying a water depth of 507 mm for the whole crop cycle, the irrigation blade was considered to be 6 to 9 m apart from the center line. The irrigation shift was controlled through the use of tensiometers distributed in the experimental plots, installed in the depths of 0.20 and 0.40 m, and the reading was done daily at seven o'clock in the morning.

The soil physical attributes evaluated were: macro and microporosity, total porosity, soil density and soil resistance to penetration (RSP).

In order to determine the porosity (total, macro and micro) and soil density, undisturbed samples were collected in each plot at depths of 0 to 0.10 and 0.10 to 0.20 m, obtained with a Kopec sampler with a metal ring 50 mm in diameter and 50 mm high. The collection occurred in two seasons, being at 42 and 97 DAS of the wheat.

After the samples were collected in a way that maintained their original characteristics and transported to the Soil Physics Laboratory of the Faculty of Agronomy and Veterinary Medicine of the Federal University of Mato Grosso in Cuiabá-MT. Macro and microporosity analyzes, total porosity and soil density were obtained by the method described by [6].

The soil penetration resistance was evaluated in the layer from 0 to 0.30 m, using an automatic electronic penetration constant penetrator, developed by [7], being collected at 97 DAS, being 5 points around each point collected with the Kopec sampler in each plot

In order to determine the productivity of the BRS-254 irrigated wheat crop, the central plants of each plot were harvested, in a useful area of 2 m2, and the corresponding values transformed in kg ha-1, with moisture corrected to 13%.

The experimental design was in randomized blocks. The treatments to evaluate the soil physical attributes: macro and microporosity, total porosity and soil density were arranged in subdivided plot scheme, with eight replications.

The data were analyzed comparing the two seasons 42 and 97 DAS and the layers 0 to 0.10 and 0.10 to 0.20 m for porosity (total, macro and micro) and soil density.

For the RSP, the standard error bars of the mean for each depth level were considered, since the analysis of variance would require the grouping of acquisition points, obtaining averages of depth intervals, which would reduce the quality of the evaluation of soil resistance in depth. Thus, at the points where the standard error bars are found, there is no difference in RSP at that depth level between managements.

For statistical analysis, the analysis of variance (Test F) was performed, and the means were compared by the Tukey test, for ($p \leq 0.05$), using the Assistat software [8].

3. RESULTS AND DISCUSSION

There was a layer and soil management effect for the variables macroporosity and microporosity ($p < 0.05$) at 42 and 97 DAS, and for total porosity ($p < 0.05$) at 97 DAS. For total porosity at 42 DAS there was interaction ($p < 0.05$) between soil and layer management (Table 1).

Table 1. Mean macroporosity, microporosity and total soil porosity as a function of management systems and days after sowing were evaluated in the 0-0.1 m and 0.1-0.2 m layers.

Managements	0-0,1 m			0,1-0,2 m		
	Macroporosity (%)					
	42 DAS	97 DAS	Mean	42 DAS	97 DAS	Mean
MC	22,8 aA	19,6 aB	21,2 ab	15,6	9,2	12,4 a
MM	22,2 aA	21,4 aA	21,8 a	16,9	8,2	12,6 a
SD	17,4 bB	21,1 aA	19,3 b	15,2	9,5	12,2 a
Mean	20,8 A	20,7 A	**20,7***	15,9 A	8,9 B	**12,4***
	Microporosity (%)					
Managements	42 DAS	97 DAS	Mean	42 DAS	97 DAS	Mean
MC	38,4	41,3	39,8 a	42,2	45,5	43,9 a
MM	38,9	37,9	38,4 a	41,3	47,4	44,3 a
SD	41,1	41,0	41,1 a	42,6	47,5	45,1 a
Mean	39,5 A	40,1 A	**39,8***	42,0 B	46,8 A	**44,4***
	Total Porosity (%)					
Managements	42 DAS	97 DAS	Mean	42 DAS	97 DAS	Mean
MC	61,1	60,9	61,0 a	57,8	54,7	56,3 a
MM	61,1	56,2	58,7 a	58,2	55,5	56,9 a
SD	58,5	62,1	60,3 a	57,8	56,9	57,4 a
Mean	60,3 A	59,7 A	**60,0***	57,9 A	55,7 B	**56,8***

*MC = Conventional management, MM = Minimum management, SD = Direct seeding. Means followed by the same lowercase letter in the column indicates no difference between handles or, upper case in the row, indicates no difference between layers, by the Tukey test (p <0.05). * Average of treatments.*

The MM and MC soil management promoted an increase in macroporosity at 42 DAS when compared to SD. The use of the disk grid in these maneuvers provided higher values (p <0.05) of macroporosity and decreased microporosity in relation to SD, corroborating with the studies carried out by [9], who attributed the highest values of macroporosity in systems with revolving to the persistence of the effects of the mobilization of the soil that results in the breakdown of the aggregates and the development of pores, especially macropores.

The results obtained are in agreement with those of [10], who verified an increase in macroporosity with the soil revolving. Thus, the assertion that soil tillage increases the volume of drainable pores [11] is also confirmed by the results obtained for tillage with this experiment. According to the authors cited in the reference [12] also verified that direct seeding reduces macroporosity, total porosity and increases soil microporosity.

At 97 DAS, the effects of the gradings were no longer verified. This is due to the soil accommodation, which returned to the initial condition, before the action of the grids, and this, may be related to the successive effects of irrigation, which potentiated the soil accommodation and formation of a new condition of structure.

Direct sowing modifies soil conditions at rates and directions different from those observed in management systems that include their rotation [13]. The soil is minimally stirred and the deposition of residues on the surface induces an increase in organic matter [14], which, together with decomposing roots, provides soil structure recovery and greater pore distribution and continuity. The fact is that in the conditions of this work the direct sowing done in the area that was also cultivated with wheat in the previous year and was set aside for one year was not enough to stabilize the SD system. According to the authors cited in the reference [15] during the first three no-tillage system decreases the porosity and the radial development potential of the topsoil and only from the fifth agricultural year does these properties once again grow.

For the effect of a layer independent of the soil management, the macroporosity was higher in the layer up to 0.10 m in both the 42 and the 97 DAS ($p < 0.05$), and the microporosity was higher in the 0.20 m layer for the evaluated ($p < 0.05$). This is probably due to soil mobilization by the grid, which promotes soil disruption and loosening so that macroporosity increases, with consequent increase in total soil porosity. On the other hand, the microporosity, which basically depends on the intra-aggregate pores, was higher in the layer where there was less soil rotation.

With soil accommodation at 97 DAS, microporosity remained different in the two studied layers, demonstrating that the soil rearrangement did not promote significant differences in the micropore volume in the layers and that the time of evaluation was not sufficient for the formation of new aggregates ensure increased micropore volume. This result demonstrates that in soil management, the effect on the increase in macroporosity in the 0 to 0.10 m layer (higher tillage layer) extends until the end of the crop cycle, and in the layer of 0.10 a 0.20 m (thinner layer) there is a marked decrease in macroporosity due to the tendency of the smaller particles of the pulverized soil to settle in the deeper layers, a potent effect with the infiltration of the irrigation water in the systems.

Soil mobilization, according to [15], can drain water more quickly than in management systems with less intensity of mobilization and temporarily influence the availability of water to the plants. Macroporosity determines the aeration capacity of the soil [16] and the results obtained in the 42 DAS suggest that the aeration capacity of the soil followed in ascending order in the management systems SD <MC <MM.

Aeration porosity values below 10% are generally adopted as restrictive for the growth and productivity of most crops, despite the dependence of the plant species and the soil biological activity, so for this experiment, it was observed that all types of management presented critical macroporosity values for the root development of the crop in the 0,10 to 0,20 m layer at 97 DAS. At 42 days, the SD system presented lower values than the others, but greater than 10%.

Considering the averages of the layer-independent management, the porous soil distribution reached values close to those considered ideal, according to [17], which characterize as good quality soil to store water and air, when the porous space in the field capacity presents 2/3 micropores and 1/3 macropores, in relation to the total porosity of the soil.

The data of macroporosity, microporosity and total soil porosity as a function of soil management and days after sowing the wheat crop, evaluated in the 0-0.10 m and 0.10-0.20 m layers are shown in Table 1.

There was a significant interaction ($p < 0.05$) between soil management and DAS for macroporosity in the 0 to 0.10 m layer, and there was no significant effect of soil management as of DAS for microporosity and total porosity in the same layer. In the 0.10 to 0.20 m layer there was a significant effect ($p < 0.05$) of days after sowing (DAS) and soil management for macroporosity, microporosity and total porosity (Table 1).

In the 0 to 0.10 m layer the soil management MM and MC promoted an increase in macroporosity at 42 DAS, when compared to SD, whereas at 97 DAS there were no significant differences between managements. MC increased the macroporosity from 42 to 97 DAS, whereas in MM there were no differences between dates and in SD there was a significant increase of macroporosity from 42 to 97 DAS, agreeing with Tormena et al. (1998) studied the alterations in aeration porosity in no-tillage, observing that over time, even without mobilizing the soil, there was an increase in macroporosity, a fact attributed by them to the action of the root system of the black oat crop. In this study, in the range of 42 to 97 DAS, higher root growth of the wheat crop could be observed in SD, especially in the 0 to 0.10 m layer, favoring the increase of macroporosity in this system.

In the macroporosity evaluated in the layer of 0.10 to 0.20 m there was a significant effect ($p < 0.05$) only of the DAS independent of the soil management where there was a significant decrease ($p < 0.05$) at 97 DAS due , possibly to an effect of accommodation of the smaller particles of the soil revolved in the surface of the soil in the deeper layers, potentiated effect with the infiltration of irrigation water in the soil profile.

For microporosity and total porosity of the soil there was also no significant effect of soil management, however, there was a significant effect of the DAS on these variables. The microporosity presented higher value at 97 DAS ($p < 0.05$) due to the effect of accommodation of the smaller soil fractions, which decreased the macropores of the soil at this date. Total porosity, as well as macroporosity, presented its highest value at 42 DAS, in response to the still recent effect of the soil rotation, which increased the mean soil macropores when the DAS average was evaluated independently of the evaluated managements.

However, there was a significant effect of soil management ($p < 0.05$) and layer ($p < 0.05$) on this variable. Regarding the effect of layer-independent soil management, at 42 DAS, it was observed that the lowest density value was found in the MM followed by MC, and this result can be attributed to the soil rotation and incorporation of residues [18]. These results are consistent with those obtained for the porosity, because in these same management macroporosity was higher. As with the porosity variable, at 97 DAS, the density values practically returned to the initial value before the management intervention. It was verified that the soil density at the end of the crop cycle had an average value around 1.02 kg dm3, similar to the soil density in SD at 42 days, which in this case can be considered as a control, since who did not undergo management intervention. This result demonstrates that 97 DAS in the experimental conditions evaluated is a sufficient time for the soil to re-match and reorganize to a physical condition similar to that of the management without soil rotation.

The mean densities obtained for the independent layer of soil management revealed significant differences at 42 and 97 DAS. In both dates, the lowest soil density value was found in the superficial layer (0 to 0.10 m) as a response to the soil-tossing maneuvers, which decreased the average of the superficial layer and did not cause significant mobilization in the deeper layer (0 , 10 to 0.20 m), which consequently obtained the highest values of density in the two dates evaluated (Table 2 and 3).

Table 2- Mean soil density (kg cm-3), as a function of management and layer, evaluated at 42 and 97 days after sowing.

	Bulk density (kg dm^{-3})

	42 DAS			97 DAS		
	0-0,1 m	0,1-0,2 m	Mean	0-0,1 m	0,1-0,2 m	Mean
MC	0,94	1,01	0,98 ab	0,98	1,09	1,03 a
MM	0,95	0,99	0,97 b	0,98	1,07	1,03 ab
SD	1,00	1,05	1,02 a	0,97	1,03	1,00 b
Média	0,96 B	1,02 A	**0,99***	0,98 B	1,06 A	**1,02***

*MC = Conventional management, MM = Minimum management, SD = Direct seeding. Means followed by the same lowercase letter in the column indicates no difference between handles or, upper case in the row, indicates no difference between layers, by the Tukey test (p <0.05). * Average of treatments.*

Table 3- Mean soil density (kg dm-3), as a function of soil management systems and days after sowing, were evaluated in the 0-0.1 m and 0.1-0.2 m layers.

	Bulk density (kg dm^{-3})					
	0-0,1 m			0,1-0,2 m		
	42 DAS	97 DAS	Mean	42 DAS	97 DAS	Meam
MC	0,94	0,98	0,96 a	1,01 ab B	1,09 a A	1,05 a
MM	0,95	0,98	0,97 a	0,99 b B	1,07 abA	1,03 a
SD	1,00	0,97	0,99 a	1,05 a A	1,03 b A	1,04 a
Mean	0,96 A	0,98 A	**0,97***	1,02 B	1,06 A	**1,04***

*MC = Conventional management, MM = Minimum management, SD = Direct seeding. Means followed by the same lowercase letter in the column indicates no difference between handles or, upper case in the row, indicates no difference between layers, by the Tukey test (p <0.05). * Mean of treatments.*

In the 0 to 0.10 m layer there was no significant interaction (p <0.05) of soil management and DAS on soil density and no effect of these factors on the variable. This result shows that already at 42 DAS the soil had an accommodation after the management change, reaching values close to that found in SD. As no significant difference was found for the means of density independent of management and DAS, then we can infer that under irrigated systems 42 days after the management is a sufficient time interval for total soil resilience, that is, period necessary for the soil reorganize, recovering from the disturbance of the soil management with tilting. This inference is still true when correlated with the results of the analysis of the variables microporosity and total porosity, which also did not present significant effects of soil management or DAS, showing that already at 42 days the soil had already recovered the condition of common porosity of the system.

In the layer of 0.10 to 0.20 m there was interaction between soil management and DAS. At 42 DAS the SD presented the highest soil density value in relation to the studied managements, but at 97 DAS the SD had the lowest density value (p <0.05). The increase in soil density at 97 DAS in the shifting management may have occurred to the detriment of the accommodation of the smaller fragmented soil particles during the rooting in the deeper layers, accommodation is enhanced by the infiltration of the irrigation water into the soil profile, which effect over time generates the process known as foot-of-grid.

Considering that the averages of soil moisture at the time of penetration resistance readings and soil density at the same date did not show significant differences between managements, we can then evaluate the relative differences between the observed RSP values (Figure 1).

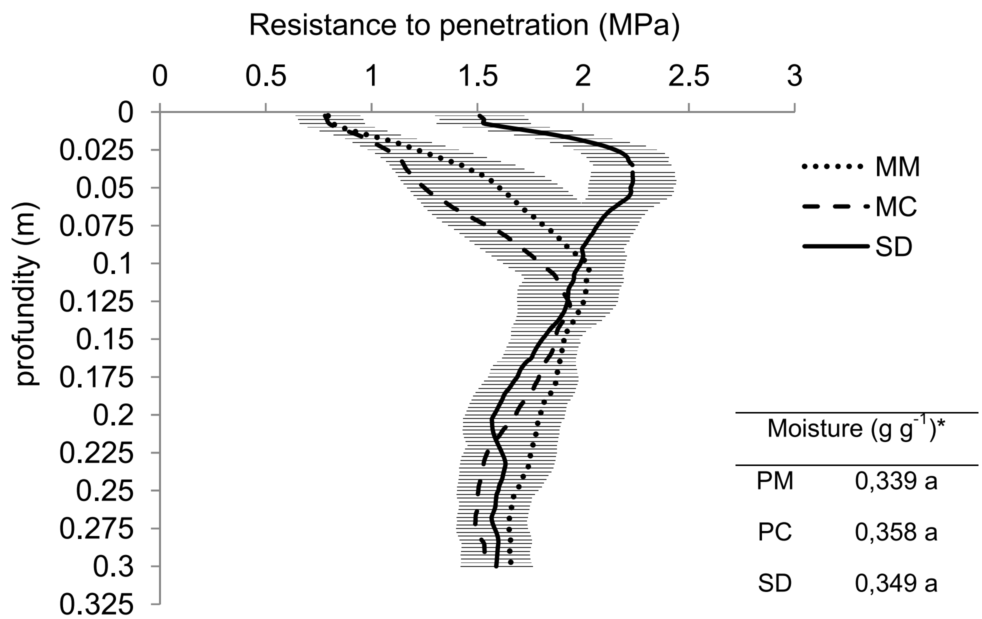

Figure 1. Soil penetration resistance (MPa) of each soil management, evaluated at 97 (DAS) in the 0-0,3 m layer in wheat irrigated in Tangará da Serra, MT. The bars indicate the standard error values of the mean and the overlap of these denotes the absence of differences between the means of the treatments. * Means followed by the same letter do not differ from each other, by the Tukey test (p <0.05).

It was observed that the resistance of the soil to the penetration between the MM and MC did not differ at any point of the depth evaluated, and both maintained resistance values always below 2 MPa. The resistance curve for the MM and MC show that the soil rotation was efficient to the depth of 0.1 m and 0.125 m, respectively, as they present values of RSP lower than those found for the non-mobilized soil. The points from this point remained close to that observed in SD up to a depth of 0.3 m.

The RSP curve for the SD presented statistically different values, according to analysis of the standard error bars of the mean, in relation to the maneuvers with tilting, to the depth of 0.070 m and, from this, there was no difference between the maneuvers. SD had values of resistance between 1.5 and 2 MPa already in the layer of 0 to 0.025 m. Between 0.025 and 0.075 m soil resistance remained with values above 2 MPa, considered not yet limiting for the development of wheat, which according to [19], states that values of RP greater than 3.5 MPa are considered as limiting its growth. From the 0.075 m the RSP presented behavior similar to the other maneuvers. This behavior of higher densities found in SD up to 0.075 m is characteristic, and represents the effect of the pressures exerted by the traffic of machines in the area, which causes this effect of greater soil densification in the superficial layers.

In general, the penetration resistance data made it clear that the soil tillage methods used in the MM and MC were efficient to promote the sowing bed of the crop, necessary for the initial good development of the plants, however, to the above depths of 0.1 m, the plants had similar conditions for root growth in all treatments, finding resistance below the critical value for growth up to the depth of 0.3 m.

The BRS-254 wheat yield did not differ among evaluated soil management (Table 4). The disk grid can promote negative aspects of subsurface compaction (foot-of-grid), and direct seeding in surface compaction. However, according to the results of soil penetration density and resistance, the grid action in MC and MM, and non-soil rotation in SD did not reach values that would limit the development of the crop and the physical attributes of the soil. Similar responses were found by [20 and 21] when evaluating different soil tillage in soybean cultivation. These authors concluded that there was no influence on grain yield, even inducing compaction of the soil by the compactor roller.

	Productivity (Kg/ha^{-1})
MC	2174,8 a
MM	2078,5 a
SD	2196,8 a

Table 4- Average productivity data of irrigated wheat BRS-254, as a function of soil management systems.

Mean	2150,1*
CV (%)	12,41
F	0,2225 ns

*MC = Conventional management, MM = Minimum management, SD = Direct seeding. Means followed by the same lowercase letter in the column indicates no difference between handles or, upper case in the row, indicates no difference between layers, by the Tukey test ($p < 0.05$). * Mean of treatments.*

The positive effect of soil mobilization by the fertilizer sowing mechanisms, which like the grid used in the MC and the MM, mobilize the soil up to approximately 0.1 m depth, facilitated the root growth of the irrigated wheat crop.

4. CONCLUSION

The use of the grid of disks in MC and MM interferes in the attributes of the soil.
Handling with stirring promoted increase in macroporosity and decrease in microporosity up to 42 DAS, but at 97 DAS the effects were no longer verified.
The densities obtained did not influence the yield of irrigated wheat.
The resistance curve for the MM and MC show that the soil rotation was efficient to the depth of 0.1 m and 0.125 m.
Soil management did not influence the yield of irrigated wheat.

COMPETING INTERESTS

We declare that no competing interests exist.

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