Original Article

# PHYSICAL INDICATORS OF SOIL QUALITY OF ALFISOL UNDER CONVENTIONAL SYSTEM OF PHYSIC NUT

## *INDICADORES FÍSICOS DA HQUALIDADE DE ARGISSOLO SOB PLANTIO CONVENCIONAL DE PINHÃO MANSO*

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**ABSTRACT**: The implantation and development of alternative crops to production of biofuel are dependents of soil structural quality. The physic nut has been considered as one of the promising sources of biofuel. The objective of this study was to quantify the influence of use systems on some indicators of soil physical quality and to identify critical values of bulk density and air-filled porosity to crop development of an Alfisol under conventional system of physic nut. For the evaluation of physical indicators of soil quality, samples were collected with disturbed and indisturbed structure in different sampling positions (crop row and interrow). The samples were taken of the layers 0.00 - 0.05; 0.05 - 0.10 and 0.10 - 0.20 m depth. In the conditions of this study, concluded that: i) except to 0.10 to 0.20 m depth, the sampling positions influenced all soil physical parameters; ii) the crop row position presented higher macroporosity and total porosity in 0.00 to 0.10 m depth; iii) the critical air-filled porosity and bulk density values for plant growth were 0.74 and 1.49 Mg $m^{-3}$ and iv) considering the bulk density and air-filled porosity only the crop row position no indicate restrictive values to plants development.

**KEYWORDS**: *Jatropha curcas.* Porosity. Aeration. Aggregation.

## INTRODUCTION

The understanding and quantification of the impact caused by soil use and management system on the soil physical quality are fundamental for the development of sustainable agriculture. The agricultural potential of crops as physic nut may be altered by a number of stress factors that are encountered by roots in their environment.

Recently, researchers have demonstrated the effects of soil fertility (MARTINS et al., 2010) and accumulated of chemical elements in the leaves and fruits of physic nut (LAVIOLA; DIAS, 2008). Studies registered the influence of different levels of wastewater and doses of phosphorus on the productivity and oil content of physic nut seeds (SOUSA et al., 2011). The management system adopted affects the plant growth and agricultural productivity. It is believed that compaction of the agricultural areas affects the physical, chemical and biological properties of soils and has been considered as one of the main causes of agricultural degradation.

The limitation of agricultural production to be depende on soil physical parameter as bulk density, mechanical impedance to root growth and air-filled porosity (LHOTSKÝ et al., 1991; FLOWERS; LAL, 1998). The satured hydraulic conductivity also is one important parameter of soil physical quality (DUNGAN et al., 2007).

The compaction depends on the internal and external factors. The external factors have been the intensity and frequency of heavy machines and stress animal trampling. The internal factors has been the soil texture and soil water content (ASSOULINE et al., 1997; DEFOSSEZ; RICHARD, 2002).

The continuous increases in the weight of farm machinery and the necessity to use heavy machines in unfavorable soil condition have increased the potential of damage (ALAKUKKU et al., 2003; ALAOUI; DISERENS 2011) and consequently the root growth of crops suffered some degree of restriction. However, a favorable environment to plant growth may be obtained by reducing the soil stress factors.

Studies have showed the effect significant of management systems on indicators of soil quality in the crop row and interrow on orchards. Timlin et al. (2001) compared the soil water content dynamics in row and interrow positions in a soybean crop under conventional (plow) tillage. Logsdon et al. (2010) evaluated the effect of corn or soybean row position on soil water. The effects of tillage and intra-row compaction on seedbed properties and red lentil emergence under dry land conditions have been tested (ALTIKAT; CELIK, 2011).

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The bulk density has been extensively used to compare tillage effects on soil structure. Sanches et al. (1999) evaluated the effects of tillage (no-till and conventional tillage) and position relative to the crop (row and interrow) on bulk density and identify whether bulk density variation relative to the crop position is systematic. The authors indicated that bulk density was higher in the interrow position.

Lima et al. (2004) reported that soil parameters was influenced by the traffic intensity on orchard, since that the compaction was different between the sampling positions (canopy projection, interrow and row).

Recently, little is known about soil management may affect physic nut growth. The critical or restrictive values have not been tested. The knowledge of the critical values would help decision about soil management and consequentely, improvements in soil quality for crop growth and yield. It is necessary to increase the studies in these areas to evaluated critical values for crop development. Despite the benefits of tillage for physic nut establishment and production, in the present study we tested the hypothesis that soil physical attributes could be altered by sampling positions (crop row and interrow) on orchards.

However, the objective of this study was to quantify the influence of use systems on some indicators of soil physical quality and to identify critical values of bulk density and air-filled porosity to crop development of an Alfisol under conventional system of physic nut.

## MATERIAL AND METHODS

### Study area

The study was performed in the Embrapa Temperate Climate Research Center, Rio Grande do Sul, state at latitude 31° 41' 10" S, longitude 52°26'00" W (reference coordinates) and altitude 13 m. The climate of the region was classified according to Köepen's classification as Cfa. The area, that has been cultivate with physic nut (PN) (*Jatropha curcas L.*) under Alfisol, with clayed medium texture (B horizon). The soil texture in the 0.20 m (topsoil) is sand loamy (180 g $kg^{-1}$of silt, 670 g $kg^{-1}$ of sand e 150 g $kg^{-1}$ of clay).

The study was stablished in two areas and two sampling positions (row, R and interrow, IR). The first one area was established in August, 2006 ($PN_{1R}$; $PN_{1IR}$) and the other implanted in October, 2007 ($PN_{2R}$, $PN_{2IR}$). The total área of the experiment is 1.024 $m^2$ with absence of crops covering in the crop row position. The crop interrow position presented growth of spontaneous vegetation. The spacing of cultivate rows and crops in the two areas was about of 3 x 2 m, respectively. The management system utilized was conventional tillage of physic nut performed with tractor of 75 CV and with others farms equipments (plow, rotary tiller and offset disk). One adjacent natural area was used as comparation to results obtained. This area has soil, vegetation type, topography and other characteristics representative of the Pampa Biome of south Brazil.

### Soil measurements

In the two areas and two sampling positions (row, R and interrow, IR), the samples were taken on March 2008 in the layers 0.00 – 0.05; 0.05 – 0.10 and 0.10 – 0.20 m depth. A total of ninety (6 field replications x 5 treatments x 3 layers) indisturbed cores (5 cm diameter by 5 cm length) were collected. In this indisturbed samples, the bulk density (BLAKE; HARTGE, 1986), the soil porosity (EMBRAPA, 1997) and the saturated hydraulic conductivity ($K_{\theta S}$) (LIBARDI, 2005) were evaluated. Acoording to Mcbride & Joose (1996) was also evaluated the air-filled porosity using the following equation: AFP = $\frac{Pd}{Bd} - 1$, where Pd: soil particle density (2.58 Mg $m^{-3}$) and Bd: bulk density (Mg $m^{-3}$).

A total of forty five (3 field replications x 5 treatments x 3 layers) disturbed cores were taken of the layers 0.00 – 0.05; 0.05 – 0.10; 0.10 – 0.20 m depth to evaluate the soil particle density (Pd), aggregate stability and mean weigth diameter (YODER, 1936; KEMPER; ROSENAU, 1986; PALMEIRA et al., 1999).

The soil macroaggregates (aggregates > 0.25 mm) and soil microaggregates (aggregates < 0.25 mm) were evaluated using method of Tisdall & Oades (1982).

### Statistical analysis

Analyses of variance and least significant difference were used to evaluate the results. Linear regression analysis between bulk density, air-filled porosity and saturated hydraulic conductivity were also established. The statistical analysis was perfomed using $P < 0.05$ probability level and the SAS software (SAS INSTITUTE, INC., 1991).

## RESULTS AND DISCUSSION

The statistical moments of the parameters obtained are shown in Table 1. The wide range of variability of the physical characteristics principally of soil macroporosity ($M_A$) (47%) and $K_{\theta s}$ (97%) (Table 1) are associated with the different sampling positions. Similarly, Lima et al. (2006) have indicated one the wide range of $M_A$ and $K_{\theta s}$ under Alfisol under citrus orchard. Lowest variability was indicated to soil microporosity (7.95%), bulk density (9%) and soil macroaggregates (9.44%) (Table 1). This indicates that these parameters were lowest sensitive to evaluate soil structural quality. The magnitude of bulk density for cultivated soils commonly varies from 0.9 to 1.8 Mg $m^{-3}$ (ERBACH, 1987). In general, the bulk density of a mineral soil is 1.3 Mg $m^{-3}$ (SINGH et al., 1992), that corroborate with the average bulk density obtained (Table 1).

**Table 1**. Statistical moments of the soil physical parameters analysed.

| Parameters[1] | Mean | Standard desviation | Minimum | Maximum | Coefficient of variation, % |
|---|---|---|---|---|---|
| $M_A$ | 13.39 | 6.24 | 2.94 | 28.60 | 46.64 |
| $M_I$ | 22.16 | 1.76 | 18.36 | 25.59 | 7.95 |
| $P_T$ | 35.56 | 5.25 | 26.46 | 47.96 | 14.76 |
| AFP | 0.76 | 0.11 | 0.55 | 0.93 | 14.69 |
| Bd | 1.42 | 0.13 | 1.16 | 1.66 | 9.00 |
| $K_{\theta s}$ | 35.95 | 34.91 | 0.70 | 177.23 | 97.11 |
| MWD | 1.61 | 0.34 | 0.80 | 2.20 | 20.86 |
| Macroag. | 68.01 | 6.42 | 54.19 | 82.08 | 9.44 |
| Microag. | 31.99 | 6.42 | 17.92 | 45.81 | 20.07 |

[1]$M_A$ = macroporosity ($m^3$ $m^{-3}$); $M_I$ = microporosity ($m^3$ $m^{-3}$); $P_T$: total porosity ($m^3$ $m^{-3}$); AFP: air-filled porosity, Bd = bulk density (Mg $m^{-3}$); $K_{\theta s}$ = saturated hydraulic conductivity (mm $h^{-1}$); MWD = mean weigth diameter (mm); macroag = macroaggregates (%); microag = microaggregates (%).

Statistical tests indicated that $M_A$ values were associated with total porosity ($P_T$). In the row position and 0.00 - 010 m depth, the Ma and $P_T$ values were highest and statistically similar. In the layer 0.10 – 0.20 m depth and interrow position ($PN_{2IR}$) was indicated significant decrease of $M_A$ probably caused by traffic of vehicle and consequently highest bulk density values in this position (Table 2).

The air-filled porosity indicates the air space present in the soil pores (LIBARDI, 2005). The AFP was lower in the interrow and higher in the row position to 0.00 - 0.10 m depth and similar to 0.10 – 0.20 m depth (Table 2). In general, the soil in the interrow position to 0.00 – 0.10 m, was denser, originating smaller water permeabiliy ($K_{\theta s}$) (Table 2) by traffic of vehicles and higher soil compaction. The values of $K_{\theta s}$ in the crop interrow were higher than indicated by Jarecki & Lal (2005). Similar statistical values of $K_{\theta s}$ (0.10 – 0.20 m) are associated with the variability of results (Table 1). It is in accordance with Silva et al. (2007).

The values of these parameters suggest that the interrow position studied has been subject to high loads, principaly to 0.00 – 0.10 m depth. Vehicles with high weight per axis and high air tire inflation pressure indicate low AFP and consequently soil compaction.

Silva et al. (2003) postulated that traffic intensity altered the bulk density, soil porosity and saturated hydraulic conductivity. However, in this study, no differences were presented only in the 0.10 - 0.20 m depth (Table 2)

In general, the mean weight diameter was influenced by sampling position in all layers studied (Table 2). However, were similar the aggregates size distribution of 2.00 – 1.00 mm and < 0.25 mm. The Figure 1 summarizes that the diameter of aggregates of 2.00 – 1.00 mm was smaller. The mean of macroaggregates and microaggregates values, i.e. aggregates higher and lower than 0.25 mm, respectively are listed in Table 3. The distribuition of soil aggregates indicated about structural quality of soil (Figure 1).

Similar results statistically were encountred in both treatments and layers, so this soil parameter demonstrated no sensitive to soil use. However, tillage systems affect soil aggregation, bulk density and seedling emergence (ALTILAK; CELIK, 2011)

**Table 2.** Macroporosity ($M_A$, m$^3$ m$^{-3}$), microporosity ($M_I$, m$^3$ m$^{-3}$), total porosity ($P_T$, m$^3$ m$^{-3}$), air-filled porosity (AFP), bulk density (Bd, Mg m$^{-3}$), saturated hydraulic conductivity ($K_{\theta s}$, mm h$^{-1}$) and mean weight diameter (MWD, mm) of an Alfisol under different areas and layers.

| | $M_A$ | $M_I$ | $P_T$ | AFP | Bd | $K_{\theta s}$ | MWD |
|---|---|---|---|---|---|---|---|
| | | | 0,00 - 0,05 m | | | | |
| $PN_{1R}$ | 21,74 a | 20.40 d | 42.13 a | 0.98 a | 1.24 c | 108.79 a | 1.70 a |
| $PN_{1IR}$ | 10.12 c | 23.62 ab | 33.74 c | 0.74 b | 1.48 a | 9.18 c | 1.76 a |
| $PN_{2R}$ | 20.96 a | 21.83 c | 42.79 a | 0.93 a | 1.28 bc | 60.64 b | 1.29 b |
| $PN_{2IR}$ | 6.64 d | 24.37 a | 31.01 d | 0.69 b | 1.53 a | 8.67 c | 1.55 ab |
| AN | 13.90 b | 22.99 bc | 36,90 b | 0.92 a | 1.33 b | 60.45 b | 1.86 a |
| Pr > F | < 0.0001 | < 0.0001 | < 0.0001 | < 0.0001 | < 0.0001 | < 0.0001 | 0.0410 |
| lsd | 2.99 | 1.33 | 2.71 | 0.079 | 0.065 | 40.45 | 0.38 |
| | | | 0.05 – 0.10 m | | | | |
| $PN_{1R}$ | 22.37 a | 19.52 c | 41.88 a | 0.94 a | 1.27 c | 9.28 b | 1.89 ab |
| $PN_{1IR}$ | 10.37 bc | 21.37 b | 31.73 bc | 0.70 cd | 1.52 ab | 10.19 ab | 2.21 a |
| $PN_{2R}$ | 21.12 a | 21.69 b | 42.81 a | 0.88 ab | 1.27 c | 11.44 a | 1.50 b |
| $PN_{2IR}$ | 6.44 c | 23.53 a | 29.98 c | 0.66 d | 1.56 a | 11.21 a | 1.85 ab |
| AN | 12.79 b | 21.26 b | 34.05 b | 0.80 bc | 1.44 b | 7.49 c | 2.08 a |
| Pr > F | < 0.0001 | 0.0012 | < 0.0001 | < 0.0002 | < 0.0001 | < 0.0001 | 0.0452 |
| lsd | 4.08 | 1.66 | 3.08 | 0.1167 | 0.082 | 5.77 | 0.47 |
| | | | 0.10 – 0.20 m | | | | |
| $PN_{1R}$ | 12.74 a | 21.66 b | 34.39 a | 0.75 a | 1,48 a | 34,24 a | 1,76 a |
| $PN_{1IR}$ | 11.03 a | 21.49 b | 32.52 ab | 0.75 a | 1.48 a | 34.25 a | 1.46 ab |
| $PN_{2R}$ | 12.31 a | 23.92 a | 36.23 a | 0.74 a | 1.46 a | 11.51 a | 1.38 b |
| $PN_{2IR}$ | 6.26 b | 23.55 a | 29.81 b | 0.64 a | 1.58 a | 19.92 a | 1.69 a |
| AN | 12.21 a | 21.21 b | 33.42 ab | 0.79 a | 1.45 a | 37.51 a | 1.76 a |
| Pr > F | 0.0450 | 0.0002 | 0.0407 | 0.0812 | 0.0837 | 0.1578 | 0.0354 |
| lsd | 4.62 | 1.25 | 4.04 | 0.1047 | 0.096 | 24.29 | 0.30 |

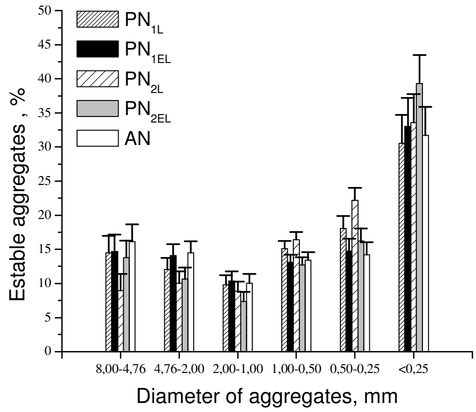
$PN_{1R}$: soil under physic nut with 19 months of implantation (crop row); $PN_{1IR}$: soil under physic nut with 19 months of implantation (crop interrow); $PN_{2R}$: soil under physic nut with 5 months of implantation (crop row); $PN_{2IR}$: soil under physic nut with 5 months of implantation (crop interrow) and AN: natural area. Same letter on the column by soil layer indicates no statistical difference at 5% significance level. Pr: probability; lsd: least significant difference.

**Table 3**. Macroaggregates (macroag.) and microaggregates (microag.) of an Alfisol under different areas and layers.

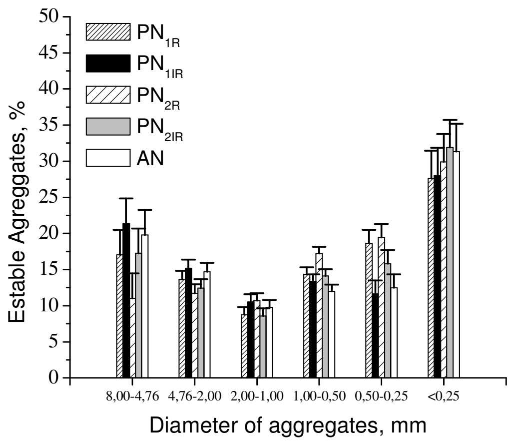
| | 0.00 – 0.05 m | | 0.05 – 0.10 m | | 0.10 – 0.20 m | |
|---|---|---|---|---|---|---|
| | Macroag. | Microag. | Macroag. | Microag. | Macroag. | Microag. |
| $PN_{1R}$ | 69.46 | 30.54 | 72.40 | 27.60 | 68.14 | 31.86 |
| $PN_{1ER}$ | 66.95 | 33.05 | 72.01 | 27.99 | 67.61 | 32.39 |
| $PN_{2R}$ | 66.40 | 33.60 | 70.07 | 29.92 | 68.71 | 31.29 |
| $PN_{2ER}$ | 60.69 | 39.31 | 68.12 | 31.88 | 67.18 | 32.82 |
| AN | 68.28 | 31.72 | 68.67 | 31.33 | 65.38 | 34.62 |

$PN_{1R}$: soil under physic nut with 19 months of implantation (crop row); $PN_{1IR}$: soil under physic nut with 19 months of implantation (crop interrow); $PN_{2R}$: soil under physic nut with 5 months of implantation (crop row); $PN_{2IR}$: soil under physic nut with 5 months of implantation (crop interrow) and AN: natural area.

a)




b)




c)

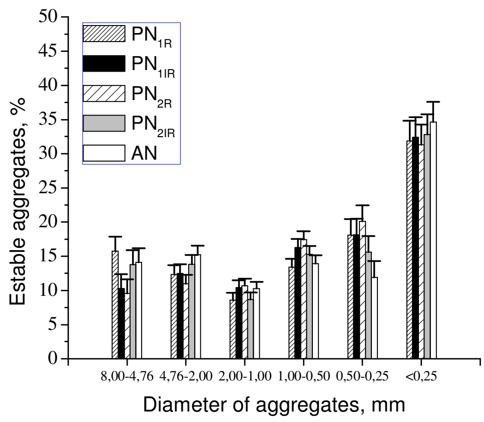


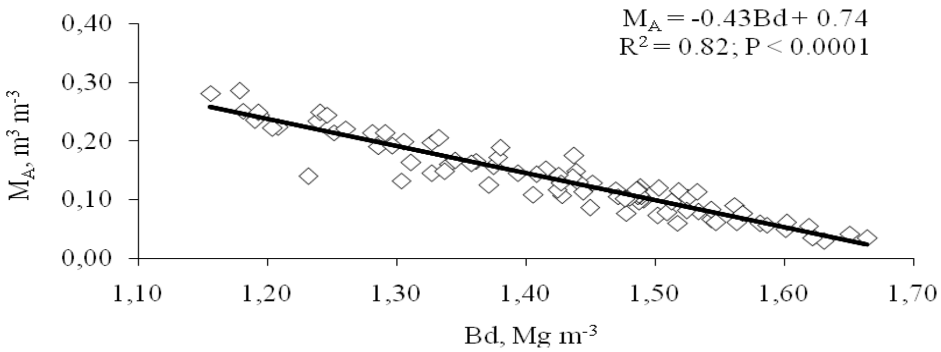

**Figure 1**. Water stable aggregates (%) in different diameter of aggregates of an Alfisol and layers: a) 0.00 – 0.05 m, b) 0.05 - 0.10 m and c) 0.10 - 0.20 m. PN$_{1R}$: soil under physic nut with 19 months of implantation (crop row); PN$_{1IR}$: soil under physic nut with 19 months of implantation (crop interrow); PN$_{2R}$: soil under physic nut with 5 months of implantation (crop row); PN$_{2IR}$: soil under physic nut with 5 months of implantation (crop interrow) and AN: natural area. The vertical bars indicate the least significant difference between soil use and within diameter of soil aggregates.

The soil quality for crop development has been evaluated with mathematical models of soil parameters (ATKINSON et al., 2007). Considering that advances in stablishing of critical values of soil physical parameters for crop growth and yield have been made (Lima et al., 2010), the regression analysis showed that the bulk density (F= 333.29; P < 0.0001; $R^2$ = 0.82) (Figure 2a) and the air-filled porosity (F= 322.15; P < 0.0001; $R^2$ = 0.82) (Figure 2b) were statistical significant and depends of $M_A$.

According to objective of this study and considering 10%, wich critical value of soil porosity for crop development (GRABLE; SIEMER, 1968), observed that critical bulk density value was 1.49 Mg $m^{-3}$ (Figure 2a). However, yet was observed that AFP > 0.74 is satisfatory for plants development (Figure 2b). The interrow position ($PN_{2IR}$) was indicated lowest $M_A$ value and critical Bd and AFP values (Table 2). This probabily was associated with the intensity of soil use in these areas.

The linear regression models associated with $K_{\theta s}$ indicated significant dependence of $M_A$ (F = 48.46; P < 0.0001; $R^2$ = 0.40) and Bd (F = 42.71; P < 0.0001; $R^2$ = 0.37) values.

a)




b)

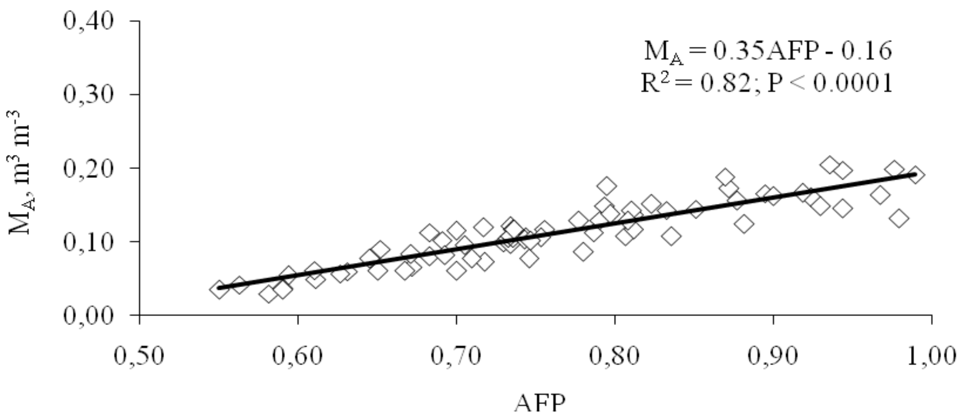



**Figure 2.** Relationship between (a) macroporosity ($M_A$) and bulk density (Bd) and (b) $M_A$ and air-filled porosity (AFP) of an Alfisol to 0.00 – 0.20 m depth.

Studies have demonstrated that crop productivity is reduced when the critical values of soil bulk density, air-filled porosity, soil macroporosity and hydraulic conductivity (defined when plant development is limited) are exceeded (SILVA; KAY, 1997; REICHERT et al., 2009). However, it is still necessary to develop more studies that allow a better understanding the compaction process of soils developed under orchard of physic nut.

## CONCLUSIONS

The row and interrow positions influenced the soil parameters studied, except 0.10 – 0.20 m depth. In the row position and 0.00 – 0.10 m was indicated higher soil macroporosity and total porosity.

The critical air- filled porosity and bulk density values for crops development were 0.74 and 1.49 Mg $m^{-3}$, respectively.

The crop row position indicated best results of soil physical properties associated with a lower bulk density and adequate air-filled porosity.

**RESUMO:** A implantação e o desenvolvimento de culturas alternativas para a produção de biocombustível são dependentes da qualidade estrutural do solo. O pinhão manso tem sido considerado uma fonte promissora de biocombustível. O objetivo deste estudo foi verificar a influência dos sistemas de uso em alguns parâmetros físicos e identificar valores críticos ao desenvolvimento de plantas de um Argissolo Vermelho Amarelo sob sistema convencional de pinhão manso. Coletaram-se amostras com estrutura alterada e inalterada, nas posições linha e entrelinha de cultivo do pinhão manso e nas camadas de 0,00 a 0,05; 0,05 a 0,10 e 0,10 a 0,20 m. Nas condições deste estudo, conclui-se que: i) as posições de amostragem influenciam os parâmetros físicos com exceção da camada de 0,10 - 0,20 m; ii) na camada de 0,00 - 0,10 m, o solo na posição linha de cultivo apresentou uma maior macroporosidade e porosidade total do solo; iii) os valores críticos ao desenvolvimento de plantas referentes ao índice de vazios e de densidade do solo são 0,74 e 1,49 Mg $m^{-3}$ e v) considerando o índice de vazios e a densidade do solo, somente o solo na posição linha de cultivo não indica valores limitantes ao desenvolvimento da cultura.

**PALAVRAS-CHAVE:** *Jatropha curcas*. Porosidade. Aeração. Agregação.

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