International Scholars Journals

African Journal of Soil Science ISSN 2375-088X Vol. 4 (5), pp. 339-346, September, 2016. Available online at www.internationalscholarsjournals.org © International Scholars Journals



*Full Length Research Paper*

# Physical attributes of an ultisol under systems planting and crop successions after ten years

**Valdinei Araújo Gonçalves[1], Igor Rodrigues de Assis[2], Lino Roberto Ferreira[3], Matheus Ferreira França Teixeira[4], Gustavo Antônio Mendes Pereira[5], Matheus de Freitas Souza[6] and Douglas Teixeira Saraiva[7]**

[1]Universidade Federal de Viçosa, Plant Science Department, Graduate Program in Plant Science, Viçosa, Minas Gerais State, Brazil, ZIP 36570-900.
[2]Universidade Federal de Viçosa, Soil Department, Viçosa, Minas Gerais State, Brazil, ZIP 36570-900.
[3]Universidade Federal de Viçosa, Plant Science Department, Viçosa, Minas Gerais State, Brazil, ZIP 36570-900.
[4]Universidade Federal de Viçosa, Plant Science Department, Graduate Program in Plant Science, Viçosa, Minas Gerais State, Brazil, ZIP 36570-900.
[5]Universidade Federal de Viçosa, Plant Science Department, Graduate Program in Plant Science, Viçosa,Minas Gerais State, Brazil, ZIP 36570-900.
[6]Universidade Federal de Viçosa, Plant Science Department, Graduate Program in Plant Science, Viçosa, Minas Gerais State, Brazil, ZIP 36570-900.
[7]Universidade Federal de Viçosa, Plant Science Department, Graduate Program in Plant Science, Viçosa Minas Gerais State, Brazil, ZIP 36570-900.

Received 06 July, 2016; Revised 05 August, 2016; Accepted 09 August, 2016; Published 29 August, 2016

**The physical quality of the soil is of great importance for a sustainable agricultural system. Thus, this study aimed to evaluate the physical attributes of an Ultisol, after ten years under two different tillage systems - tillage and no-tillage, and two crops successions - corn-beans and soybean-wheat. It will determined the bulk density, macroporosity, microporosity, total porosity and the content of organic matter in depths 0-5; 10-15 and 20-25 cm and soil mechanical resistance to penetration to a depth of 60 cm. In the depth of 0-5 cm greater volume of micropores in soil with corn-beans succession at the no-tillage. The succession soybean-wheat under tillage resulted in the highest levels of organic matter. Higher density values were observed in the no-tillage system with corn-beans succession. Values critical for soil resistance to penetration were observed between 5 and 25 cm deep at the no-tillage/succession soybean-wheat. The bulk density is the physical attribute of Ultisol less influenced by the assessed management systems. The total porosity of Ultisol did not differ between no-tillage and tillage system, after ten years of crop succession. After ten years, no-tillage system and corn-beans succession were the least negatively affected of the evaluated physical attributes of Ultisol.**

**Keywords**: Tillage, no-tillage, corn-bean, soybean-wheat, management, soil of degradation.

## INTRODUCTION

The soil preparation for the planting can minimize their physical degradation if accomplished of appropriate management. Otherwise, it can commit the physical quality of the soil, impeding the full establishment and development of the crops. Tillage practices carried out over the years can induce changes, improving or not, in soil physical properties such as soil bulk density, total porosity, content of organic matter aggregate stability,

Corresponding author. E-mail: valdinei.goncalves@ufv.br

water movement and storage in soil (Jabro et. al., 2016).
The tillage system (TS) planting can involve the plow use and grating provides intense mobilization and disruption of the soil. Moreover, TS makes the soil more susceptible to increased risk of water erosion, intensifying the degradation process (Rós et al., 2014). Due to the negative aspects of the tillage system, that has been substituted by the no-tillage system (NT).

In no-tillage, compared to the tillage system, there is minimal tillage from soil. This means that there less decomposition of vegetation, accumulating organic matter, bringing the total organic carbon content, which stabilizes the soil structure, by cementing effect on the formation and maintenance of aggregates (Sales et. al., 2016). In addition, the use of tillage can contribute to the integrated soil fertility under construction chemical, physical and biological, reduce fuel costs and maintenance of machinery (McGarry, 2003; Bolliger et al, 2006;. Llanillo et al., 2013).

The effect of no-tillage on soil physical properties can be enhanced by the use of crops successions. This practice is the cultivation of species with different root systems and mulch capacity, in the same area and in different seasons (Stone and Silveira, 2001). This system minimizes the risk of water erosion and increases the stock of organic matter in the soil, maintaining the productive capacity (Leite et al., 2003). In succession system of crops, the cultivated species, cultivation duration and frequency of crops during the year are factors that modify the physical soil quality (Stone e Silveira 2001).

Cropshavedifferenttypesof root systems and are sownwithdifferentrowspacings. Therefore, in additiontodifferencesduetoopeningofplantingfurrows, eachcropcanalso cause changes in soilphysicalconditions (Moreira et. al., 2016). Silveira Neto et al. (2006) found that crops successions with species belonging to different botanical families resulted in positive effects on the physical attributes of an Oxisol after performing ten crops for five consecutive years.

The intense soil use can take his degradation and to commit the capacity of agricultural production. However, the soil physical alterations are more difficult perception because it happen long term. Thus, experiments of long duration are essential to understand these alterations and like this to propose more effective conservationist practices of soil, allowing the maintainable agricultural production.

Thus, this study aimed to evaluate the changes of the physical attributes of a clay Ultisol, after ten years under two different cropping systems –no-tillage and tillage, and two crops successions - corn-bean and soybean-wheat.

## MATERIAL AND METHODS

The soil was maintain under same planting system and cultures succession for ten years in experimental area of the Federal University of Viçosa, Minas Gerais State, Brazil, with geographical coordinates 20° 45' 54'' S, 45° 52' 54'' W and the altitude is 650 m. The weather according to Köppen classification is Cwa type, characterized by hot and rainy summer and dry winter. The soil of the experimental area is an Ultisol, whose particle-size distribution in the layer of 0-25 cm deep is 257 g $kg^{-1}$of sand, 174 g $kg^{-1}$of silt and 569 g $kg^{-1}$of clay.

The experiment was carried out in split plot scheme and completely randomized design with four replications. In plots of 25 m² were arranged the planting systems: no-tillage (NT) and tillage system (TS), and the subplots of 12.5 m² crops succession: corn-bean (C-B) and soybean-wheat (S-W). The sowing of corn (*Zea mays* L.) and soybean (*Glycine max* L. Merr.) were held in november (summer) and bean (*Phaseolus vulgaris* L.) and wheat (*Triticumaestivum* L.) in june (winter). When necessary, irrigation sprinkler was used satisfying the requirement of the crops.

The preparation of the area for no-tillage system consisted of the herbicides desiccant application for control of the vegetation and formation of straw. In the tillage system, the soil preparation was accomplished by plow of disks, following by harrowing. The sowing was carried out with a seeder SEMEATO SHM 11/13 pulled by tractor. The post-emergent weed management in the crops was done with herbicides and harvesting as required by individual crop.

After harvesting the tenth year of cultivation, soil samples with undisturbed structure were collected at depths of 0-5, 10-15 and 20-25 cm in the line and between lines of soybean and corn. These samples were withdrawn with a volumetric ring stainless steel with dimensions of 5 cm in diameter and, with the assistance auger type Uhland. The analyses were bulk density (Bd), total porosity (Tp), microporosity (Mic) and macroporosity (Mac).

To determine the microporosity, samples were saturated in water tray containing up to two thirds of the height corresponding to the height of the ring for 48 h. After saturation, the samples were drained on the tension equivalent to 6kPa in tension table for 72 h. The water remaining in samples after the drain is the water retained in the micropores. After, the soil moisture was determined by thermogravimetric method (Embrapa, 2011). The particle density (Pd) used to determine the total porosity has been obtain in the dry unstructured sample, using the volumetric flask method (Embrapa, 2011). The calculation of Tp was carried out using the expression $Tp = 1–Bd/Pd$, proposed by Kiehl (1979). The Mac was obtained by the difference between Tp and Mic.

The soil mechanical penetration resistance (Pr), evaluated in the line and between lines of corn and soybeans, up to 60 cm deep, with 15 replications per subplot. For this we used a digital penetrometer, PenetroLOG, PLG1020 Falker model with conical tip 30° (Lanzanova et al., 2007). When determining the Pr, soil samples from depths of 0-10, 10-20, 20-30, 30-40, 40-50 and 50-60 cm were collected to determine soil moisture. These data were used to correct the Pr values, as proposed by Busscher (1990). The content of soil organic matter (SOM) was determined according to the methodology proposed by Walkley and Black (1934).

The data were submitted to analysis of variance and having significant effect of crop succession within each planting system was conducted unfolding of interaction by Tukey test at 5% significance level.

## RESULTS AND DISCUSSION

### Macroporosity, microporosity, and total porosity

There was no significant difference between cropping systems, in the line for the physical attributes microporosity, macroporosity and total porosity at depths of 0-5 and 20-25 cm. This result corroborates with Assis & Lança (2005) and Silva et al. (2006), which did not observe differences between tillage and no-tillage to Mic, Mac and Tp in Red Clay Soil and Red Ultisol at 0-5 cm depth.

In the 10-15 cm depth only the microporosity in the tillage system was higher than no-tillage system, both on line and in between planting line (Figures 1a and 1b). According to Mishra & Kushwaha (2016), these results were not expected, because the lowest mobilization of the soil in the no-tillage system can be reduced the number of, macroporosity and increase the microporosity, without changing the total porosity.

Bertoli et al. (2004) evaluated the influence of cropping systems on soil microporosity not found any difference for this variable. According to these authors, the Mic is a variable bit influenced by planting systems, but note that when there is an increase in value, particularly in TS, it may be advantageous, since favor the occurrence of the capillarity phenomenon, which facilitates the movement of water and nutrients in the soil profile.

Evaluating effects of crop on the soil physical properties at the no-tillage systems, there was significant difference only in the 0-5 cm depth. At this depth, the variables microporosity and total porosity were in the line, 10.33 and 12.13% higher in succession C-B compared to S-W succession, respectively (Figure 2a). In the between planting line only the microporosity in the C-B succession was higher than S-W succession (Figure 2b).

Lanzanova et al. (2007) associated the high porosity values with the larger mass of roots per soil volume, so, greater root density as well as better spatial distribution of roots of corn and beans in the soil profile. These roots to decompose originate pores in the soil.

In tillage system was also observed influence of crop succession in the microporosity and total porosity at the 0-5 cm depth. However, in this case, the highest values were observed for S-W succession (Figures 2a and 2b). The fact the crop succession is associated with the tillage system, the effect of crops root may be masked by soil tillage (Wutke et al., 2000).

### Soil organic matter

The SOM content in the between planting line not varied significantly comparing the crops successions in the soil surface, both tillage and in no-tillage system. In the 10-15 and 20-25 cm depth, the S-W succession provided higher organic matter content in both planting systems (NT and TS) (Table 1). The organic matter content increase in the soil under the S-W succession can improve the aggregates stability of most soils, because the organic matter is the main component to form soil structure (Paul et al., 2013).

In line of tillage system, the SOM content was significantly different between the crop succession sin the three depths sampled, with the highest value observed in the S-W succession (Table 1). The fact of using the tillage system can accelerate the decomposition of waste plant and organic matter mineralization (Mishra & Kushwaha, 2016).

In this case, the higher content of SOM can contribute to improvement in certain physical attributes, among these the bulk density and stability of soil structure (Klein et al., 2008).

At the no-tillage system, the difference between the crop successions was observed only for the 0-5 cm depth, with a higher SOM content in the soil with the C-B succession (Table 1). This is due to greater accumulation of mineral fertilizers on the surface this planting system, providing greater development of roots in soil profile. Moreover, there is a greater deposition of organic residues in this layer compared to the deeper layers (Pacheco & Cantalice, 2011 and Marasca et al., 2013).

### Bulk density

The highest values of Bd, both in line and between planting line, were observed on the no-tillage system (Figures 3a and 3b), as found by Llanillo et al. (2006) and Rós et al. (2014). These authors claim that this is a consequence of natural accommodation of the soil due to the lack of tillage in this planting system.

Jaboro (et al., 2016), studying tillage systems over four years, found that soil tillage reduces the Bd due to loosening of the soil layers and increased total porosity.

On the other hand, Stone and Silveira (2001) argue that, over the years, there may be a tendency of decreasing soil density under NT, making it equivalent to the TS. This is because the accumulation of organic matter in surface can minimize the effects of the cumulative traffic of machines and equipments on the soil. However, this was not confirmed in the present study after ten years.

The bulk density at 10-15 and 20-25 cm depth was higher C-B succession than S-W succession, regardless of the

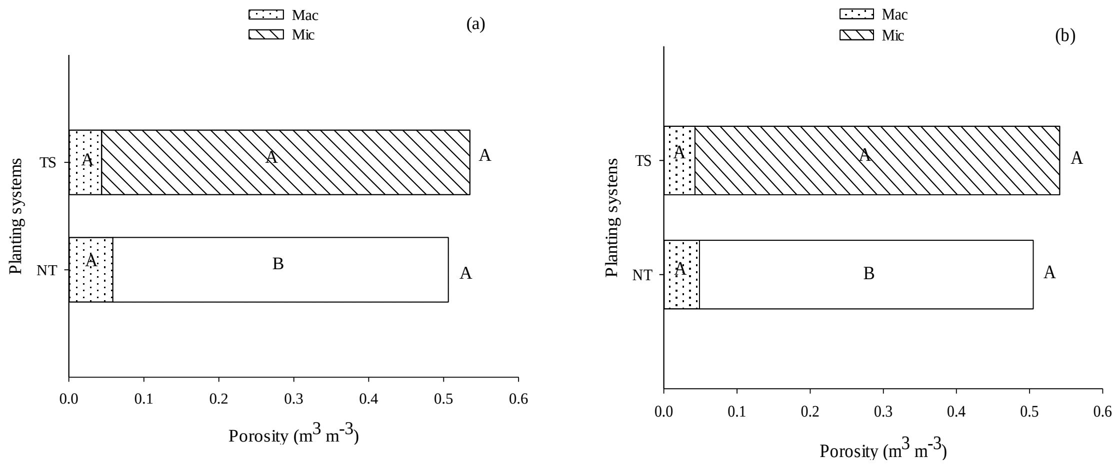


**Figure 1.** Microporosity (Mic), Macroporosity (Mac) and total soil porosity (Mic + Mac) in line (a) and between line (b) in planting systems (NoTillage - NT and Tillage System- TS) at a depth of 10-15 cm, in a Red-Yellow Ultisol. Planting systems followed by the same letter do not differ by F test at 5% significance level.

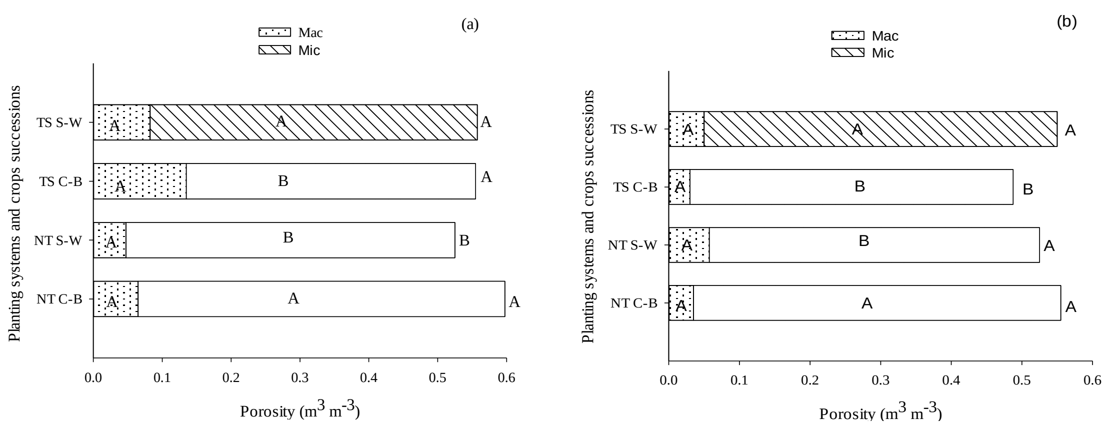


**Figure 2.** Microporosity (Mic), Macroporosity (Mac) and total soil porosity (Mic + Mac) in line (a) and between line (b) in planting systems (No-tillage - NT and tillage system - TS) and crop successions (Corn-Bean – C-B- and Soybean-Wheat – S-W) at a depth of 0-5 cm, in a Red-Yellow Ultisol. For the same planting system, the same letter do not differ by Tukey test at 5% significance level.

used planting system (Figures 3a and 3b). Higher Bd in C-B succession may be a result of lower organic matter content observed in the soil cultivated with these crops, especially in between line. The SOM lower content may lead to increases in the Bd values and thus reduce the water retention capacity (Jarecki et al., 2005). The highest value of Bd in this case suggests the need for monitoring of soil compaction, since the depth up to 25 cm are concentrated 85 to 90% of the roots of these crops (Reichert et al, 2009;. Garcia & Rosolem, 2010).
The bulk density is a physical attribute that responds differently as soil use, its history of cultivation and straw built of previous crops or maintained surface (Rós et al., 2014).

## Soil mechanical resistance to penetration

To characterize the soil compaction occurrence were used the penetration resistance (Pr) values after correction with soil moisture data in the 0-60 cm depth(maize-bean - NT 24.8%; soybean-wheat - NT 23.7%; maize-bean - TS 24.1%; soybean-wheat - TS 23.5%). The estimated of field capacity was carried out in the matric potential of -30 kPa, where the soil moisture

**Table 1.** Average levels of organic matter in the line and between line, in cropping systems (No tillage system - NT and tillage system- TS) and crop successions (Corn-Bean - CB- Soybean and Wheat - SW) at three depths of a Red-Yellow Ultisol.

| Depth (cm) | LINE | | | | BETWEEN LINE | | | |
|---|---|---|---|---|---|---|---|---|
| | NT | | TS | | NT | | TS | |
| | C-B | S-W | C-B | S-W | C-B | S-T | C-B | S-W |
| | g $kg^{-1}$ | | | | | | | |
| 0-5 | 42.9 A | 34.5 B | 31.4B | 39.7 A | 39.5 A | 37.1 A | 37.4 A | 37.1 A |
| 10-15 | 28.1 A | 33.9 A | 20.5 B | 38.7 A | 29.4 B | 34.5 A | 19.8 B | 36.8 A |
| 20-25 | 25.6 A | 29.4 A | 17.0 B | 35.5 A | 27.2 B | 32.3A | 19.2 B | 35.2 A |

Means followed by the same letter on the line do not differ under the same planting system, by Tukey test at *P<0.05 significance level.

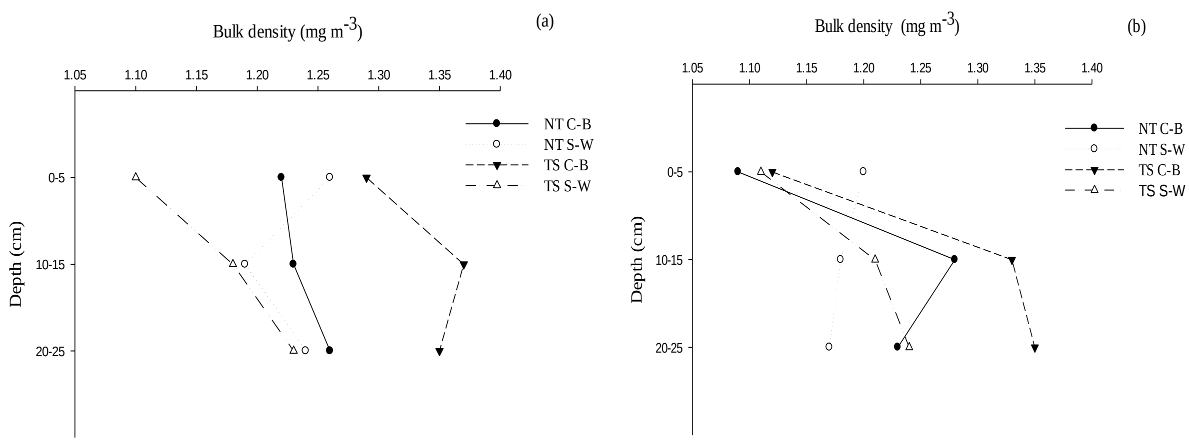


**Figure 3.** Soil bulk density (Bd) on the line (a) and between line (b) in planting systems (No-tillage - NT and tillage system - TS) and crop successions (Corn-Bean – C-B and Soybean-Wheat – S-W), in a Red-YellowUltisol.

was 0.37 kg $kg^{-1}$.

The largest variations in this soil attribute were observed between 5 and 25 cm depth, where concentrates the most of the cultivated species roots in the soil profile (Reichert et al, 2009; Garcia & Rosolem, 2010) (Figures 4a and 4b).

Both on line and in between line, the Pr from 5 to 25 cm was higher in soil under NT (Figures 4a and 4b), more than 2 MPa - value considered critical for the establishment and development of most annual crops when soil moisture is close to field capacity (Tormena et al., 2004). Domit et al. (2014)observed similar result, which reported higher penetration resistance in soils under no-tillage to a depth of 30 cm, with a reduction from that depth. The indicative compaction found on the NT may be related to lack of soil disturbance and cumulative effect of traffic machines on the soil surface (Tormena et al., 2004).

However, according Ralisch et al. (2008), keeping the no-tillage in the same area for more than ten years the effect of compression begins to be more limiting to plant growth, due to improved soil structure provided by the system long implementation period.

The soil under tillage system were not seen Pr values considered critical in the layer of 5-25 cm (Figures 4a and 4b), corroborating Rós et al. (2014). This can be attributed to the periodical soil disturbance that breaks the compacted layers. In all, it is noteworthy that the

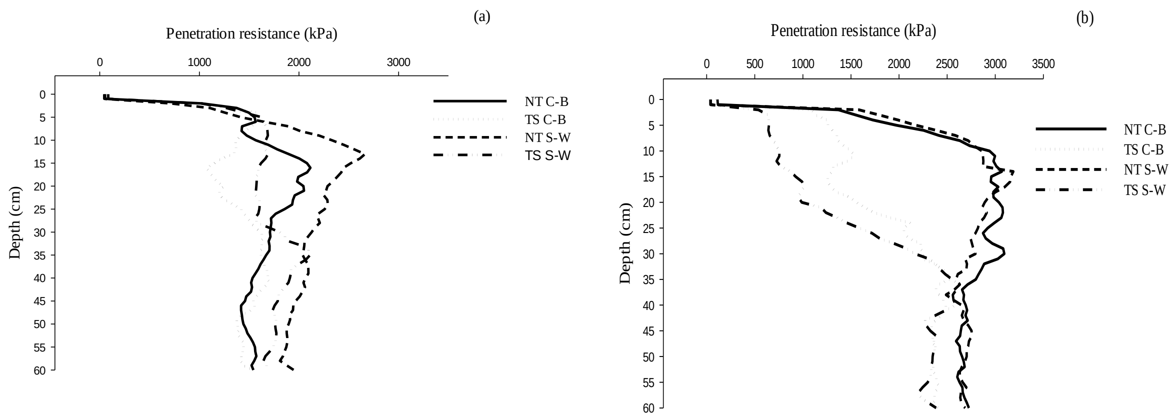


**Figure 4.** Mechanical resistance to penetration in line (a) and between line (b) in planting systems (No Tillage - NT and Tillage System - TS) and crop successions (Corn-Bean – C-B and Soybean-Wheat – S-W), to a depth of 60 cm, in a Red-Yellow Ultisol.

apparent advantage of the TS succession under the penetration resistance may be negligible because of the revolving expose the soil conditions that favor erosion and loss of organic matter (Fidalski, 1997).

In no-tillage, Pr between crops successions in the planting line was higher in soil under the S-W succession (Figure 4a). According to Stoner & Silveira (2001) and Silveira et al. (2008) most Pr in soils with S-W succession is a result of increased tractor wheels impact directly on the soil surface, since it are crops generally established at smaller spacings, increasing the frequency of the machines traffic in the area.

The planting line under tillage system there was less Pr between 5-25 cm depth with the C-B succession. In the between planting line was found lower Pr under S-W succession (Figures 4a and 4b). However, it is important to have caution when considering the influence of crop succession on Pr when using the TS. The disturbance can rearrange the soil layers masking the effect of culture on the soil mechanical resistance to penetration (Cunha et al. 2002).

## CONCLUSIONS

The bulk density is the physical attribute of Ultisol less influenced by the evaluated management systems, after ten years.

The total porosity of Ultisol did not differ between no-tillage and tillage system, after ten years of crop succession.

The no tillage and corn-beans succession were the managements that resulted in minor alteration to the soil physical properties, after twenty years.

## ACKNOWLEDGMENT

We thank the Foundation for Research Support of Minas Gerais (FAPEMIG) by granting scholarship to the first author.

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