

*Full Length Research Paper*

## **Soil hydro-physical attributes under management practices for pineapple genotypes cultivation**

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**Pineapple is a rustic species but may respond positively to conservation practices of soil management. This work aimed to evaluate the physical properties of the soil under conservation management practices for the cultivation of pineapple genotypes. The treatments consisted of four varieties of pineapple, two levels of gypsum (0 to 4 t ha<sup>-1</sup>), two levels of management (with and without cover crop - millet), and two soil layers (0 -0.05 and 0.05 - 0.20 m). A randomized complete block design was used, with four replications and treatments arranged in a 4 x 2 x 2 x 2 factorial scheme, resulting in 128 plots. Soil samples were collected in volumetric corer of 100 cm<sup>3</sup>. The water retention curve of the soil was obtained using the Van Genuchten model. By model fit, residual moisture values ( $\theta_r$ ), saturation moisture ( $\theta_s$ ), inflection point ( $\theta_{fwc}$ ), S index and available water capacity (AWC) were obtained. Also, there was a significant effect of layer and genotype on the properties studied. The combination of gypsum 4 t ha<sup>-1</sup> (G4) and millet significantly reduces the value of  $\theta_r$  and increases water availability (AWC).**

**Key words:** *Ananas comosus*, available water capacity, Red-Yellow Latosol, cover crop.

### **INTRODUCTION**

Pineapple, *Ananas comosus* (L.) Merrill, var. *comosus* is a perennial herbaceous fruit belonging to the

Bromeliaceae family and is thought to have originated in lowland South America, possibly in the southwest of

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Brazil (Santana et al., 2013; Ming et al., 2016). The other possibility is that *A. comosus* var. *comosus* has been domesticated in the Guiana Shield (Coppens d'Eeckenbrugge and Duval, 2009). Particular attributes of pineapple fruit associated with asexual reproduction, wide adaptation to different environments, and the beginning of its agriculture in the South America at Amazon region suggest that the pineapple domestication Occurred between 6,000 and 10,000 ago (Coppens d'Eeckenbrugge and Duval, 2009).

In Brazil, two main breeding programs in pineapple are being conducted, in which one is coordinated by the Empresa Brasileira de Pesquisa Agropecuária (Embrapa), located in Cruz das Almas (BA), which has already released varieties as 'BRS Imperial', 'BRS Ajubá' and 'BRS Vitória' and the other one is being conducted by the Instituto Agrônômico de Campinas (IAC) that has developed 'IAC Fantástico' and 'Gomo de Mel' varieties (Viana et al., 2013).

The great success of pineapple crop in Brazil is due to the wide adaptability of species in tropical and subtropical areas, high rusticity, easy propagation, and especially great fruit acceptability (Crestani et al., 2010). Species, especially commercial varieties derived from plant breeding programs, shows response to chemical soil improvements (Guarçoni and Ventura, 2011).

Even as the chemical conditions and the good physical conditions also benefit the pineapple crop, particularly those conditions related to soil, as well as water availability, which responds positively to the productivity and fruit quality (Santana et al., 2013). According to Dexter (2004), when soil physical quality is improved indirectly, improvements in biological and chemical conditions occur, since these soil quality aspects are mutually dependent. There are many symptoms regarding poor soil quality such as low aeration, low water infiltration and reduced root system, which reflects deterioration of soil structure (Dexter, 2004; Krebstein et al., 2014).

However, there are other indicators of soil physical quality as well as water retention curve, hydraulic conductivity, porosity, inflection point and soil water retention characteristics that make evaluation process of this quality simple, faster and less complex (Silva et al., 2014).

Proper soil management is crucial to crop success, because although pineapple may be a rough and resistant plant, the knowledge of soil physical and chemical characteristics as well as intervention for deviation correction is critical. Therefore, this study is aimed at evaluating soil hydro-physical attributes under different management practices for cultivation of pineapple genotypes.

## MATERIALS AND METHODS

The experiment was conducted in the experimental area of the

Instituto Federal de Educação, Ciência e Tecnologia de Mato Grosso, Campus Cáceres - Prof. Olegário Baldo, located in Cáceres - MT, with average coordinates of 16° 7'50"S and 57°41'41"W and altitude of 120 m. The annual average temperature is 26.24°C; the total annual rainfall is 1.335 mm, with the period of highest average rainfall concentration occurs from December to March and the largest dry season occurring from June to August; the average potential evapotranspiration is 1.650 mm (Neves et al., 2011). Soil from experimental area is classified as Red-Yellow Latosol (LVA), Sandy texture, with flat topography.

The pineapple cultivars, Pérola, Smooth Cayenne, IAC - Fantástico and Imperial were used in this study. In addition, soil correction levels were performed without gypsum (G0) and with application of gypsum at dose of 4 t ha<sup>-1</sup> (G4), adapted from Cantarutti et al. (1999). The management were performed with and without millet cover crop.

A randomized block design in factorial 4x2x2x2 were used, totaling 32 treatments and four replications. Each plot consisted of 20 plants arranged in double row planting, 0.30 x 0.40 x 0.90 m spaced, totaling 1,280 plants. The average length of seedlings used in planting was 44.3, 44.6, 22.9, and 23.6 cm for Pérola, Smooth Cayenne, IAC Fantástico and Imperial varieties, respectively.

Gypsum was distributed as continuous thread in planting furrow at a layer of 15 cm, and then covered with a thin layer of soil, following fertilization and planting itself. Gypsum moisture was determined for quantity correction to be applied at a dose of 4 t ha<sup>-1</sup>. The cover crop with millet was grown between lines of double rows, with 2 g m<sup>-1</sup> of seed. Millet management was performed with cuts of 0.10 m above the soil when plant reached a height of 60 cm.

For soil sample collection, the same experimental design was used. A sample per plot with preserved structure was collected, positioned 0.10 to 0.20 m from plant base, using volumetric core of approximately 100 cm<sup>3</sup> (0.048 m in diameter by 0.049 m in height) in 0.0 to 0.05 m and 0.05 to 0.20 m layers in each experimental unit.

For the soil water retention curves (WRC) determination, samples contained in core were first saturated and posteriorly subjected to metric tension of 1, 2, 4, 6, 8 and 10 kPa using porous plate funnels (Haines, 1930) of 33, 66, 100, 300, 1,500 kPa in Richards Chambers (Richards, 1965). After reaching water equilibrium at each tension, samples were weighed and subjected to the next tension, constituting curve method by drying. After the last tension, samples were dried at 105±2°C for 24 h to determine soil water content ( $\theta$ ) (Teixeira et al., 2017).

The model proposed by Van Genuchten (1980) was adjusted to the experimental data of water retention in each experimental unit. The data were drawn by adjustment procedures of nonlinear model of R software and the values of residual moisture ( $\theta_r$ ) and saturation moisture ( $\theta_s$ ) were obtained.

For the adjustment, the following parameterization of Van Genuchten model was considered (Equation 1):

$$\theta(x) = \theta_r + \frac{\theta_s - \theta_r}{(1 + \exp\{n(\alpha + x)\})^{1-1/n}} \quad (1)$$

Where  $\Theta(x)$  is soil moisture (m<sup>3</sup> m<sup>-3</sup>),  $x$  the log in 10 base of applied matricial tension (kPa),  $\theta_r$  is residual moisture (inferior asymptote),  $\theta_s$  is the saturation moisture (superior asymptote), while  $\alpha$  and  $n$  are empirical parameters of water retention curve form. Once values of these terms are known, S index (S) (Equation 2), tension at inflection point of curve (I) (Equation 3) and moisture at inflection point ( $\theta_I$ ) (Equation 4) are obtained:

$$S = -n \cdot \frac{\theta_s - \theta_r}{(1 + 1/m)^{m+1}} \quad (2)$$

**Table 1.** Summary of variance analysis for study variables in four cultivars of pineapple, two levels of agricultural gypsum, two soil cover levels and two study layers:  $\theta_r$  (residual moisture),  $\theta_s$  (saturation moisture), S index, Inflection Point ( $\theta_{fwc}$ ), Available water capacity (AWC).

Treatments	GL	Means squares				
		$\theta_r$	$\theta_s$	ÍNDICE S	$\theta_{fwc}$	AWC
Cover	1	0.0000014 <sup>NS</sup>	0.004879 <sup>NS</sup>	0.0016143 <sup>NS</sup>	0.00764 <sup>NS</sup>	0.0008848 <sup>NS</sup>
Gypsum	1	0.0000746 <sup>NS</sup>	0.001788 <sup>NS</sup>	0.0000810 <sup>NS</sup>	0.00142 <sup>NS</sup>	0.0009368 <sup>NS</sup>
Layer	1	0.0014229**	0.075827**	0.0102480 <sup>NS</sup>	0.00142**	0.0156296**
Variety	3	0.0002433 <sup>NS</sup>	0.000386 <sup>NS</sup>	0.0023324 <sup>NS</sup>	0.01396 <sup>NS</sup>	0.0004352 <sup>NS</sup>
Cover crop:gypsum	1	0.0044550**	0.006721 <sup>NS</sup>	0.0000115 <sup>NS</sup>	0.17452*	0.0059612**
Cover crop:layer	1	0.0000297 <sup>NS</sup>	0.003100 <sup>NS</sup>	0.0046337 <sup>NS</sup>	0.02022 <sup>NS</sup>	0.0006589 <sup>NS</sup>
Cover crop:variety	3	0.0005295.*	0.003247 <sup>NS</sup>	0.0046337 <sup>NS</sup>	0.08687.*	0.0008682 <sup>NS</sup>
Gypsum: Layer	1	0.0002396 <sup>NS</sup>	0.003934 <sup>NS</sup>	0.0018293 <sup>NS</sup>	0.05364 <sup>NS</sup>	0.0008682 <sup>NS</sup>
Gypsum:Variety	3	0.0000978 <sup>NS</sup>	0.001158 <sup>NS</sup>	0.0069133 <sup>NS</sup>	0.06601 <sup>NS</sup>	0.0002086 <sup>NS</sup>
Layer:Variety	3	0.0000455 <sup>NS</sup>	0.010138*	0.0036408 <sup>NS</sup>	0.15943**	0.0038503**
Residue	108	0.0002144	0.002576	0.0036408	0.03506	0.0007084

\*\* , \* and <sup>NS</sup>: significant at 1% and 5% probability and not significant respectively.

$$I = -\alpha - \log(m)/n \quad (3)$$

$$\theta I = \theta (x=I) \quad (4)$$

Where S is the rate at inflection point, a parameter which is considered an indicator for soil physical quality evaluation as well as  $\theta I$  that corresponds to the tension log at inflection point of soil water retention curve (Dexter, 2004). The moisture corresponding to the tension at inflection point is represented by  $\theta I$ . Field water capacity ( $\theta_{fwc}$ ) was considered moisture in  $\theta I$  ( $\theta_{fwc} = \theta I$ ). Permanent wilting point ( $\theta_{pwp}$ ) was obtained in water content in  $\theta_r$  and in 1500 kPa potential. Available water capacity (AWC) was calculated by the difference between  $\theta_{fwc}$  less  $\theta_{pwp}$ .

All data were subjected to analysis of variance (ANOVA) at 1 and 5% probability, and means compared by t test using the R program (R Core Team, 2015).

## RESULTS AND DISCUSSION

Significance for layer factor was observed in relation to almost all the variables, except for S index. Regarding residual moisture ( $\theta_r$ ) and available water capacity (AWC), positive effect was observed in relation to cover  $\times$  variety interaction; in relation to cover  $\times$  gypsum interaction, there were significance to saturation moisture ( $\theta_s$ ), residual moisture ( $\theta_r$ ), moisture at inflexion point ( $\theta_{fwc}$ ) and available water capacity (AWC). For  $\theta_s$ , AWC and  $\theta_{fwc}$ , there was interaction in relation to layer  $\times$  variety (Table 1).

Significant difference was observed for  $\theta_r$  results in the comparison of 0.0-0.05 and 0.05-0.2 m layers. In the first layer, the mean was  $0.09 \text{ m}^3 \text{ m}^{-3}$  and at 0.05-0.2 m layer was  $0.08 \text{ m}^3 \text{ m}^{-3}$  (Figure 1A). The increase in  $\theta_r$  decreases the AWC to the plants. In the absence of the cover crop, the gypsum increased the residual moisture; however, the effect of the gypsum was inverse in the presence of the cover crop. The combination of cover crop and gypsum was positive to decrease  $\theta_r$  and

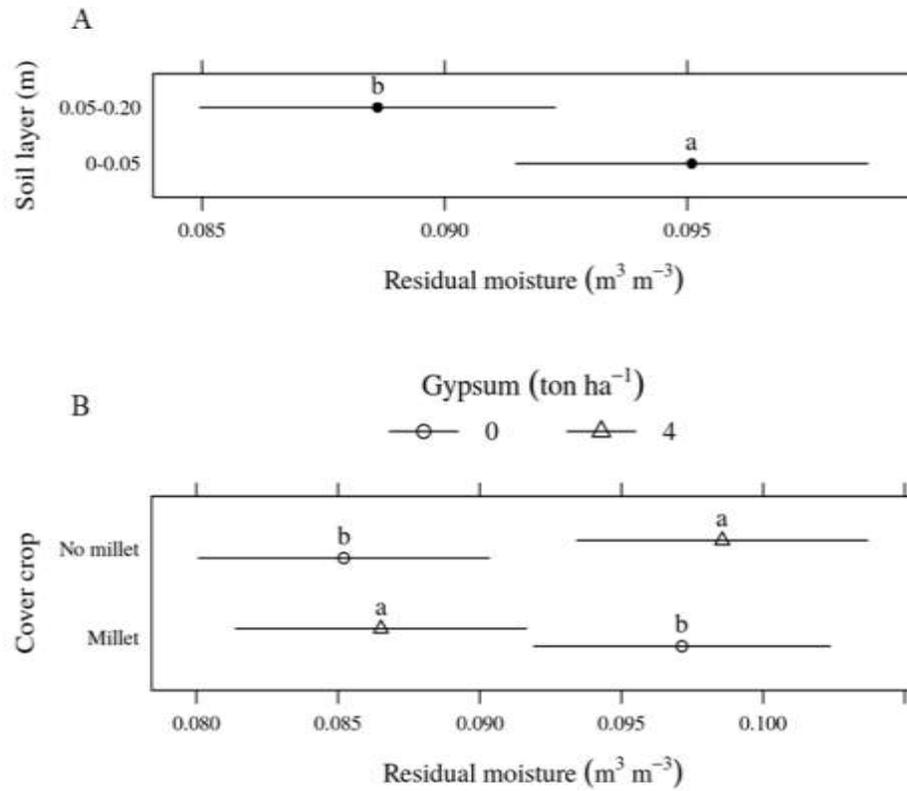
contribute to the increase of AWC (Figure 1B).

In interaction split of gypsum  $\times$  cover crop factors,  $\theta_r$  significance of G4 in relation to G0 was observed in the absence of cover crop and reverse in cover presence. For treatments with G0, the means were 0.085 and 0.097  $\text{m}^3 \text{ m}^{-3}$  with and without cover respectively. For G4 values, it was 0.085 and 0.098  $\text{m}^3 \text{ m}^{-3}$  with and without cover crop, respectively (Figure 2). It is observed that gypsum effect is conditioned by cover crop, and its desired effect of reducing  $\theta_r$  stands out only in the presence of cover crop. The gypsum  $\times$  millet combination, besides reducing  $\theta_r$ , provides other advantages such as enrichment of Ca, S and input of organic matter in soil.

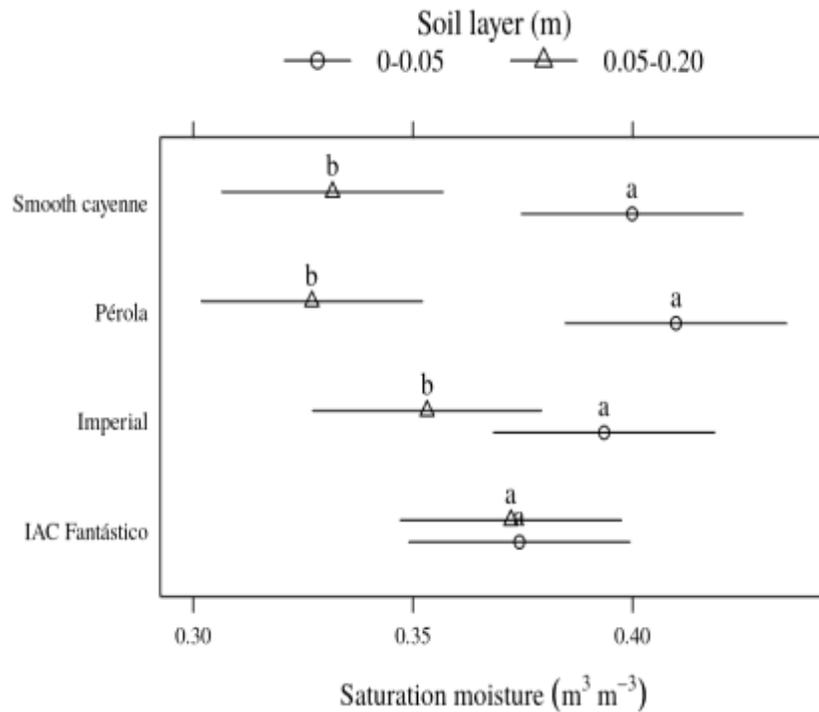
It was found that for  $\theta_s$ , significant effect was only observed for the interaction of variety  $\times$  layer factors. For Imperial, Pérola and Smooth Cayenne varieties,  $\theta_s$  was significantly higher in the 0.0 to 0.05 m layer with values of 0.393, 0.409 and 0.399  $\text{m}^3 \text{ m}^{-3}$ , while in the 0.05-0.2 m layer, values were 0.353, 0.327 and 0.331  $\text{m}^3 \text{ m}^{-3}$ , respectively. For IAC Fantástico variety, there was no significant difference between studied layers, with values of 0.374 and 0.372  $\text{m}^3 \text{ m}^{-3}$  for 0-0.05 and 0.05-0.2 m, respectively (Figure 2).

In a study on the row and between rows of coffee trees, as well as combined mixture of gypsum and organic material from brachiaria between rows, significant increase in  $\theta_s$  value were observed (Serafim et al., 2013). This analogy can be used to compare layers 0-0.05 and 0.05-0.2 m, where there is greater accumulation of organic material on surface. This is not the case for IAC Fantástico whose growth was slowly leaving soil permanently exposed with the adverse effects of this exposure.

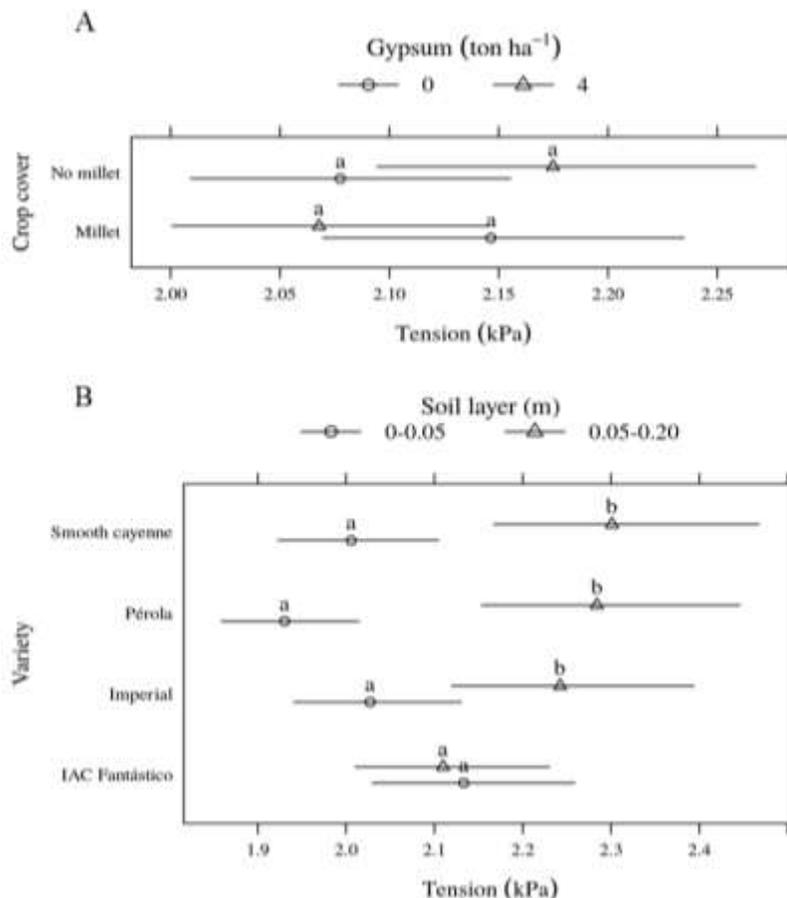
Regarding tension at inflection point (I), it was observed significance for layer  $\times$  varieties interaction in which the Imperial Pérola e Smooth Cayenne varieties had higher



**Figure 1.** Residual moisture (1500 kPa) in the layers of 0.0-0.05 and 0.05-0.2 m [A] and in the conditions with and without cover crop for the two levels of gypsum (G0 and G4) [B].



**Figure 2.** Saturation moisture for layers 0.0-0.05 and 0.05-0.2 m according to pineapple varieties.



**Figure 3.** Tension values (kPa) corresponding to inflection point ( $\theta_i$ ) for the interaction doses gypsum x millet [A] and tension values (kPa) corresponding to inflection point ( $\theta_i$ ) at 0.0-0.05 and 0.05-0.2 m layers and at different pineapple varieties [B].

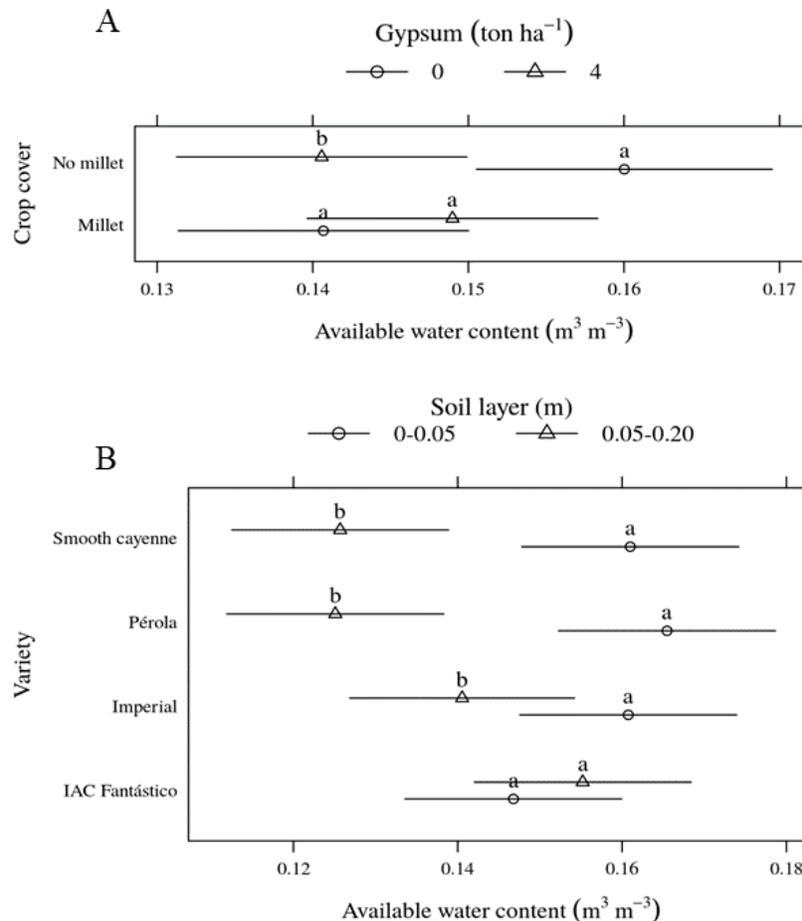
mean in surface layer with values of 1.41, 1.21 and 1.43 kPa, in relation to 0.05 to 0.2 m layer, which values were 1.23, 1.21 and 1.20 kPa, respectively. On the other hand, for IAC Fantástico variety, there was no significant difference in the studied layers (Figure 3B).

In the interaction of gypsum x cover factors, there was no significant difference for  $\theta_i$  in the presence of G4 in relation to G0 for treatments with and without millet crop cover in which means with millet were 1.37 and 1.30 kPa for G4 and G0 respectively, and without millet values were 1.28 and 1.36 kPa for G4 and G0 respectively (Figure 3A). The lack of significant difference between management systems for potential or soil moisture in  $\theta_{fwc}$  and  $\theta_{pwp}$  is described by Rocha et al. (2015). The  $\theta_{fwc}$  results from the complex interaction between clay content, structure, density and soil organic carbon, whose impact of the change of these factors on soil moisture in  $\theta_{fwc}$  may be delayed for longer periods than one year. The  $\theta_{pwp}$  is strongly related to the clay content which is not affected by management systems.

According to Silva et al. (2014), the inflection point of

curve marks the division between the two distinct pores classes, analogous to macro and micropores. Usually, lower values on the surface are expected and assume greater potential values in subsurface layers with lower organic matter content. Ferreira and Marcos (1983) also found corresponding potential values to the inflection point less than 6 kPa by evaluating different Latosols. This behavior may be associated with high porosity of these soils, due to its granular type structure of high macroporosity as well as high amount of micropores, responsible for water retention in soil at field water capacity.

For the AWC, there was significance to layer x variety interaction, where Imperial, Pérola and Smooth Cayenne varieties had a significant higher effect in 0.0-0.05 m layer, with values of 0.160, 0.165 and 0.160 m<sup>3</sup>m<sup>-3</sup> compared to 0.05-0.2 m layer, where values were 0.140, 0.125 and 0.125 m<sup>3</sup>m<sup>-3</sup> respectively (Figure 4A). The IAC Fantástico variety showed no significant difference in the studied layers, with values of 0.146 and 0.155 m<sup>3</sup>m<sup>-3</sup> compared to 0-0.05 and 0.05-0.2 m layers, respectively



**Figure 4.** Available water content (AWC) compared to gypsum x cover crop [A] and available water content compared to layer x variety interaction [B].

(Figure 4B). The difference observed between layers in this work, was amplified by millet cover crop which increased organic matter in the first layer compared to the second. As already described, the non-closure of culture in IAC Fantástico, accelerated decomposition cycle, reducing C accumulation in surface and profile.

The AWC indicates the soil ability to store and provide water that is available to the roots. Despite not consider the dynamics of soil-water-plant-atmosphere interrelations (Silva et al., 2014), this concept has distinct practical importance for water balance, dry climate, setting of planting period, agricultural zoning, and specially in irrigation projects, which becomes a great important parameter in land use planning.

There was no significant interaction between gypsum x cover crop for the variable AWC. Regarding treatment without millet, there was significant difference of AWC for G4 and G0 in which means were 0.140 and 0.160 m<sup>3</sup> m<sup>-3</sup> for G4 and G0, respectively (Figure 4). In this variation source there is grouping of two studied layers, which may have diluted the effect of the treatment, especially residue which was deposited only on surface. This result

differs from results of Serafim et al. (2012) and Silva et al. (2014), who shows the positive effect of cover crop and agricultural gypsum on increased AWC in coffee area, however, for longer period of conservation management.

AWC values obtained in this study are high, even in the most unfavorable situation, as described by Serafim et al. (2013) in Latosol and Cambisol, and Fidalski et al. (2013) in Quartz Neosol. This existing feature in soil, complicate the detection of positive effects of gypsum or cover crop (millet), within the study period of this study.

## Conclusions

All the pineapple varieties except IAC Fantástico had better indexes in the 0.0-0.05 m layer for  $\theta_r$ ,  $\theta_s$ ,  $\theta_{fwc}$  and AWC physical attributes compared to 0.05 – 0.20 m layer, except for IAC Fantástico variety. The gypsum 4.0 t.ha<sup>-1</sup> (G4) and cover with millet combination contributed to increased water availability (AWC) by reducing tension value in  $\theta_{fwc}$  and reduced residual moisture ( $\theta_r$ ). This occurred regardless of pineapple cultivar.

**CONFLICT OF INTERESTS**

The authors have not declared any conflict of interests.

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