INFILTRATION RATE OF A ULTISOL CULTIVATED WITH MAIZE UNDER DIFFERENT MANAGEMENTS AND WITH THE USE OF COWPEA AS PREVIOUS CROP

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ABSTRACT: The objective of this work was to evaluate how various soil management and the use of cowpea as previous culture influenced on the soil water infiltration capacity and the fit of the empirical equations of Horton, Kostiakov, Kostiakov-Lewis and Philip in adjusting the infiltration phenomenon. The experiment was carried out in an area where the effects of soil management with no-tillage, minimum tillage and conventional tillage along with rotational crop use between maize, such as main, and cowpea *(Vigna unguiculata L. Walp)* as previous corp. Water infiltration tests were carried out in the soil, using the double cylinder infiltrometer methodology, with three replications in each management, in a period previous to planting the main crop. To analyze the results, the statistical indices of residual mass coefficient (CMR), coefficient of adjustment (CA), and efficiency (EF) were used. The plots treated with no-tillage benefited much more the process of water infiltration in the soil, as well as the adjustment of the phenomenon with mathematical models. The best statistical results were obtained by Philip's model, Horton's model was able to estimate better the stable infiltration rate and Kostiakov-Lewis's model did not fit the soil well and obtained the worst results.

KEYWORDS: no-tillage, minimum tillage, conventional tillage.

VELOCIDADE DE INFILTRAÇÃO DE UM ULTISOL CULTIVADO COM MILHO SOB DIFERENTES MANEJOS E COM O USO DE CAUPI COMO CULTURA ANTECEDENTE

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RESUMO: O objetivo deste trabalho foi avaliar como variados manejos do solo e a utilização de feijão Caupi como cultura antecedente influenciaram na capacidade de infiltração da água no solo e a adequação das equações empíricas de Horton, Kostiakov, Kostiakov-Lewis e Philip no ajuste do fenômeno da infiltração. O experimento foi realizado em uma área onde já vem sendo estudados, a um longo período, os efeitos do manejo do solo com plantio direto, plantio mínimo e plantio convencional junto ao uso rotacional de cultura entre o milho, como a principal, e o feijão caupi (*Vigna unguiculata L. Walp)* como antecedente. Foram realizados testes de infiltração da água no solo, utilizando a metodologia do duplo cilindro infiltrômetro, sendo três repetições em cada manejo, num período anterior ao plantio da cultura principal. Para analisar os resultados foram utilizados os índices estatísticos de coeficiente de massa residual (CMR), coeficiente de ajuste (CA), e eficiência (EF). As parcelas tratadas com plantio direto beneficiaram muito mais ao processo de infiltração da água no solo, como também o ajuste do fenômeno com modelos matemáticos. Os melhores resultados estatísticos foram obtidos pelo modelo de Philip, o modelo de Horton conseguiu estimar melhor a velocidade de infiltração básica (VIB) e modelo de Kostiakov-Lewis não se adequou bem ao solo e obteve os piores resultados.
PALAVRAS-CHAVE: plantio direto, plantio mínimo e plantio convencional.

INTRODUCTION

The soil infiltration rate can be described as the rate at which water infiltrates the soil through its surface, usually expressed per unit height of water depth infiltrated in a determined soil profile per unit of time, due to the wetting of the profile, the water infiltration rate into the soil tends to decrease with time, assuming a near constant value called the stable infiltration rate (Bernardo et al.,2008; Gondim et al., 2010).

Some factors can modify the infiltration capacity of a soil, for example, different types of soil use in a hydrographic basin can cause variations in the physical attributes of the soil, so each type of soil use can interfere differently in the physical-hydric conditions of an area (Nerger et al., 2016).

Another factor that may influence the infiltration of water into the soil is the vegetation cover, constantly maintaining a cover when the soil is not being used for agricultural purposes is important, because in this way the soil will be protected against the direct impact of the rain drops, which may favor sealing of the soil surface. The cover also protects against direct radiation from the sun rays, improving and maintaining soil moisture conditions for longer, favoring the increase of microporosity, which will directly influence the preferred way of water during infiltration (Oliveira, 2005).

The knowledge of the water infiltration rate in the soil is fundamental to define techniques of soil conservation and environmental protection, to plan irrigation and drainage systems, as well as contribute to a better understanding of water retention and soil aeration (Paixão et al., 2009; Wang et al., 2014).

The objective of this work was to evaluate how various soil management and the use of cowpea as previous culture influenced on the soil water infiltration capacity and the fit of the empirical equations of Horton, Kostiakov, Kostiakov-Lewis and Philip in adjusting the infiltration phenomenon.

MATERIALS AND METHODS

The experiment was carried out in the experimental area of the rural campus of the Federal University of Sergipe, located in the Poxim river basin, in soil classified as Red-Yellow Argissolo, Ultisol for USDA soil taxonomy. The region has a rainy climate with dry summer and rainfall around 1,200 mm annually, with rainfall concentrated in the months of April to September.

The infiltration tests were performed in an area of approximately 3000 m², which was divided into three large plots, where since 2001 each plot has been managed on three different types of soil management: conventional tillage, where the disc leveling grid and the disk plowing were used; minimum tillage, which used only the grading grid for soil revolution; and no-tillage, which does not use any agricultural machinery. In these plots, crop rotations were carried out, where the main crop was maize Biomatrix variety BM 3061, the variety has a dual purpose: ears of corn and green matter for fodder, and the previous crop was the cowpea (*Vigna unguiculata L. Walp*) used only when maize was not planted, with the function of protecting and improving soil conditions.

The soil water infiltration tests were conducted following the double ring infiltration methodology described by Brandão et al. (2006), with the replacement of the water depth at the end of each reading, to maintain a less variable hydraulic load. For statistical purposes, three replications were performed in each management.

In order to adjust equations, we used equations 1 to 4, which are empirical models proposed by Horton (1940), Kostiokov (1932), Kostiokov-Lewis (1945) and Philip (1957) and described by Brandão et al. (2006), using the software VIBK (SANTOS et al., 2015).

$$I = i_f\ t + \frac{(ii - if)}{\beta}(1 - e^{-\beta t}) \quad (1)$$

$$I = kt^{\alpha} \quad (2)$$

$$I = kt^{\alpha} + i_f t \quad (3)$$

$$I = f_1\ t^{1/2} + f_2\ t \quad (4)$$

Where, **I** is the infiltration rate ($mm.h^{-1}$), **ii** initial infiltration rate, **if** stable infiltration rate, **t** represents the accumulated time e ***k*, α, β, f1, f2** are empirical constants obtained through regression.

The statistical indices of residual mass coefficient (CMR), coefficient of adjustment (CA), and efficiency (EF), equations 5, 6 and 7, respectively, were used to perform the analysis of the performance of mathematical models, as described by Cunha et al. (2015).

$$CMR = \frac{\sum_{i=1}^{n} O_i - \sum_{i=1}^{n} P_i}{(\sum_{i=1}^{n} O_i)} \quad (5)$$

$$CA = \frac{\sum_{i=1}^{n}(O_i - \bar{O})^2}{\sum_{i=1}^{n}(P_i - \bar{O})^2} \quad (6)$$

$$EF = \frac{\sum_{i=1}^{n}(O_i - \bar{O})^2 - \sum_{i=1}^{n}(P_i - O_i)^2}{\sum_{i=1}^{n}(O_i - \bar{O})^2} \quad (7)$$

Where, ***Oi*** represents the observed values, $\bar{O}$ the arithmetic mean of the observations, ***Pi*** estimated values, **n** is the number of observations.

RESULTS AND DISCUSSION

Analyzing the stable infiltration rate observed in the field, Table 1, we can say that there was a very clear trend of increase as less field machinery was used, an increase of 25.8 times in the rate of stable infiltration in no-tillage was observed in relation to conventional tillage and an increase of approximately 4.7 times in relation to the minimum tillage, this increase could be explained by the root system of the previous crop, which was able to develop much better in the soil managed with no-tillage when compared to the more conventional systems of cultivation.

In an experiment that analyzed recovery works and related the management, coverage of organic matter and infiltration rate, Marchini et al. (2015) noted that the stable infiltration rate of exposed soil doubled when being managed and using pork beans and crotalaria as cover.

Studying the effects of vegetation cover and soil management on soil water infiltration in a Dystrophic Red Argisol, Almeida et al. (2018) observed that the soil using no-till yielded a VIB that was 3 times higher than no-till.

Table 1. Average of observed and estimated stable infiltration rates, statistical results and equations coefficients adjusted.

	Conventional tillage						
	SIR	**R^2**	**CMR**	**CA**	**EF**	**K1**	**K2**
Observed	10.00	1	0	1	1		
Horton	10.00	0.915	0.177	1.254	0.814	-15.427	
Kostiakov	10.08	0.961	0.055	1.346	0.912	57.675	0.337
Kostiakov-Lewis	16.70	0.954	0.319	4.259	0.564	27.986	0.399
Philip	-2.55	0.947	0.299	1.115	0.897	85.732	-32.257
	Mimimum tillage						
	SIR	**R^2**	**CMR**	**CA**	**EF**	**K1**	**K2**
Observed	55.00	1	0	1	1		
Horton	55.00	0.949	0.053	1.359	0.921	-14.594	
Kostiakov	42.51	0.983	0.056	1.946	0.840	111.240	0.581
Kostiakov-Lewis	60.07	0.963	0.278	4.962	0.458	32.096	0.276
Philip	27.35	0.968	0	1.066	0.938	133.158	-18.774
	No-tillage						
	SIR	**R^2**	**CMR**	**CA**	**EF**	**K1**	**K2**
Observed	258.00	1	0	1	1		
Horton	258.00	0.966	0.042	1.059	0.928	-8.629	
Kostiakov	229.12	0.979	0.011	1.227	0.953	406.932	0.683
Kostiakov-Lewis	284.85	0.979	0.158	3.097	0.655	100.313	0.406
Philip	250.94	0.983	0	1.036	0.966	236.760	168.919

*for Horton k1=β, for Kostiakov and Kostiakov-Lewis k1=k and k2= α, for Philip k1=f1 e k2=f2.

**SIR-stable infiltration rate

In relation to the empirical equations used, can be seen in Table 1, there was also a trend of improvement in the adjustment as the soil is less managed. For the stable infiltration rates adjusted, the equation of the Horton model could be emphasized. because in all the tests the calculated stable infiltration rate was the same as observed in the field.

Paixão et al. (2009), Schreiner et al. (2010), Tomasini et al. (2010), Santos (2014), Carvalho et al. (2015), they also showed in their studies that the Horton equation is perfectly adherent, being the one that best expresses the stable infiltration rate described in the soil through mathematical models, and Santos (2014) used the same watershed studied in this work to perform your experiment.

In the Philip model, were obtained the results that were more distant from the real values observed in the field in conventional and minimum cultivation, getting to obtaining negative values of VIB in conventional cultivation, a fact that was also observed by Zadeh et al. (2007), where they performed a conventional double-ring infiltrometer test on 9 different soil types and also observed coefficients of determination indicating that the Philip model could successfully describe the infiltration phenomenon, in his case more than 99% of the total variations of infiltration were explained. The model also obtained a very small estimation standard error, but in some soils were obtained unrealistic values (negative) for parameter f2 in Philip's two-term infiltration equation. This phenomenon happens due to the low speed of stabilization of the equation, caused by the power constant of the equation, which is set at -0.5, unlike the other empirical equations used, where this constant is calculated. Indicating a good mathematical representation of the phenomenon, but a poor physical representation.

The Kostiakov and Kostiakov-Lewis models showed their very common characteristics in their adjustments, the VIB was underestimated by the Kostiakov model and overestimated by the Kostiakov-Lewis model in practically all adjustments, this phenomenon is commonly observed by several authors and in several soil types, such as, for example, Cunha et al. (2015) in a Yellow Latosol and by Paixão et al. (2009) in a sand texture soil.

The best coefficients of determination (R^2) were found in no-tillage, followed by minimum tillage and worst in conventional tillage, but all were above 91%, which is considered good results. The worst results of the determination coefficient were verified in the Horton model and the best results were observed in the Kostiakov model.

In relation to the residual mass coefficient (CMR), it was possible to say that the Philips model obtained a near perfect result, because in no-tillage and conventional cultivation the coefficient value was zero, which indicates that the accumulated infiltration calculated by the model was the same as that found in the field, whereas the Kostiakov-Lewis model obtained the worst results, probably due to its characteristic of overestimating infiltration rate values (Tomasini, 2010).

For the coefficient of adjustment (CA) all methods achieved similar results, with the exception of Kostiakov-Lewis, again being able to have relation with its characteristic of overestimation. In relation to the efficiency coefficient (EF), the Philip model obtained the best results of the experiment, on the other hand, once again the Kostiakov-Lewis model achieved the worst results.

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CONCLUSIONS

The plots treated with no-tillage benefited much more the process of water infiltration in the soil, as well as the adjustment of the phenomenon with mathematical models.

The best statistical results were obtained by the Philip model, the Horton model was able to estimate better the stable infiltration rate and the Kostiakov-Lewis model did not fit well to the soil and obtained inferior results to the other methods.

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