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POTASSIUM ADSORPTION ON SUBSTRATES FORMULATED WITH VERMICULITE AND PEAT

Bruno de Paula Leal[1] (ID), Michael Silveira Thebaldi[2] (ID), Yasmin Fernandes Silva[2] (ID), Pâmela Rafanele França Pinto[2] (ID), Ivani Pose Martins[1] (ID) & Ronan Souza Sales[1] (ID)

1 - University Centre of Formiga, Formiga, MG, Brazil

2- Federal University of Lavras, Lavras, MG, Brazil

ABSTRACT

The substrates composition can take place from different raw materials, being an influencer of the water and nutrient retention capacity, an important dynamic in the management of the cultivation in containers due to the possibility of nutrient leaching. It was aimed to quantify the Potassium adsorption to substrates with different proportions of vermiculite and peat, in addition to determining adsorption isotherms which would best fit the observed adsorption data, for contact periods of one and seven days. We carried out batch adsorption essays, using as an adsorbent media substrate prepared with different proportion of vermiculate and peat, and as adsorbate, solutions with concentrations of 0, 25, 50, 75 and 100 mg/L of K. The substrate that showed the highest adsorption capacity, then less leaching potential, was the one constituted with the largest amount of peat. The Freündlich's isotherm best represents the K adsorption phenomenon in all the studied treatments.

ADSORÇÃO DE POTÁSSIO EM SUBSTRATOS FORMULADOS A BASE DE VERMICULITA E TURFA

A composição de substratos pode se dar a partir de diferentes matérias primas, sendo essa influenciadora na capacidade de retenção de água e nutrientes, dinâmica importante no gerenciamento do cultivo em recipientes de volume restrito, em função da disponibilidade hídrica e possibilidade de lixiviação de nutrientes e outros contaminantes. Objetivou-se quantificar a adsorção de potássio a substratos com diferentes proporções de vermiculita e turfa, além de determinar, modelos matemáticos de isotermas de adsorção que melhor se ajustariam aos dados observados de adsorção, para tempos de contato de um e sete dias. Foram realizados experimentos de adsorção em batelada, usando como meio adsorvente substratos preparados com diferentes proporções de vermiculita e turfa, e como adsorvato, soluções com concentrações de 0, 25, 50, 75 e 100 mg/L de K. O substrato que mostrou possuir maior capacidade de adsorção de K, e assim menor potencial de lixiviação, foi o constituído de maior quantidade de turfa. O modelo de isoterma de adsorção de Freündlich é o que melhor representa o fenômeno de adsorção de K em todos os tratamentos estudados.

SECTION EDITOR IN CHARGE

Renato Augusto da Conceição Alves

INTRODUCTION

The substrate is characterized as all porous material that provides the retention of water, oxygen, and nutrients to be made available to plants, and can be used in its pure form or mixed with other elements (FARIA *et al.*, 2016). The composition of the substrates is varied, however, their production can take place using different proportions and raw materials, as rice husks, pine husks, coconut fiber, peat and vermiculite (KRATZ & WENDLING, 2016**).**

Among these, vermiculite is a substrate frequently used in the production of forest species seedlings and laboratory seeds analysis as a germination standard test (PAGLIARINI *et al.*, 2015; RONTANI *et al.*, 2017). Peat presents as its main characteristic a good water retention capacity and for having the ability to contract excessively when dry, it must always be kept moist (FERRAREZI *et al.*, 2017; MARTINS *et al.*, 2011; MENEZES JÚNIOR *et al.*, 2000).

It is necessary to have a wider knowledge of the characteristics of a substrate, therefore, studies of aspects linked to the retention and leaching of ions have great importance, since for production in nurseries and greenhouses, higher fertilization rates are used than in other crops (MOLITOR, 1990), thus, the lost water may have a significant amount of unused fertilizer (DUMROESE *et al.*, 2005; JUNTENEN *et al.*, 2002) and be a potential pollution source of subsurface and surface water (DUMROESE *et al.*, 2006) in the nursery vicinity.

Also, with the nutrients carried with the percolated water, there will be a nutrient deficit and an economic expense to remedy this loss (MELO *et al.*, 2013; MORAIS *et al.*, 2015; ROS *et al.*, 2017). As an aggravating factor, seedlings and plants grown in containers are usually over-irrigated, due the lack of information on the water requirement in this type of cultivation to have an optimal growth (BAYER *et al.*, 2014).

Therefore, adsorption, as a process of retention and accumulation of ions and molecules on the surface of a solid, can be analyzed by adsorption isotherms, characterized as tools for determining their availability and loss in the medium by the leaching process, being considered the most important ions lost by the process the phosphorus, nitrogen, and Potassium (CARDOSO *et al.*, 2017; MENEZES JÚNIOR *et al.*, 2000).

Among the mentioned elements, Potassium stands out as an object of study, for being a cation considered very mobile and, thus, it can be easily leached when excessive irrigation depths are applied (OLIVEIRA *et al.*, 2004). As an example, the work by Thebaldi *et al.* (2015), that verified the dynamics of chemistry characteristics of a substrate in sub-irrigation tanks with recirculation; they found that the number of irrigations caused a significant reduction in the concentration of Potassium in different containers, with its concentration also having increased in the recycled irrigation water.

From that, we aimed with this paper to quantify the Potassium adsorption to substrates formulated with different amounts of vermiculite and peat for two adsorbate-adsorbent contact periods, besides verifying, among the mathematical models of adsorption isotherms of Langmuir, Linear, and Freündlich, which one presents better fit to the observed adsorption data.

MATERIAL AND METHODS

The substrates were formulated based on peat and vermiculite in proportions of 75% peat and 25% vermiculite (S1); 50% peat and 50% vermiculite (S2); and 25% peat and 75% vermiculite (S3). With the substrates already formulated for different percentages of peat and vermiculite, their cation exchange capacity (CEC) was evaluated, according to the method described in IN 17 (BRASIL, 2007). Thus, 997.332, 832.908 and 638.352 $mmol_c/kg$ were obtained for S1, S2, and S3, respectively.

Subsequently, columns made up of polyvinyl chloride (PVC) tubes segments were filled with the three types of substrates, and, using Mariotte's Bottles, deionized water was percolated by the porous media to perform its leaching. Complete leaching was achieved when it was found that the effluents from the columns had zero electrical conductivity. At the end of this process, the material was dried in an oven at 40 ºC.

For proceed with the Potassium adsorption tests in batch, 5 g of substrate and 75 mL of a solution of Potassium Chloride (KCl) were placed in beakers,

using the initial concentrations 0, 25, 50, 75 and 100 mg/L of K. The first homogenization of the substrate/solution set was carried out manually with the aid of a glass stick. The beakers were placed in an incubating shaker at a constant temperature of 20 °C, in contact periods of 1 and 7 days (T1 and T7, respectively).

After the sorption periods, the supernatant solutions of the beakers were filtered so, the Potassium equilibrium concentration determination could be performed. The concentrations of adsorbed K were measured using a Flame Photometer model 910M from the manufacturer Analyzer. The concentration of Potassium adsorbed to the substrate was obtained with the use of Equation 1.

$$S = (C_0 - C_e) \times \left(\frac{v}{m}\right) \quad (1)$$

where,
S = solute mass adsorbed to the porous medium amount (mg/kg substrate);
C_0 = initial Potassium concentration in the solution (mg/L);
Ce = equilibrium Potassium concentration in the solution (mg/L);
v = volume of solution added to the beaker (L); and
m = substrate mass added to the beaker (kg).

From the determination of the Potassium concentration adsorbed to the substrates and the equilibrium concentration of the solutions, it was possible to adjust the Linear, Langmuir's and Freündlich's adsorption isotherms (Equations 2, 3 and 4, respectively) to the observed data.

$$S = k_d \times C_e \quad (2)$$

$$S = \frac{k_L \times C_e \times b}{1 + (k_L \times C_e)} \quad (3)$$

$$S = k_F \times C_e^{\frac{1}{n}} \quad (4)$$

where,
Kd = partition coefficient (L/kg);
b = maximum adsorption capacity (mg/kg);
k_L = adsorbate/adsorbent interaction constant (L/mg);
1/n = constant related to the heterogeneity of the surface; and
kf = Freündlich's adsorption capacity constant $(mg^{1-(1/n)} L^{1/n}/g)$.

For the treatments effect evaluation on Potassium adsorption to the substrates, a completely randomized design (DIC) was set up in a 3 x 2 x 5 factorial scheme with three replications, being the sources of variation the effect substrate type (three levels: S1, S2, and S3), contact periods (two levels: 1 and 7 days) and initial K concentrations (five levels: 0, 25, 50, 75, and 100 mg/L).

If we found a significant difference in the simple effects or interactions between the sources of variation using the F Test at 5% probability, a comparison of means was performed using the Scott-Knott test at 5% probability for qualitative variables and regression analysis, also at 5% probability, for quantitative variables.

Additionally, the mathematical models of adsorption isotherms fitting were made using the Microsoft Excel® Solver package, and then the parameters of each of the above-mentioned models were obtained, to minimize the sum of the squared deviations between observed and simulated adsorbed concentrations.

We performed the mathematical models fitting quality determination with the following statistical indicators: root mean square error (RMSE) and mean absolute error (MAE), presented in Equations 5 and 6, respectively, determination coefficient (R^2) and F Test (Equation 7).

$$RMSE = \left[\frac{1}{N} \times \sum_{i=1}^{N} \left(X_{observed,i} - X_{ajusted,i}\right)^2\right]^{\frac{1}{2}} \quad (5)$$

$$MAE = N^{-1} \sum_{i=1}^{N} \left|X_{adjusted,i} - X_{observed,i}\right| \quad (6)$$

$$F\ Test = \frac{\sum \overline{X}^2_{adjusted,i}}{\sum \overline{X}^2_{residual,i}} \quad (7)$$

where,
N = number of observations for each batch test;
$X_{observed,i}$ = adsorption obtained experimentally (mg/kg);
$X_{adjusted,i}$ = adsorption fitted by the model (mg/kg); and
$X_{residual,i}$ = residual adsorption, defined as the difference between $X_{observed,i}$ and $X_{adjusted,i}$ (mg/kg).

RESULTS AND DISCUSSION

The results presented in Table 1 show that the simple effect of the causes of variation is significant ($p < 0.01$), however, when the interaction between the contact periods with any other source of variation is evaluated, there is no significant effect of the interaction. Thus, there is no change in the behavior trend of the K adsorption values for the substrates and initial concentrations evaluated at different contact periods (1 and 7 days), even though the K adsorption has increased with the increment in time of contact. In contrast, the relation between substrate and initial K concentration had a significant effect at the level of 1% statistical probability.

Analyzing the simple effect of the different substrate types in K adsorption, it can be established that the more peat present in it, the higher the adsorption, referring to the S1 substrate. Also, the K adsorption means for the three substrates were different from each other, as shown in Table 2.

It is verified that the greater substrate CEC (997.332 mmol$_c$ kg^{-1} for S1), the greater the K adsorption, as also checked by Linhares *et al.*

(2009), then the lower CEC, greater is the tendency for anion adsorption. Studies indicate that at pH less than 6.5, the magnitude of the adsorption is controlled by the CEC isolated from each constituent of the soil, having a high charge density that becomes adsorbed on the charged surfaces (KAWAMURA *et al.*, 1993; ZACHARA *et al.*, 1992). Substrates can adsorb and exchange cations, and their sorption and buffering capacity are linked to CEC, with substrate affinity increasing with increasing charge (SCHAFER; LERNER, 2022). Binner et al. (2017) points out that the CEC can be an indication to help the choice of clays for substrates to be used in horticultural crops.

Nicochelli *et al.* (2012) in an experiment that evaluated the Potassium adsorption from the soil - solution ratio variation and adsorbent - adsorbate contact period in the Potassium mobility on soil samples, found that the Potassium ion showed greater affinity with the samples that had a higher percentage of clay and a higher CEC. A higher CEC value indicates a greater retention of the number of cations present, given that CEC indicates the retained cations amount on the porous medium surface (LIMA *et al.*, 2018; LOPES *et al.*, 2018).

Table 1. Summary of the ANOVA evaluating the effects of different contact periods, K initial concentrations and substrates formulated with vermiculite and peat on K adsorption

Cause of variation	DF	Mean square and F significance
Substrate (S)	2	228652.50**
Contact Period (P)	1	33062.50**
Initial concentration of K (C)	4	2177550.00**
S x P	2	2132.50[NS]
S x C	8	41199.38**
P x C	4	2362.50[NS]
P x S x C	8	2173.13[NS]
Residual	60	2640.00
Total	89	
Coefficient of variation (%)		13.09
Overall Mean		392.50 mg/kg

Where: DF: degrees of freedom, **: significant at 1% probability, NS: not significant

Table 2. Simple effect of the different types of substrate, formulates with peat and vermiculite, on K adsorption

Substrate	Adsorption[1] (mg/kg)
S1	481.5 a
S2	389.0 b
S3	307.0 c

[1]Means followed by the same letter do not differ by the Scott-Knott test at 5% of statistical probability

The addition of clay to peat can help to improve its chemical and physical properties, since peat is widely used as a substrate for horticulture (BINNER et al., 2017). McCarter, Weber and Price (2018) studied the effect of Na^+, K^+ and NH_4^+ cations on the adsorption balance of peat from swamps and observed that, for multicomponent adsorption, K^+ adsorption was not influenced by the presence of the other two cations , while K^+ did not influence the adsorption of Na^+, however, it influenced that of NH_4^+.

Silber et al. (2012) studied the adsorption of zinc on a perlite substrate, and its relationship with pH and temperature. They concluded that there is a dependence between these variables with the adsorption, being the pH is related to the surface charge, and that the temperature increasing causes an increase in the pH and, consequently, there is also an increase in the Zn adsorption by the pearlite.

The effect of the evaluated contact periods on K adsorption in the studied substrates can be verified in Table 3.

When observing the contact period effect over K adsorption, it could be found that the longer period resulted in higher adsorption, being the average adsorption for 7 days 1.10 times greater than that for one day, approximately.

The contact period increase causes an increase in the adsorption rate, considering that after a certain time; it starts to have a constant, stable adsorption (VENANCIO et al., 2005; SHARMA & KAUR, 2011), a trend we did not observe in our evaluations. This can be explained by the high adsorption capacity of the substrates, due to the physicochemical nature of their constituents: Couillard (1994) states that the peat suitability as a natural adsorbent is corroborated by countless experiments involving different types of low-quality water, where it has proved to be more efficient than other traditionally used adsorbents; and vermiculite has higher CEC compared to other clays, such as hectorite, saponite and montmorillonite (FERNÁNDEZ et al., 2013). The different initial concentrations of K and their effect over K adsorption on substrates formulated with vermiculite and peat are shown in Figure 1.

Through the analysis of Figure 1, it was found that with increasing initial concentrations of K, there is an increase in its adsorption by the substrates in general. This adsorption behavior can

Table 3. Simple effect of the evaluated contact periods on K adsorption to substrates formulated with vermiculite and peat

Contact Period (days)	Adsorption[1] (mg/kg)
7	411.7 a
1	373.3 b

[1]Means followed by the same letter do not differ by the Scott-Knott test at 5% of statistical probability

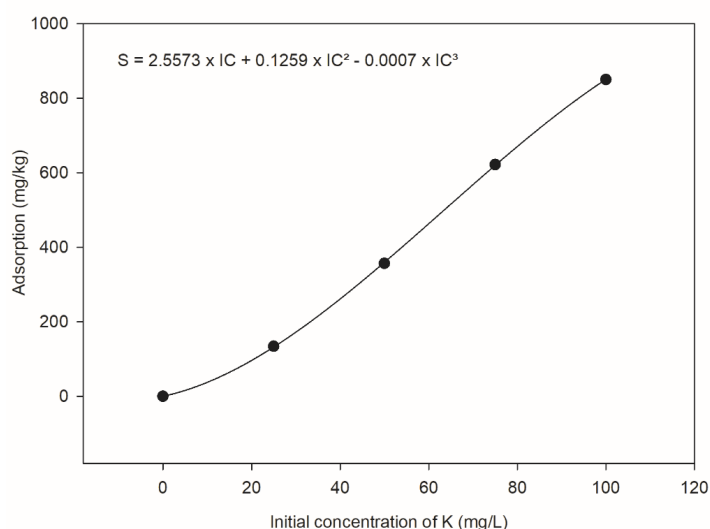$$S = 2.5573 \times IC + 0.1259 \times IC^2 - 0.0007 \times IC^3$$

Figure 1. Different initial concentrations of K and their effect on K adsorption on substrates formulated with vermiculite and peat

be described by a polynomial mathematical model of 3rd degree, in which the model fits the observed data with an adjusted coefficient of determination (R^2) of 0.99 and standard error of the estimate of 2.8375. Besides, interaction slice of the initial concentrations within each substrate over the K adsorption can be checked in Figure 2.

It is observed that increasing the initial concentration of K there is an increase in the adsorption by the substrate, being the values of R^2 for S1 and S2 were 0.9957 and 0.9971, respectively, and for S3, it was 0.9309 (Figure 2). Studies carried out by other researchers show an increase in adsorption related to the increase in concentration, however, it is found that with the concentration of ions available in solution increase, the availability of adsorption sites decreases (DUARTE NETO *et al*., 2018; SHIKUKU *et al*., 2015), which, in some cases, leads to the stabilization of the values of the ion equilibrium concentration in the adsorbate solution, even with the increase of the initial ion concentration.

It is then observed that for S1, there is a greater K adsorption even from the initial concentration of 25 mg/L of K when compared with the other two substrates, with the adsorption observed in S2 being higher than S3. In the same way, as discussed, the higher the proportion of peat in the substrate, the greater the K adsorption, which is explained by the higher CEC of S1.

Further, by the observation of Figure 2, there is an increasing tendency of K adsorption in S3 with the increase of the initial concentrations, while for S1 and S2 there is a sorption stabilization possibility more pronounced at initial concentrations close to 100 mg/L.

These results corroborate with the data presented by Lamim *et al*. (2000), who found that peat presents a good water absorption capacity, CEC and buffering power. CEC is linked to the cation's availability and their reduction through leaching, i.e., the higher the CEC the greater the accumulation of adsorbed cations (THEBALDI *et al*. 2015). Potassium concentrations increase in groundwater due to leaching, and attention should be given to this fact, taking measures to reduce the loss of K through this process (GRECCO *et al*., 2019). In table 4, the adsorption variation in the substrates for different initial K concentrations is presented.
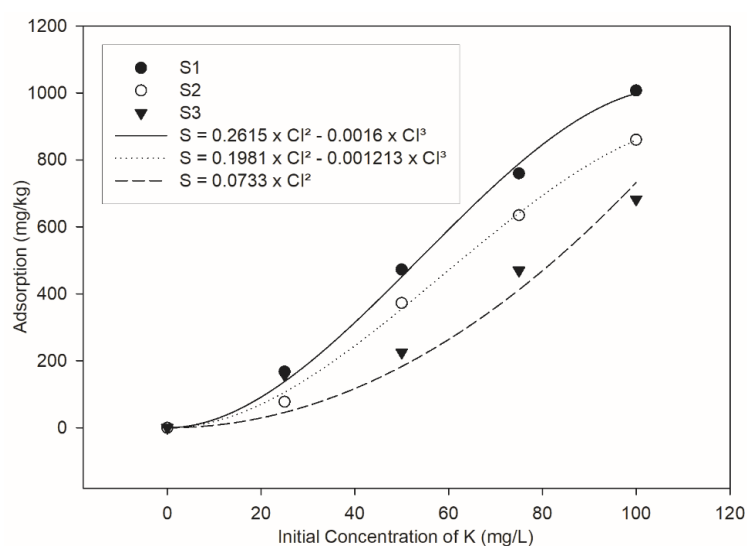

Figure 2. Effect of the initial K concentrations evaluated on each substrate composed of different proportions of vermiculite and peat over K adsorption

Table 4. Potassium adsorption[1], in mg/kg, for the different substrates in each evaluated initial concentration

Substrate	Initial concentrations of K (mg/L)				
	0	25	50	75	100
S1	0 a	167.5 a	472.5 a	760.0 a	1007.5 a
S2	0 a	77.5 b	372.5 b	635.0 b	860.0 b
S3	0 a	157.5 a	225.0 c	470.0 c	682.5 c

[1]Means followed by the same letter in the column do not differ by the Scott-Knott test at 5% of statistical probability

Initially, for a null initial concentration, the same statistical behavior is observed for the three substrates. When the concentration of 25 mg/L is analyzed, it is noticed that there is a statistical similarity between the amount adsorbed by substrates S1 and S3. For the initial concentrations of 50, 75 and 100 mg/L, there is no similarity between the studied substrates, with the highest adsorption being observed for S1 and the lowest in S3.

Thus, it is possible to observe a K adsorption reduction for the concentrations of 50, 75 and 100 mg/L as the amount of peat in the substrate is reduced. This behavior did not happen for the initial concentration of 25 mg/L, where there was a similarity in the adsorption between S1 and S3: possibly this happened due to the low K concentration, limiting the adsorption rate, whereas the higher the ion concentrations, the quicker their sorption in the adsorbent porous media (VILELA *et al.*, 2018). But, in general, a higher K adsorption was achieved in S1.

Studies conducted by Binner *et at.* (2017) prove greater K adsorption on substrates with a higher proportion of peat. However, in addition to the physicochemical nature of the materials, the influence of the size and distribution of pores on the adsorption of water on the substrates must be stood out, which can lead to leaching and loss of nutrients (CONCEIÇÃO *et al.*, 2015).

Through the adsorption values and equilibrium concentrations for each initial concentration defined, it was possible to fit the Linear, Langmuir and Freündlich adsorption isotherms mathematical models. Then, the statistical parameters indicative of the fit quality of the K adsorption isotherms on different substrates were calculated for the contact periods of 1 and 7 days, as shown in Table 5. These parameters are the R^2, which indicates the curve fit to the data; MAE, the mean absolute error; RMSE, root mean square error; and the F Test, which analyzes and compares variances within and between samples.

Table 5. Statistical parameters indicative of the fit quality of the K adsorption isotherms on different substrates for contact periods of 1 and 7 days

Substrates	Contact periods	Parameters	Linear	Langmuir	Freündlich
S1	1 day	R^2	0.93	0.93	0.99
		RMSE	115.08	115.63	44.97
		MAE	85.18	87.88	37.29
		F Test	26.21	24.99	177.20
	7 days	R^2	0.98	0.98	0.99
		RMSE	65.92	65.95	37.80
		MAE	45.67	45.77	32.07
		F Test	85.90	85.75	263.28
S2	1 day	R^2	0.74	0.74	0.88
		RMSE	176.68	176.68	112.09
		MAE	144.47	144.50	83.11
		F Test	6.62	6.62	17.94
	7 days	R^2	0.97	0.97	0.97
		RMSE	65.68	65.76	52.60
		MAE	44.76	44.86	35.73
		F Test	63.65	63.41	99.80
S3	1 day	R^2	0.93	0.93	0.96
		RMSE	61.19	72.44	57.95
		MAE	42.07	48.20	46.60
		F Test	33.26	29.24	46.04
	7 days	R^2	0.97	0.97	0.99
		RMSE	57.92	57.96	19.26
		MAE	47.34	47.39	15.39
		F Test	52.27	52.18	480.95

According to the presented in Table 5, the Freündlich's model for the three substrates and between the two analyzed contact periods presents a better fit to the observed data (higher R² value, lower values of MAE and RMSE; and higher F Test value), therefore, the Freündlich's isotherm was chosen in all the evaluated scenarios as best representing the studied adsorption phenomenon (Table 6).

Analyzing the Linear and Langmuir models, it could be found that as the contact period of the substrate to the adsorbate increases, these models are better fit to the observed data - there is a decrease in the statistical errors obtained. This is due to a greater linearization of the observed adsorption values with the contact period of 7 days, compared to 1 day, as can be seen in Figure 3.

Table 6. Mathematical models of adsorption isotherms that best represent the K adsorption process in the evaluated treatments

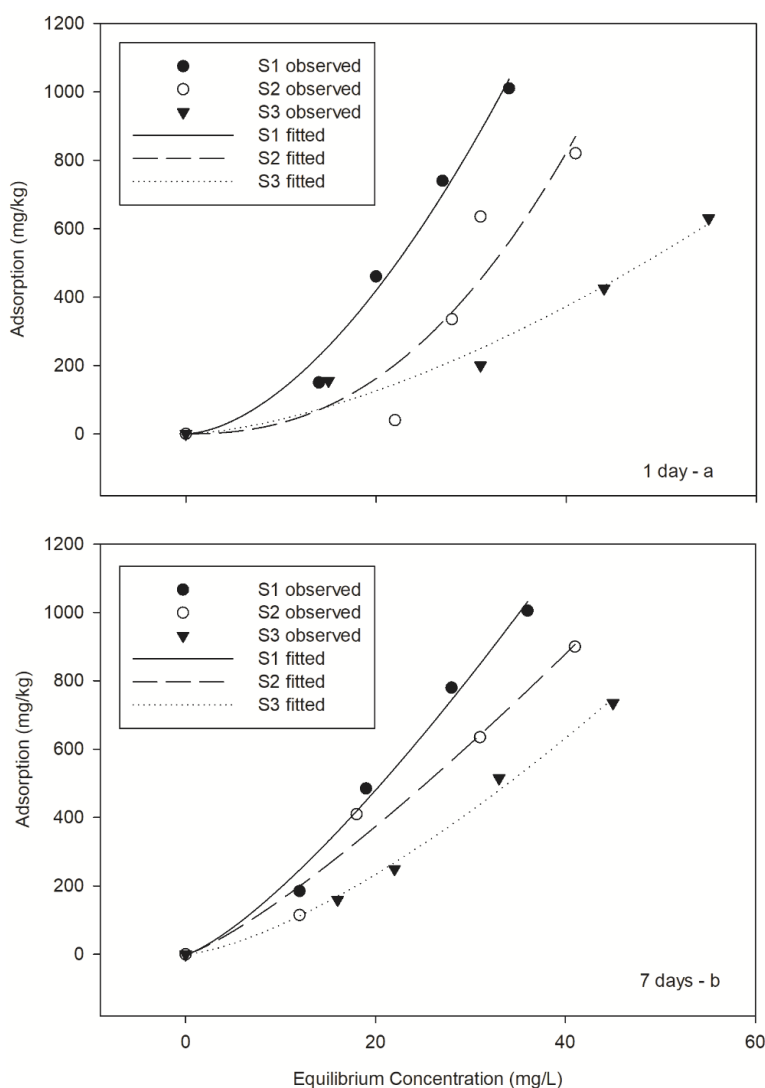| Contact Period	S1	S2	S3
1 day	$S = 2.5068 \times C_e^{\frac{1}{0.5853}}$	$S = 0.1438 \times C_e^{\frac{1}{0.4265}}$	$S = 2.9135 \times C_e^{\frac{1}{0.7395}}$
7 days	$S = 9.7757 \times C_e^{\frac{1}{0.7692}}$	$S = 9.3555 \times C_e^{\frac{1}{0.8121}}$	$S = 3.1803 \times C_e^{\frac{1}{0.6970}}$

Figure 3. Graphical representation of the adsorption isotherms chosen in each treatment, for contact periods of 1 day (a) and 7 days (b)

Analyzing the graphical representation of the adsorption isotherms (Figure 3), as seen in Figure 2, it is possible to see that the greater the amount of peat present in the substrate, the greater is the adsorption. When analyzing the obtained isotherms (Table 6) for the different contact periods, it is observed that the constant related to the heterogeneity of the surface (n), in most cases, increased with the contact periods.

This parameter indicates the affinity of the substrate with the solute, which is dependent on the heterogeneity of the surface, which is influenced by the size and nature of the adsorption sites (MALEK & FAROOQ, 1996). Values of n between 2 and 10 indicate favorable adsorption (PEREIRA & SILVA, 2009), not verified in this study, which indicates a slow kinetics of K adsorption to the evaluated substrates. These slow kinetics trend can be explained by the monovalent K charge and the and by the already observed substrates high adsorption capacity, leading to a difficulty in filling the porous medium exchange sites. Because of this behavior, Freundlich's isotherms could represent well the evaluated treatments, as the Linear isotherm fits the adsorption occurrence in constant proportions and the Langmuir's conceptually presents a maximum adsorption limit ("b" parameter – Equation 3), far to be achieved in our essays.

The Freündlich adsorption capacity constant (kf) demonstrates the capacity of the adsorbent medium to retain a solute. The "n" and "kf" provided by the Freündlich's exponential equation are considered the best descriptive adsorption parameters adsorption, and "n" variations are responsible for showing that the elements were adsorbed under different energy levels (BUCHTER *et al*., 1989; SOARES, 2004). Indeed, it is acknowledged the higher the values of "n" and "kf", more the solute is adsorbed to the medium (LINHARES *et al*., 2009).

Observing these variations between the isotherms for each substrate, there is not an equally relation to that previously observed: for the contact period of 1 day the "n" decreases from S1 to S2 and increases from S2 to S3, as well as the "kf" value. For the 7 days of contact period, the isotherms suffered a decrease in the "kf" values between the substrates, and there was an increase in the "n" value from S1 to S2 and a decrease from S2

to S3. This shows that for the studied substrates the highest values of "n" were found for S3 and S2, over 1 and 7 days, respectively. For "kf", the highest values were calculated for S3 (1 day) and S1 (7 days).

The higher "kf" value in the 1 day isotherms was obtained in S3, a substrate with a lesser amount of peat in its composition, which indicates that there were still exchange sites possible to adsorb K, requiring a longer contact period between the solute and the porous medium. It is noteworthy, however, that equilibrium conditions are generally reached in 24 hours, as presented by Roy *et al*. (1992), with equilibrium time being the minimum necessary to establish a concentration variation rate of solute in solution, equal or less than 5% for a 24-hour interval.

García-Rodríguez et al. (2022) analyzed the effect of semi-hydroponic lettuce growth with peat and vermiculite substrate (30%) with replacements between 15 and 70% of the total volume by biochar from vineyard pruning. These authors concluded that the best biochar replacement percentage for growing lettuce is 30%, in which there is a supply of physical, chemical and nutritional factors, when compared to higher percentages of replacement, with a supply of nutrients without symptoms of stress and there are improvements in the crop yield.

Hoskins et al. (2014) points out that it is essential to reduce the leaching of dissolved mineral nutrients, by understanding their movement in the substrates. The greater adsorption of K generates a lower concentration of this element in the solution, which results in a lower risk of its leaching (BINNER et al., 2017) and, consequently, contamination.

CONCLUSION

- The Freündlich's isotherm best represents the K adsorption phenomenon in all the studied treatments, being classified as unfavorable, which denotes a slow kinetics of adsorption of this ion to the substrates. As a result, a higher K adsorption at 7 days of contact period was verified, compared to that determined after 24 hours. It is noteworthy, however, the maximum adsorption capacity of the material for this ion

has not been reached, due to the high CEC of the adsorbent media.

- From the presented results, the highest adsorption occurred in S1, which has a higher proportion of peat in its composition, over 7 days of contact period. In contrast to their low water retention capacity, substrates provide less K leaching possibility in irrigated nurseries when compared to soils, especially those with a higher proportion of peat in their constitution. With this, when subirrigation is carried out, there would be a better quality of recycled water when using closed systems. For over canopy irrigation, as inverted micro-sprinkler, less contamination of soil and subsurface water can occur, when the water application is made with depths higher than the water retention limit, a common practice in nurseries.

AUTHORSHIP CONTRIBUTION STATEMENT

LEAL, B.P.: Data curation, Formal Analysis, Investigation, Writing – original draft; **THEBALDI, M.S.:** Conceptualization, Methodology, Project administration, Writing – original draft, Writing – review & editing; **SILVA, Y.F.:** Data curation, Formal Analysis, Writing – review & editing; **PINTO, P.R.F.:** Data curation, Writing – review & editing; **MARTINS, I.P.:** Funding acquisition, Resources; **SALES, R.S.:** Funding acquisition, Resources,

DECLARATION OF INTERESTS

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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