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RESEARCH ARTICLE

# Study on estimation of infiltration rate with different soil conditioners and evaluation of infiltration models

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## Abstract

Soil conditioners enhance soil properties, particularly for moisture conservation in rain-fed agriculture. This study evaluated the effects of various soil conditioners, including hydrogel (0.001 t $ha^{-1}$ and 0.002 t $ha^{-1}$), gypsum, coir pith and press mud on the infiltration capacity of sandy clay loam soils at the Agricultural Engineering College and Research Institute in Kumulur, Tamil Nadu, a semi-arid region. Infiltration was measured using a double-ring infiltrometer and four models, Kostiakov, Horton, Green-Ampt and Philips, were used to predict the infiltration rates. Initial infiltration values measured were 19.2, 18, 16.8, 12, 10.8 and 9.6 cm $h^{-1}$ for treatments with hydrogel (0.002 t $ha^{-1}$), hydrogel (0.001 t $ha^{-1}$), gypsum, coir pith, press mud and the control (without conditioner), respectively. Results showed that hydrogel significantly improved infiltration, with the highest rate observed at 0.002 t $ha^{-1}$ (19.2 cm $h^{-1}$), compared to the control (8.2 cm/$h^{-1}$). The Nash–Sutcliffe efficiency of the Philips model varied from 0.75 to 0.95 for the different soil conditioners and provided the most accurate prediction of infiltration rates, followed by the Horton model. This study highlights the importance of soil conditioners in improving water retention and infiltration, which are essential for effective water management in agricultural systems, particularly in semi-arid regions.

**Keywords:** hydrogel; infiltration models; infiltration rate; semi-arid agriculture; soil conditioners

## Introduction

Dry regions account for 45 % of the worlds' land area, of which 7 % is arid, 20 % is semi-arid and 18 % is dry subhumid (1). In India, about 15 million ha (Mha) of dryland lies in the arid region, which receives <500 mm rainfall; another 15 Mha is in the semi-arid region with 500-750 mm annual rainfall. Rainfed agriculture (which relies exclusively on green water) is typically less productive than irrigated operations because it is more susceptible to climatic shocks and the vagaries of local weather conditions (2). Agriculture in India faces numerous challenges in managing soils. Most soils across the country are characterized by low nutrient levels, with the average soil organic carbon (SOC) around 0.54 percent. India also confronts challenges stemming from land degradation and the deterioration of soil health. With about 30 % of the total geographical area under land degradation, the deficiency of several plant nutrients adversely affects the nutrition intake among the local population.

Nutrient depletions and deficiencies in soil, coupled with inappropriate fertilizer application, lead to declining productivity. Adequate replenishment of nutrients, appropriate fertilizer applications tailored to soil types and analyses and increasing organic contents in soil are some of the practices essential for ensuring sustainable food production. It is also noteworthy that an estimated 3 billion tonnes of soil are carried away by water and wind annually in India. Improving production and resilience requires optimizing soil water use by improving rainwater capture, increasing soil moisture retention, maximizing infiltration and minimizing surface runoff and evaporation. Soil moisture is key to soil health and function. It helps to sequester SOC and stops carbon-rich soils from drying out and increasing their emissions. Soil conditioners may improve infiltration and water-holding capacity in dry, coarse soils that do not hold water well. Hydrogel polymer technology has recently been widely used in the agricultural and horticultural sectors as soil conditioner because of its multifunctional roles in excellent water absorbency and water-retaining ability.

The hydrophilic groups, *viz.,* acrylamide, acrylic acid, acrylate, carboxylic acid, etc., of the polymer chain are responsible for water absorption in a hydrogel. When the polymers come in contact with water, the water penetrates the hydrogel system by osmosis and hydrogen atoms react and come out as positive ions (3). This process leaves several negative ions along the length of the polymer chain.

These negative charges repel each other, force the polymer chain to unwind, open up and attract water molecules and bind them with hydrogen bonding (4). The hydrogel can absorb more than 400-1500 times its dry water weight in this process and act as a miniature water reservoir. When the root zone begins to dry up, the hydrogel dispenses up to 95 % of its stored water to plant absorption (5, 6).

In sandy soils of arid desert conditions, applying hydrogel at 150 g plant$^{-1}$ with 80 percent irrigation requirement to Banana (Grand Naine) resulted in a 14.9 per cent yield increase without hydrogel treatment (7). The application of Pusa hydrogel at 2.5 kg ha$^{-1}$ in sandy loam soil registered a 5.3 percent increase in yield and a 5.52 percent increase in water use efficiency, as reported by (7). A similar yield increase (6.2 per cent) was observed by (8) in aerobic rice (Super basmati) with 2.5 kg ha-1 hydrogel application to sandy loam soil with a 23.7-37.2 percent increase in soil moisture. Stockosorb soil conditioner applied at 100 g plant -1 increased the yield of Citrus limon by 43 per cent in highly drained sandy loam soils of Arunachal Pradesh (8).

In fine-textured soils, where soil crusting is a significant problem due to the beating action of raindrops, the addition of gypsum was found promising to increase the infiltration rate of the soil since many individual small clay particles bind together to obtain larger particles, thus enhancing the soil moisture storage resulting in less runoff and soil loss as well as phosphorus leaching due to calcium in gypsum binding with phosphorus. Because of its easy accessibility and cost-effectiveness, gypsum is used to cure saline-affected soils and reclaim the soil structure. Gypsum application decreases the SARs, improves infiltration, reduces soil compaction and consequently improves crop production (9). Steady infiltration rates indicated 2-fold increases due to surface gypsum applications and 4 to 6 fold increases due to slotted gypsum. This should provide increased moisture storage and reduced soil erosion hazards during prolonged heavy rainfall periods, provided that a crust does not form under the impact of raindrops (10). Field studies on the Appling soil have shown the utility of surface-applied gypsum over the growing season in increasing water infiltration and decreasing soil loss. The longevity of this effect appears to extend over at least a crop -growing season under average field conditions. Regular yearly applications, perhaps at a rate of 1-2 mt/ha, seem necessary for a continued effect, although longer-term changes in soil properties may also occur. In one study cotton emergence was marginally increased by gypsum application (11).

The amelioration of soils with chemical amendments is constrained due to the high reclamation cost and limited supply due to their extensive use in non-agricultural sectors. Studies used organic amendments like coir pith (raw and composted), paddy husk, sawdust, goat and poultry manure, farm yard manure and press mud from sugar industries. Pressmud is a soft, spongy, amorphous and dark brown-white material containing nitrogen, cellulose, lignin, protein, sugar fibre and coagulated colloids, including cane wax, albuminoids, inorganic salts and soil particles and all other carbon-containing components available in the final product (12). The application of sugarcane pressmud is also at a low cost with a slower release of nutrients and trace elements, high water holding capacity and mulching properties (13). Adding pressmud improves soil aeration and drainage in heavy soils, whereas it helps improve moisture retention in sandy soils. When added to agriculture fields, it increases the cane yield, improves the juice quality and enhances the ammonifying power of soils (14). Another essential organic amendment most commonly used is composted coir pith to retain water in soils in dry regions.

Coir pith is an organic material that improves moisture retention in soil and lowers the water demands of crops (15), making it particularly useful in regions with limited rainfall. These amendments have been particularly beneficial in flood-affected and drought-affected areas of the world, where soil conditions are often poor and agricultural productivity is significantly hindered in regions of Sub-Saharan Africa, Southeast Asia and South America, where frequent droughts and floods reduce soil fertility and water retention, the application of soil conditioners has helped improve plant survival and growth.

Accurate assessment of infiltration rates is essential to evaluate the effectiveness of different soil and crop management practices and for applications such as irrigation planning, stormwater management and soil erosion prediction. Field infiltration measurement with infiltrometers provides valuable site-specific data but is labour-intensive, time-consuming and may be influenced by local soil heterogeneities and manual errors. As an alternative, various mathematical models have been developed to estimate infiltration rates based on soil properties and environmental conditions. The accuracy of these models depends on the precision of input parameters, such as soil hydraulic properties, which can be challenging to determine accurately. Moreover, models may not deal with the complexities of field conditions, such as soil layering, macropores and variable antecedent moisture content.

In practice, a combined approach is often recommended. Field measurements using infiltrometers can provide baseline data to calibrate and validate infiltration models. Once validated, these models can estimate infiltration rates over large areas or under varying conditions, reducing the need for extensive fieldwork. Popular models for predicting infiltration include Kostiakov, Horton, Green-Ampt and Philips (16). The data on infiltration influenced by different soil amendments is limited for planning any soil and water management programs. Hence, this research work was contemplated with the objectives of evaluating the impact of varying soil conditioners on infiltration rates in sandy clay loam soil and identifying the most accurate model, namely, Philips, Horton, Kostiakov (empirical models) and Green-Ampt (physical model) for predicting infiltration in soils treated with different conditioners.

## Materials and Methods

The research was conducted at the Agricultural Engineering College and Research Institute in Kumulur (latitude is 10.92° N; longitude is 78.82°E; 62 m above sea level), in Thiruchirapalli, Tamil Nadu. The study area is classified as a semi-arid region. Infiltration rates were measured in soils treated with chemical soil conditioners (hydrogel and gypsum) and organic conditioners (press mud and coir pith) and compared with control (without soil conditioner). The rate of application of soil conditioners is as follows: Hydrogel: 0.001 t $ha^{-1}$ and 0.002 t $ha^{-1}$; Gypsum: 1.0 t $ha^{-1}$; Coir Pith: 12.5 t $ha^{-1}$ and Press Mud: 37.5 t $ha^{-1}$

A double ring infiltrometer was used to quantify the infiltration rate (Fig. 1-2), depicting the study areas' field view.

The measured infiltration rate was used to calibrate and validate the following infiltration models.

### Infiltration models

#### Hortons' Model

Horton (17) expressed decrease of infiltration capacity with time as an exponential decrease as formula in Equation 1 (17).

$$f = fc + (fo - fc)e^{-Kt} \quad \text{(Eqn.1)}$$

Where f is infiltration capacity at any time t.

fc is the final steady-state infiltration capacity.

fo is initial infiltration capacity.

k Hortons' constant represents the rate of decrease in infiltration capacity.

t is time in hours.

#### Green - Ampt Model

Green and Ampt proposed a model for infiltration capacity based on Darcys' law as given in Equation 2 (18).

$$fp = m + \frac{n}{Fp} \quad \text{(Eqn.2)}$$

Where

$f_p$ is infiltration capacity.

$F_p$ is cumulative infiltration.

m and n are Green - Ampt parameters of infiltration.

#### Philips' Model

Philips' infiltration capacity is expressed as Equation 3 formula (19).

$$fp = \frac{1}{2}st^{-\frac{1}{2}} + K \quad \text{(Eqn.3)}$$

Where

$f_p$ is infiltration capacity.

S is a function of soil suction potential called sorptivity

K is Darcys' hydraulic conductivity.

The constant parameters of each model were calculated and the data were compared with the observed field infiltration rate.

#### Kostiakov Model

The Kostiakov model expresses cumulative infiltration capacity as a formula in Equation 4 (20)

$$f = at^b \quad \text{(Eqn.4)}$$

Where

f is cumulative infiltration at any time t.

t is time in min.

a and b are constants with a > 0 and 0 < b < 1.

### Nash-sutcliffe efficiency (NSE)

Nash-Sutcliffe efficiency is a widely used statistical index to compare hydrological models by assessing their goodness of fit (21). The value of NSE is an indicator of the performance of the model. A higher value indicates the goodness of the model. NSE is calculated as Equation 5 formula (22).

$$NSE = 1 - \frac{\sum_{i=1}^{n}(O_i - P_i)^2}{\sum_{i=1}^{n}(O_i - \overline{O})^2} \quad \text{(Eqn.5)}$$

Where $O_i$ are the observed value, the predicted value and the mean of the observed value.

The range of NSE lies between 1.0 and -∞. The value 1.0 represents the perfect model fit and vice-versa.

### Scanning electron microscope (SEM) images of soil amendments

Fig. 3 shows the SEM images of the different conditioners. The organic conditioners' SEM images, namely pressmud and coir pith, revealed their distinct morphological features, enhancing their suitability as soilless media substrates (23). Pressmud exhibited a fibrous structure with aggregated cellulose fibres and a protein matrix, along with surface porosity ranging from 20-25 µm, which aids in water retention and nutrient exchange (13). In contrast, coir pith displayed an open matrix of thin-walled, ribbon-shaped cells arranged in a honeycomb-like structure, providing high porosity and void spaces that improve aeration and water retention (24). Both pressmud and coir pith benefit from incorporating hydrogels, which further enhance their water retention capacity and help mitigate water stress in plants (25). Similarly, adding gypsum improves soil structure and enhances nutrient availability, benefiting the physical properties of these organic substrates (26).

**Fig. 1**. Double ring infiltrometer.

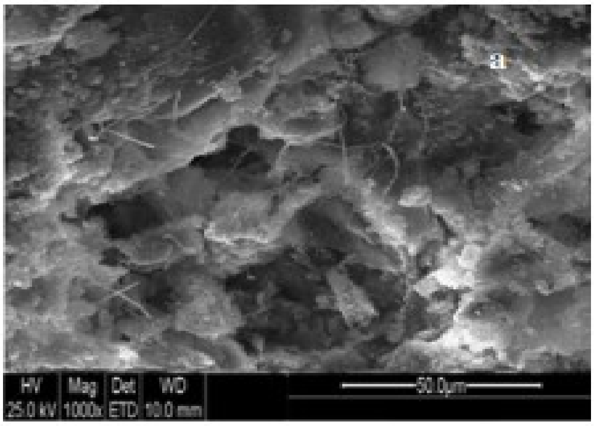
**Pusa hydrogel**

**Gypsum**

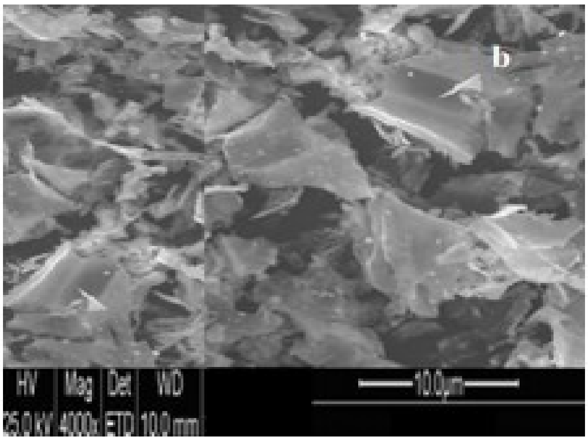
**Press mud**

**Coir pith**

**Fig. 2.** Field view of the study area.

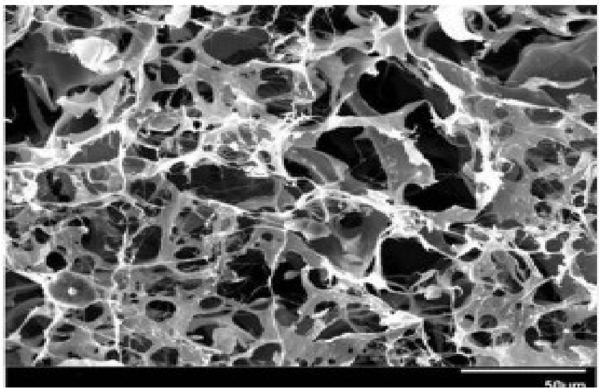



**Press mud**




**Coir pith**


**Gypsum**



**Hydrogel**

**Fig. 3.** Scanning electron microscope images of pressmud, coir pith, gypsum and hydrogel (Image courtesy: 23, 24, 25).

## Results and Discussion

### Effect of soil conditioners on infiltration rate of soil

The application of hydrogel (0.001 t ha$^{-1}$ and 0.002 t ha$^{-1}$), gypsum (1 t ha$^{-1}$), coir pith (12.5 t ha$^{-1}$) and press mud (37.5 t ha$^{-1}$) improved moisture retention and altered soil infiltration rates (Fig. 4). The introduction of these soil conditioners led to an initial rise in infiltration rates. Initial infiltration values measured were 19.2, 18, 16.8, 12, 10.8 and 9.6 cm h$^{-1}$ for treatments with hydrogel (0.002 t ha$^{-1}$), hydrogel (0.001 t ha$^{-1}$), gypsum, coir pith, press mud and the control, respectively. Over time, these values decreased and reached a steady rate of 1.2, 1.2, 0.9, 0.9, 0.7 and 0.8 cm h$^{-1}$ for the respective treatments. The application of hydrogel enhanced the initial infiltration rate by twofold, followed by gypsum (1.8 times). Among the organic conditioners, coir pith improved the initial infiltration rate by 1.25 times, followed by a 1.13-time increase in press mud applied plots compared to the control. Applying soil conditioners improved soil structure by enhancing aggregation, porosity and hydraulic conductivity while reducing bulk density. This led to better infiltration, permeability and water retention capacity, ultimately allowing the soil to retain more moisture for plant use (27, 28).

The results indicated that hydrogel was the most effective in enhancing soil infiltration rates, likely due to its ability to aggregate the soil particles, which creates pore space that facilitates water movement (29). When applied to the surface, gypsum dissolves during irrigation or rainfall, discharging electrolytes into the soil solution. This process reduces clay dispersion and minimizes crust formation, improving infiltration rates (30). Coir pith helps bind clay particles together, with the fibrous nature of coir enhancing the infiltration rate by altering soil structure (31). Press mud improves soil aeration and drainage, boosting infiltration (32). Each soil conditioner contributes uniquely to increasing the infiltration rate of the soil. Moreover, the long-term effects of these treatments may be influenced by factors such as soil texture, organic matter content and climate variability. Thus, future research should better investigate these factors' combined impact to optimize soil conditioner applications for different agricultural contexts.

In addition, previous studies have highlighted the synergistic effects of combining organic and inorganic conditioners. For instance, research indicates that co-applicating hydrogel and organic amendments like coir pith improved soil water retention and reduced water runoff, especially in regions prone to erratic rainfall patterns (33). Similarly, applying gypsum and press mud helped alleviate soil compaction and improved infiltration in heavy clay soils (29). The interactive effects of conditioners are crucial to optimizing infiltration and water retention across diverse soil types.

Applying soil conditioners enhances infiltration and contributes to the overall health of the soil ecosystem. Improving soil porosity and reducing bulk density leads to better root penetration, subsequently improving plant nutrient uptake (34). This, in turn, helps crops withstand drought or water stress more effectively, ultimately contributing to more resilient agricultural systems. Further studies could explore how these conditioners impact soil microbial communities and their role in long-term soil fertility.

Furthermore, the effect of conditioner application may vary based on the specific climatic conditions of a region. In regions with high rainfall intensity, the benefits of soil conditioners may be more pronounced in reducing surface runoff and enhancing infiltration rates (35). In contrast, the focus may shift to improving water retention and storage capacity in arid climates with less frequent rainfall. Understanding these regional differences is critical for developing site-specific strategies for using soil conditioners in sustainable agriculture.

### Comparison of infiltration models

Kostiakov, Horton, Green-Ampt and Philipss' infiltration models were selected to compare the infiltration data. The infiltration rates for each soil conditioner were calculated using the tabulated parameters for different models (Table 1). Infiltration models provide an alternative for the observed field data as they are often time-consuming and laborious. The graphical representation of observed and predicted model infiltration rates is given in Fig. 5.

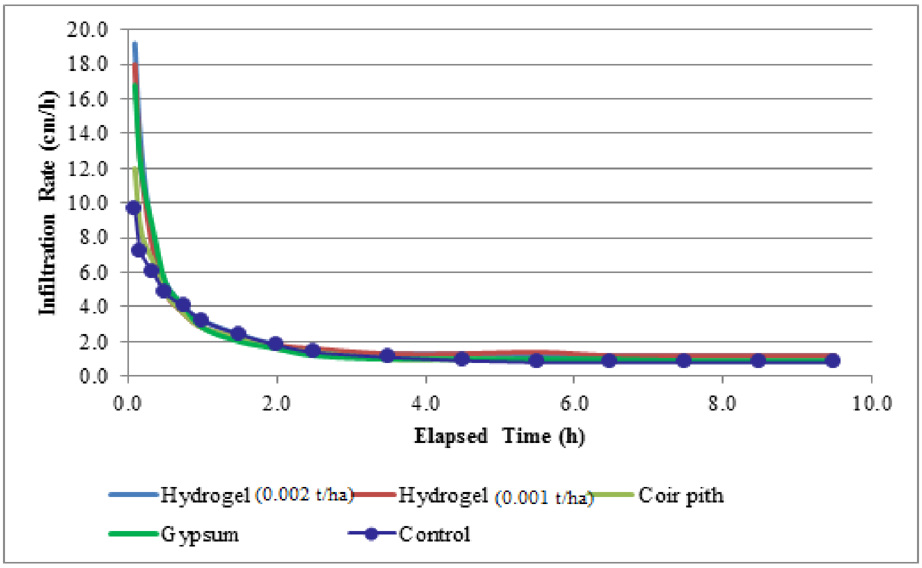



**Fig. 4**. Infiltration rate of different soil conditioners.

**Table 1**. Values of constants of infiltration models

| Soil Conditioners | Hortons' Model $f = fc + (fo - fc)e^{-Kt}$ | Philips' Model $fp = \frac{1}{2}st^{-\frac{1}{2}} + K$ | | Kostiakov model $f = at^b$ | | Green-Ampt model $fp = m + \frac{n}{Fp}$ | |
|---|---|---|---|---|---|---|---|
| | K | s | K | a | b | m | n |
| Hydrogel (0.002 t ha$^{-1}$) | 1.23 | 10.64 | -1.47 | 1.76 | 0.48 | -1.21 | 29.39 |
| Hydrogel (0.001 t ha$^{-1}$) | 1.31 | 11.83 | -1.46 | 1.90 | 0.48 | -1.12 | 34.08 |
| Gypsum | 2.26 | 10.60 | -1.56 | 1.74 | 0.46 | -1.08 | 27.21 |
| Coir pith | 2.30 | 7.42 | -0.64 | 1.53 | 0.52 | 0.11 | 13.03 |
| Press mud | 2.30 | 6.94 | -0.50 | 1.50 | 0.53 | 0.41 | 10.75 |
| Control | 2.39 | 6.08 | -0.18 | 1.45 | 0.56 | 0.76 | 8.16 |

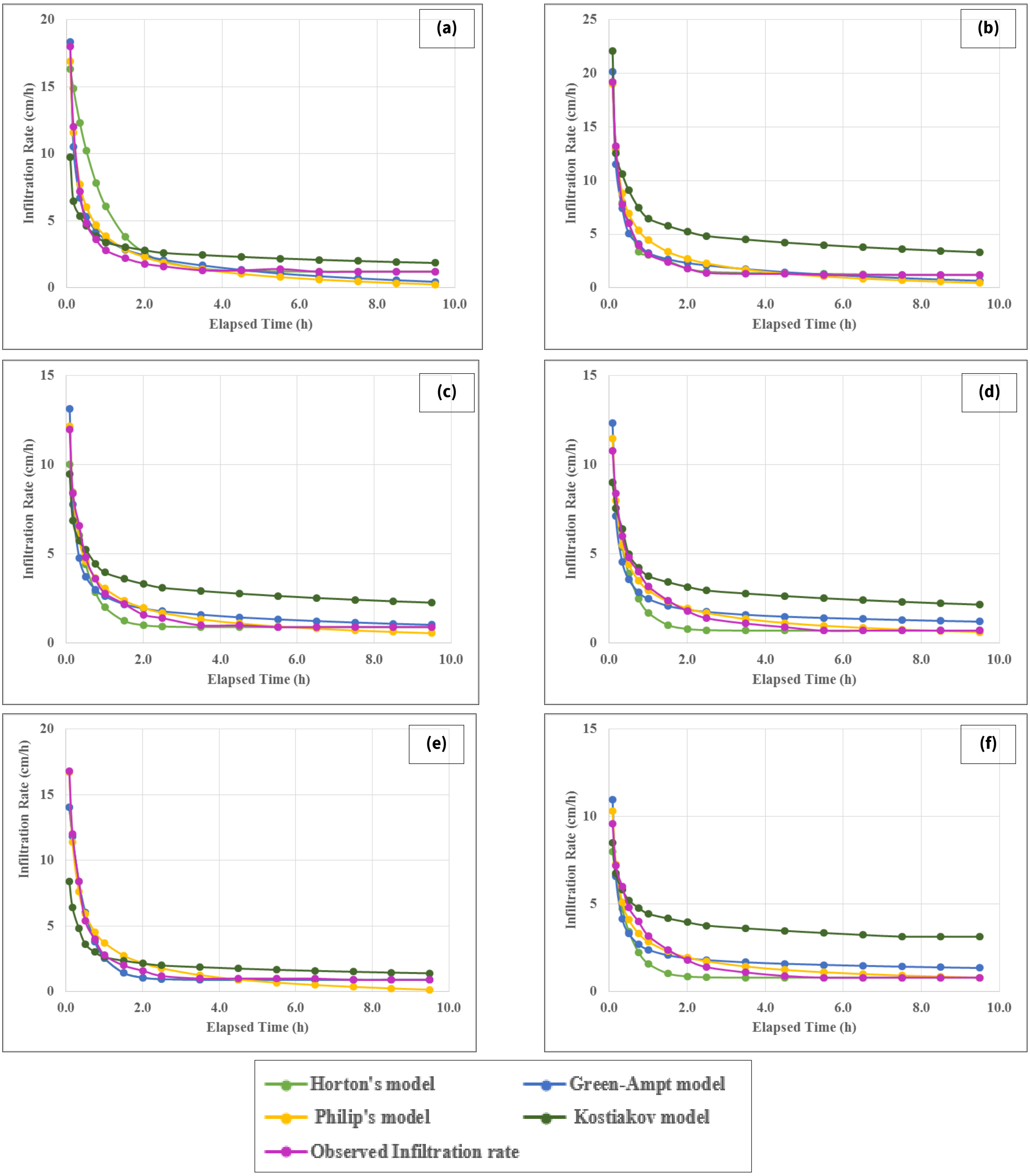



**Fig. 5**. Observed and predicted infiltration rate (a) hydrogel (0.002 t ha-1); (b) hydrogel (0.001 t ha-1); (c) coir pith; (d) press mud; (e) gypsum; (f) control.

## Model Efficiency

Nash-Sutcliffe efficiency was used to evaluate infiltration models in each soil conditioner (Fig. 6). Comparing the models, the highest efficiency was observed in the Philips model. The Philips models' NSE value ranged from 0.75 to 0.95 for every soil conditioner. The following best was the Hortons model, which has an NSE value between 0.50 and 0.85. The green-Ampt model has a value ranging from 0.50 to 0.75 and the Kostiakov model has a comparatively lesser value range. As a result of comparing the infiltration models with NSE, the Philips model performs better than the Hortons model. Similarly, the infiltration study concluded that the Philip model was the most effective in representing the infiltration process (36). Philips' models' satisfactory performance in predicting water infiltration in the soils of Aba, Abia state, Nigeria, has also been observed (37). The infiltration data measured in organic mulches, namely castor dust, sorghum straw, glyricidia and control (without mulch) were fitted to Horton, Philip and modified Kostiakov models and found that Philips' model recorded the maximum model efficiency values ranging from 97.6 to 99.8 percent in both sandy loam and sandy clay loam soils (38). Three models (Green-Ampt, Philip and Horton) showed that all three models provided similar fits to the numerical results regarding infiltration rates (39). Infiltration data from highly permeable soils under five different land use histories on the Nsukka plains of southeastern Nigeria showed that either the modified Kostiakov model or the Philip model could be used for routine characterization of the infiltration process (40). Research indicates that the Kostiakov, Horton and Philip infiltration models were used under various tillage conditions in Iran and the Horton model provided the most accurate prediction of infiltration rates in that region (41). The effectiveness of infiltration models depends on factors such as soil type, climate and water availability and no single model has been identified as universally suitable for all areas.

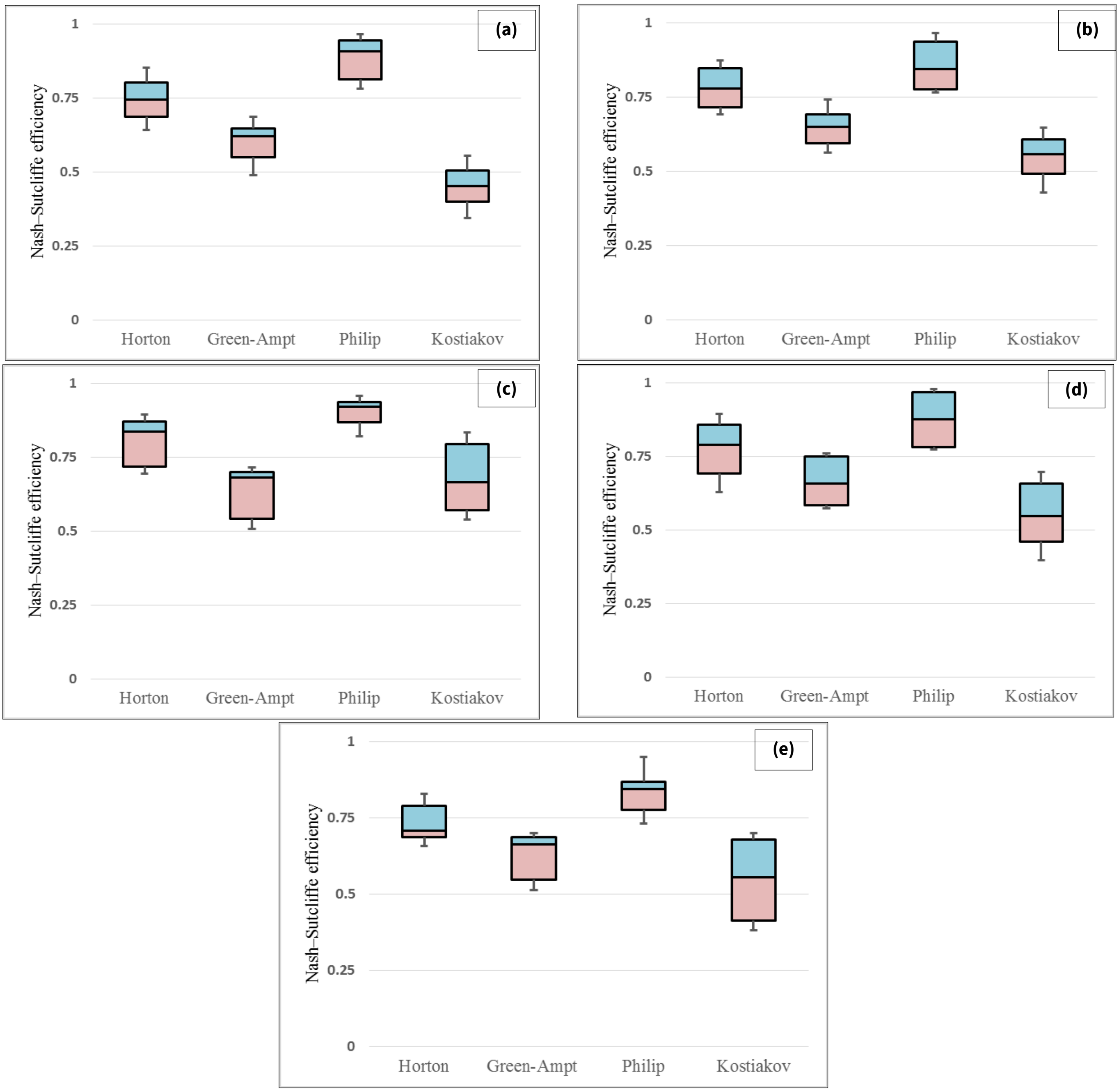



**Fig. 6.** Boxplot representing NSE values for (a) hydrogel (0.002 t ha$^{-1}$); (b) hydrogel (0.001 t ha$^{-1}$); (c) coir pith; (d) press mud; (e) gypsum.

## Conclusion

This study highlights the significant role of soil conditioners in enhancing the infiltration rates of sandy clay loam soils, which is crucial for effective water management in agricultural practices. The findings demonstrate that hydrogel, followed by gypsum, coir pith and press mud, substantially improved soil moisture retention and infiltration capacity. Furthermore, the comparative evaluation of various infiltration models revealed that the Philip model provided the most accurate predictions of infiltration rates, supported by its high Nash-Sutcliffe efficiency values. In contrast, the Horton model also performed well, although with slightly lower efficacy. These insights emphasize the importance of selecting appropriate soil amendments and infiltration models tailored to specific agricultural conditions, contributing to more sustainable water management strategies in rain-fed farming systems. Future research should focus on long-term impacts and the optimization of combinations of soil conditioners to further enhance soil health and crop productivity.

### Concrete solution

#### Best soil conditioner

Hydrogel at the rate of 0.002 t $ha^{-1}$ can be amended in sandy clay loam soils to improve soil infiltration, which plays a pivotal role in the hydrologic cycle for enhancing water and nutrient use efficiency for sustained crop production. Among the organic amendments, coir pith is promising to improve the infiltration rate.

#### Infiltration model

The Philip model is recommended for accurately predicting the infiltration rates of sandy clay loam soils in semi-arid areas since the model provided the best fit with observed data.

#### Integrated approach

Integrating chemical and organic amendments creates a synergistic effect, combining the immediate benefits of chemical amendments with the long-term improvements offered by organic amendments in improving soil organic carbon, water retention, buffering soil pH, ensuring sustained crop yields over multiple growing seasons.

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## Authors' contributions

NJ collected and organized the data, contributed to the literature review and assisted in drafting and revising the manuscript. MR conceptualized the study, designed the research framework and led the data analysis.

## Compliance with ethical standards

**Conflict of interest:** Authors do not have any conflict of interests to declare.

**Ethical issues:** None

## References

1. FAO. Food and Agriculture Organization Year Book. [internet]. Rome: FAO; 2000 [cited 24 Oct, 2024]. Available from: https://www.fao.org/home/en
2. Subba Rao A. Soil health issues in rainfed agriculture. Indian J of Dryland Agric Res Dev. 2011;26:1–20.
3. Saini AK, Patel AM, Saini LH, Malve SH. Growth, phenology and yield of summer pearl millet (*Pennisetum glaucum* L.) as affected by varied application of water, nutrients and hydrogel. Int J Ecol Environ Sci. 2020;2(3):248–52.
4. Kalhapure A, Kumar R, Singh VP, Pandey DS. Hydrogels: a boon for increasing agricultural productivity in water-stressed environments. Curr Sci. 2016;111(11):1773–9. https://doi.org/10.18520/cs/v111/i11/1773-1779
5. Peterson D. Hydrophilic polymers - effects and uses in the landscape. Restor Reclam Rev. 2003;13(4):111–5.
6. Johnson MS, Veltkamp CJ. Structure and functioning of water-storing agricultural polyacrylamides. J Sci Food Agric. 1985;36(9):789–93. https://doi.org/10.1002/jsfa.2740360905
7. Pattanaaik SK, Singh L, Wangchu P, Debnath B, Hazarika N, Pandey AK. Effect of hydrogel on water and nutrient management of Citrus lemon. Int J Agric Innov Res. 2015; 3(5): 2319–1473.
8. Gharaibeh MA, Eltaif NI, Shunnar OF. Leaching and reclamation of calcareous saline-sodic soil by moderately saline and moderate SAR water using gypsum and calcium chloride. J Plant Nutr Soil Sci. 2009;172(5):713–9. https://doi.org/10.1002/jpln.200700327
9. El-Ghamry AM, El-Sherpiny MA, Alkharpotly AE, Ghazi DA, Helmy AA, Siddiqui MH, et al.The synergistic effects of organic composts and microelements co-application in enhancing potato productivity in saline soils. Heliyon. 2024;10(12):e32694 . https://doi.org/10.1016/j.heliyon.2024.e32694
10. Jayawardane NS, Blackwell J. Effects of gypsum-slotting on infiltration rates and moisture storage in a swelling clay soil. Soil Use Manag. 1986; 2(3): 114–8. https://doi.org/10.1111/j.1475-2743.1986.tb00693.x
11. Miller WP. Use of Gypsum to improve physical properties and water relations in southeastern soils. Bartow: FIPR Publication; 1989. https://fipr.floridapoly.edu/library-and-publications/publications
12. Yadav DV. Utilization of pressmud cakes in Indian agriculture. Ind J Sugar Tech. 1992;7:1–16.
13. Bhosale PR, Chonde SG, Nakade DB, Raut PD. Studies on physico-chemical characteristics of waxed and dewaxed pressmud and its effect on water holding capacity of soil. ISCA J Biol Sci. 1(1):35–41.
14. Hussain N, Hassan G, Arshadullah M, Mujeeb F. Evaluation of amendments for the improvement of physical properties of sodic soil. Int J Agric Biol. 2001;3:319–22.
15. Dhanapal R, Tayade AS, Bhaskaran A, Geetha P. Efficient water management in sugarcane with composted coir pith and sugarcane trash under tropical Indian conditions. Sugar Tech. 2019;21:256–64. https://doi.org/10.1007/s12355-019-00656-8
16. Marqasi M, Hashemi SR, Siuki AK, Shahidi A, Neyshabouri SZ. Simulation model of water infiltration in soil using combination technique. Ain Shams Engin J. 2023;14(11):102550. https://doi.org/10.1016/j.asej.2023.102550

17. Horton RE. Hydrologic interrelations of water and soils. Soil Sci Soc Am Proc. 1937;1:401–29. https://doi.org/10.2136/sssaj1937.03615995000100000074x

18. Green WH, Ampt GA. Studies in soil physics. I. The flow of air and water through soils. J Agric Sci. 1911;4(1):1–24. https://doi.org/10.1017/S0021859600001441

19. Philip JR. The theory of infiltration: 4. Sorptivity and algebraic infiltration equations. Soil Sci. 1957;84(3):257–64. https://doi.org/10.1097/00010694-195709000-00010

20. Kostiakov A. On the dynamics of the coefficient of water percolation. Trans Int Soc Soil Sci, Part A. 1932;17–21.

21. Nash JE, Sutcliffe JV. River flow forecasting through conceptual models: Part I. A discussion of principles. J Hydrol. 1970;119(3):429–42. https://doi.org/10.1016/0022-1694(70)90255-6

22. Miranda MFA, Freire MBGDS, Almeida BG, Freire AG, Freire FJ, Pessoa LGM. Improvement of degraded physical attributes of a saline-sodic soil as influenced by phytoremediation and soil conditioners. Arch Agron Soil Sci. 2018;64(9):1207–21. https://doi.org/10.1080/03650340.2017.1419195

23. Rout PP, Arulmozhiselvan K. Investigating the suitability of pressmud and coir pith for use as soilless substrate by SEM, XRF, UV-Vis and FTIR spectroscopy techniques. Cellulose Chem Technol. 2019;53(5-6):599–607. https://doi.org/10.35812/CelluloseChemTechnol.2019.53.59

24. Abdel-Fattah MK, Fouda S, Schmidhalter U. Effects of gypsum particle size on reclaiming saline-sodic soils in Egypt. Comm Soil Sci Plant Anal. 2015;46(9):1112–22. https://doi.org/10.1080/00103624.2015.1018528

25. Reinsch S, Robinson DA, van Soest MA, Keith AM, Parry S, Tye AM. Temperate soils exposed to drought-Key processes, impacts, indicators and unknowns. Land. 2024 ;13(11):1759. https://doi.org/10.3390/land13111759

26. Vedovello P, Sanches LV, da Silva Teodoro G, Majaron VF, Bortoletto-Santos R, Ribeiro C, et al. An overview of polymeric hydrogel applications for sustainable agriculture. Agriculture. 2024;14(6):840. https://doi.org/10.3390/agriculture14060840

27. Garg A, Huang H, Cai W, Reddy NG, Chen P, Han Y, et al. Influence of soil density on gas permeability and water retention in soils amended with in-house produced biochar. J Rock Mech Geotech Eng. 2021;13(3):593–602. https://doi.org/10.1016/j.jrmge.2020.11.005

28. Abobatta W. Impact of hydrogel polymer in agricultural sector. Adv Agric Environ Sci. 2018;1(2):59–64. https://doi.org/10.31031/AAE.2018.01.000508

29. Yu J, Lei TW, Shainberg I, Mamedov AI, Levy GJ. Infiltration and erosion in soils treated with dry PAM and gypsum. Soil Sci Soc Am J. 2003;67(2):630–6. https://doi.org/10.2136/sssaj2003.630

30. Rajeswari M, Sankar GR, Ranghaswami MV, Mishra PK. Screening of soil amendments for efficient water-holding capacity based on a rainfall-infiltration model in a vertisol. Journal of Irrig Drain Eng. 2007;133(5):468–74. https://doi.org/10.1061/(ASCE)0733-9437(2007)133:5(468)

31. Kumar S, Meena RS, Jinger D, Jatav HS, Banjara T. Use of pressmud compost for improving crop productivity and soil health. Int J Chem Stud. 2017;5(2):384–9. https://doi.org/10.22271/chemi.2017.v5.i2.384

32. Machiwal D, Jha MK, Mal BC. Modelling infiltration and quantifying spatial soil variability in a wasteland of Kharagpur, India. Biosyst Eng. 2006;95(4):569–82. https://doi.org/10.1016/j.biosystemseng.2006.08.007

33. Thomas L, Green A, Patel R. Synergistic effects of hydrogel and coir pith for improved soil water retention and reduced runoff in semi-arid regions. Soil Sci J. 2019;59(2):102–10.

34. Mohammed AH. Evaluation of Kostiakov, Horton and Philips' infiltration equations as affected by tillage and rotation systems in a clay-loam soil of Northwest Iran. World Cong Soil Sci. 2006;75-2.

35. Jones J, Thompson R, Miller S. Combined effects of gypsum and press mud on soil compaction and infiltration in clay soils. J Soil Water Conserv. 2017;72(3):275–83.

36. Pang Z, Li Y, Zhao D. Effects of organic amendments on soil porosity, bulk density and root penetration in semi-arid regions. Agric Water Manag. 2020;225:105804.

37. Adindu RU. Philip model capability to estimate infiltration for soils of Aba, Abia State. J Earth Sci Geotech Engineer. 2015;5(2):63–8.

38. Smith W, Grant T, Nichols K. Influence of soil conditioners on water retention and infiltration under high-intensity rainfall conditions. Environ Soil Sci. 2021;45(1):56–63.

39. Hsu SM, Ni CF, Hung PF. Assessment of three infiltration formulas based on model fitting on Richards equation. J Hydrol Eng. 2002;7(5):373–9. https://doi.org/10.1061/(ASCE)1084-0699(2002)7:5(373)

40. Reddy KS, Kumar M, Umesha B, Farooque U, Venkanna K, Rao IB, et al. Infiltration characteristics of alfisols under different plant residue mulches. Indian J Dryland Agric Res Dev. 2012;27(2):31–5.

41. Mbagwu JS. Quasi-steady infiltration rates of highly permeable tropical moist savannah soils in relation to land use and pore size distribution. Soil Technol. 1997;11(2):185–95. https://doi.org/10.1016/S0933-3630(96)00138-9


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