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EVALUATING UNSATURATED HYDRAULIC CONDUCTIVITY OF A TROPICAL SOIL AMENDED WITH ORGANOMINERAL FERTILIZER AT VARIOUS TIME SCALES IN A SCREENHOUSE IN ILE-IFE, NIGERIA

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ABSTRACT

The study investigated the effect of organomineral fertilizer (OMF) on unsaturated hydraulic conductivities ($K_{0.5cm}$ and K_{2cm} i.e. 0.5 cm and 2 cm suctions, respectively) in an Ultisol at different time scales and the soil properties when amended with organomineral fertilizer (OMF). The hydraulic conductivity was measured using a mini-disk infiltrometer at 0.5 and 2 cm suctions. The K_{2cm} was done weekly while $K_{0.5cm}$ was carried out at sub-daily (7.00 GMT and 12.00 GMT), daily and weekly time scales following OMF addition at three rates (0 kg OMF, 40 kg Urea-N/ha + 2.5 tons/ha organic fertilizer (OF) and 40 kg Urea-N/ha + 5 tons/ha OF) based on some Nigerian indigenous vegetables nutrient requirements. Particle size distribution, phosphorus and pH were measured using standard methods while the temperature was measured using thermometer. The results revealed that more detailed understanding of the K dynamics was manifested at daily plus the necessity for inclusion of sampling at the immediate days of amendment addition. Furthermore, occasional sub-daily variation (morning and afternoon) occurred in response to ambient temperature. Organomineral fertilizer at 40 kg/ha Urea + 2.5 tons/ha OF compete with higher rate (40 kg Urea-N/ha + 5 tons/ha OF) and therefore sufficient for the improvement of available P and soil pH. Conclusively, the study showed that K was high in the immediate days following application of OMF and declined afterward, and also highlights the necessity of adequate sampling frequency for an all-range coverage of near saturated hydraulic conductivity dynamics and management.

Keywords: Sampling frequency, Hydraulic conductivity, Organomineral fertilizers, Soil properties.

INTRODUCTION

Enhancing the sustainability as well as efficiency of agricultural systems necessitates an attention on water management. Water is an essential requirement by plants' roots, hence for sustainable and efficient agricultural systems, water management is vital (Hillel, 1998; Chartzoulakis and Bertaki, 2015; Qui *et al.,* 2022). Quantifying and controlling of fluids ultimately govern the conveyance of water and solutes into the soil. The two variables that have the greatest influence on controlling conveyance of water (and other useful fluids that plants can store) are hydraulic conductivity and soil porosity (Koch *et al.,* 2018; Smith *et al.*, 2020). Consequently, there is the need for the determination of soil hydraulic conductivity which may be conducted in a laboratory or on the field. Saturated hydraulic conductivity and unsaturated hydraulic conductivity are two separate aspects of soil hydraulic conductivity (Hillel, 1998; Kirkham, 2005). Unsaturated hydraulic conductivity is probably the most difficult of all the hydrological properties to quantify and as well as the most important, as it coordinates, along with other parameters, the conveyance of fluids and movement of pollutants in the vadose zone (Lal and Shukla, 2004; Villagra-Mendoza and Horn, 2018). It has been proposed to be the significant variable for simulating the flow process (or soil water flow models) in unsaturated soil and depends on the soil moisture content (Kirkham, 2005; Saqib *et al.,* 2021). Many agricultural and environmental applications depend on unsaturated soil hydraulic conductivity (Naik *et al.,* 2018).

Measures of unsaturated hydraulic conductivity in soil augmented with organomineral fertilizer (OMF) have been reported (Adesodun *et al.,* 2013; Castellini *et al.,* 2021). By increasing organic carbon (via addition of organic materials or amendments), soil aggregation and soil structure, would be improved leading to better water infiltration by raising meso- and macro-porosity (Eusufzai and Fujii, 2012). There is a global inclination and attention to the utilization of OMF in agriculture probably due to its combine organic and inorganic components which could result to improve soil structure, moisture retention and nutrient availability (Abd El-Mageed *et al.,* 2015; Xu *et al.,* 2023). Organomineral fertilizer have been reported to have the capacity to enhance the formation of stable aggregates and improve organic C, leading to improved water infiltration (Frouz *et al.,* 2013; Turky *et al.,* 2020). The feedback effect is a reduction in soil erosion and improve soil water availability for crop growth and performance (Bashi *et al.,* 2021; Castellini *et al.,* 2021). Previous studies indicated that OMF can enhance soil hydraulic properties by promoting soil porosity, water retentive ability, and soil water infiltration rates (Weil and Magdof, 2004; Zougmore *et al.,* 2009; Demir, 2020; Bouhia *et al.,* 2023). Furthermore, the organic C in an organomineral fertilizer can serve as a substantive beneficial element for growth and activity of soil microorganisms (Babalola *et al.,* 2007; Saqib *et al.,* 2021). These soil microorganisms contribute immensely to the decay of organic matter and the release and availability of nutrients, thus improving soil fertility and hydraulic properties (Oshunsanya and Akinrinola, 2014). Moreover, the addition of OMF into the soil can have positive feedbacks on soil hydraulic properties, leading to improved soil water storage and agricultural yields (Gai *et al.,* 2018). Parts of these feedbacks include reduction in nutrient leaching and pollution of water bodies (Qui *et al.,* 2022). Babalola *et al.* (2007), Hou *et al.* (2010), Gai *et al.* (2018) and Smith *et al.* (2020) reported that SOC retention, soil C sequestration and soil infiltration are significantly affected by OMF. Also, vegetable farmers reported that organomineral fertilizers (OMF) improved soil properties and growth of vegetable (*Amaranthus cruentus*, *Abelmoschus esculentus*) compare to the untreated soil (Olowoake 2014; Olowoake *et al.,* 2015).

Studies on strategic soil fertility management for the production of some indigenous vegetables using OMF involving organic matter and a little dose of inorganic fertilizer has been reported (Oyedele *et al.,* 2017). Generally, the use of organomineral fertilizers can improve soil hydraulic properties by enhancing soil structure, water holding capacity (WHC), and infiltration rates. Adebooye *et al.* (2018), in their study of fertilizer micro-dosing of indigenous vegetables found, 20 kg, 40 kg and 60 kg Urea-N/ha gave returns greater than 80 kg Urea-N/ha. And in their three cycles of vegetable harvest form micro-dosing found that there was no significant difference from the conventional fertilizer applications method (80 kg Urea-N/ha), asserting that fertilizer micro-dosing in combination with organic manure can be used to sustainably produce these indigenous vegetables (Akponikpe *et al.* 2018; Ayanwale *et al.*, 2018).

In most soil studies researchers have reported high resolution monitoring of nutrient dynamics such as Carbon, Nitrogen, Phosphorous etc., but only few reported temporal variability of fluid and its dynamics in soil (Bowes *et al.,* 2009; Grift *et al*, 2016; Cao *et al.*, 2021; Chamizo *et al.*, 2022). High frequency monitoring is vitally necessary for better understanding of temporal variability of fluid as it is being reported for nutrient dynamics (Zeng *et al.,* 2016; Sith *et al.,* 2017; Bréchet *et al.,* 2021).

This study hypothesized that temporal variability at daily and sub-daily scales exists with unsaturated K and that its dynamics vary with rate of fertilizer application. The objectives of this study were to (1) investigate the difference in sub-daily, daily and weekly monitoring of unsaturated K and recommend the best sampling frequency; and (2) determine the temporal variability of K as affected by temperature and organomineral fertilizers, and (3) examine the effect of OMF on selected properties of soil.

MATERIALS AND METHODS

Description of Study site

The study was carried out on an Ultisol (Okusami and Oyediran, 1985) in the screen house of the Faculty of Agriculture, Obafemi Awolowo University, Ile-Ife, Nigeria (latitude 7° 31'14.76" and longitude 4° 31' 49.13"). The soil is a *Typic Paleustult* (Soil Survey Staff (1975) belonging to Iwo Soil Series (Smyth and Montgomery, 1962). Air temperature in the screenhouse, where the experiments were conducted ranged as 18.9^0C - 23.3^0C (minimum) and 27^0C - 35^0C (maximum).

Soil sampling and preparation, experimental design and layout

Bulk soil samples at depth of 0 – 15 cm were taken from a surface soil of a continuously cultivated maize field at the Teaching and Research Farm (T

& R), OAU, Ile-Ife, Nigeria (Latitudes 7° 32' N and 7° 33' and Longitudes 4° 32' and 4° 34'). Composite samples were taken for laboratory analyses. The soil samples were air-dried, gently crushed and then passed through a 2-mm mesh sieve.

The OMF was prepared from the combination of urea fertilizer and un-amended compost (organic fertilizer, OF; Sunshine Grade B) developed by the Sunshine Fertilizer company owned by the Ondo State Government of Nigeria. The composition of the OF were Nitrogen (3.5%), Phosphorous (1.0%) and Potassium (2.5%) (Ondo State Government, 2012). Table 1 shows the treatments combinations used for the experiment. The treatment used (Table 1) were thoroughly mixed with the air-dried soil weighing 4 kg each in pots that were each in 4.5 m^3 volume and perforated at the base for drainage and air movement. The experiment was a completely randomized design with four replicates given a total of 12 pots and the soil was maintained at 75% field capacity (FC) for five weeks. The ambient temperature was monitored throughout the period of the study using a thermometer.

Table 1. The description of the treatment

No.	Treatment	Code
1	Control (0 kg Urea-N/ha + 0 tons/ ha OF)	OMF1
2	First Rate (40 kg Urea-N/ha + 2.5 tons/ha)	OMF2
3	Second Rate (40 kg Urea-N/ha + 5 tons/ha)	OMF3

Measurement and Calculation of Hydraulic Conductivity

Mini disc infiltrometer model MI 1 0.5 cm suction and MI2 2.0 cm suction (509-332-2756, Decagon Devices, Inc., USA). The assessment of $K_{0.5cm}$ and K_{2cm} was carried out at weekly (a coarse measurement), while only $K_{0.5cm}$ was carried out at daily, sub-daily time scale [7.00 GMT (morning) and 12.00 GMT (afternoon)] for thirty-one days.

There are a number of methods of estimating soil hydraulic conductivity. Zhang suggested a straightforward method that is helpful for measuring infiltration into dry soil from mini disk infiltrometer data. It involves calculating cumulative infiltration vs. time and fitting the data with the following function:

Calculations:

Area of the base of the infiltrometer = $\pi r^2 (cm^2)$ 1

$$\text{Infiltration rate (cm)} = \frac{Cummulative\ Vol.}{Area\ of\ the\ base}\ (\text{cm s}^{-1}) \quad 2$$

And applying the method proposed by Zhang (1997) that involves measuring cumulative infiltration against time and fitting the results in the following equation:

$$I = C_1 t + C_2 \sqrt{t} \quad 3$$

Where: C_1 (ms^{-1}) and C_2 ($ms^{-½}$) are curve fitting parameters; C_1 is related to hydraulic conductivity, and C_2 is related to soil sorptivity.

The hydraulic conductivity of the soil (K) was then computed by using the following equation:

$$K = \frac{C1}{A} \quad 4$$

Where:

K = hydraulic conductivity

C = slope (derived from the graph of cumulative infiltration rate against the square-root of time)

A = value relating to the Van Grenuchten parameters for given soil type to the suction rate and radius of the infiltrometer, $Kh_{(0.5\ cm)}$ was determined at sub- and daily time scale while and $Kh_{(2\ cm)}$ was determined at a weekly time scale.

Laboratory and Screenhouse Analyses

Physical properties

Particle size distribution was determined using a modified hydrometer method as described by Gee and Or (2002); The FC was determined by saturation method (Flint and Flint, 2002) while bulk density by the use of core method (Stolt, 1997). These parameters were determined before imposing the treatment.

Chemical properties

Soil organic matter, soil pH and available phosphorus were analysed before the treatments were applied to the soil. Soil sample was carefully collected weekly from the potted soils and stored in the refrigerator at 4^0C for the determination of pH. using digital pH meter (Walk lab Ti 9000) in a 2:1 0.01 M $CaCl_2$ solution to soil suspension calibrated to buffers pH 4 and 7 (Thomas, 1996). Available P was also determined at the beginning and end of the experiment. Soil organic matter was determined using the dichromate oxidation method (Nelson and Sommers, 1996) and available phosphorus determined by Bray-1 method (Bray and Kurtz, 1945; Kuo, 1996).

Statistical analysis

The data were analysed using analysis of variance (ANOVA). Means of treatments that were significant ($P \leq 0.05$) were separated using Duncan's Multiple Range Test (DMRT).

RESULTS

Properties of the Soil before imposing the Treatments

The soil properties showed that the textural class was sandy loam using the USDA textural triangle. The bulk density was 1.56 gcm^{-3} and had a soil organic matter (SOM) of 1.55% (Table 2). The soil's available phosphorus was 8.3 mg kg^{-1} while hydraulic conductivity (K) were 1.39 x 10^{-3} cm s^{-1} and 5.61 x 10^{-4} cm s^{-1} at 5 cm and 2 cm suctions, respectively.

Table 2. The antecedent properties of soil.

Soil property	Value
Sand (g kg^{-1})	702
Clay (g kg^{-1})	197
Silt (g kg^{-1})	101
Textural class	Sandy loam
Bulk density (Mg m^{-1})	1.56
$K_{(-0.5cm)}$ (cm s^{-1})	1.39 (10^{-3})
$K_{(-2cm)}$ (cm s^{-1})	5.61 (10^{-4})
SOM (%)	1.55
pH	5.1
Avail. P (Bray-1) (mg kg^{-1})	8.3

K = Soil hydraulic conductivity, SOM = soil organic matter, Avail. P = Available phosphorous.

Table 3. Selected properties of soil at the beginning and end of the study.

TREATMENT		Week 1	Week 5
OMF1		4.75b	4.48b
OMF2	**Soil pH**	4.80ab	4.65a
OMF3		4.93a	4.75a
OMF1		8.25c	8.25b
OMF2	**Avail. P. (mg kg^{-1})**	8.28b	8.29a
OMF3		8.30a	8.29a

OMF1, OMF2 and OMF3 = (0 tons/ha OF + 0 kg Urea-N/ha), (2.5 tons/ha OF + 40 kg Urea-N/ha) and (5 tons/ha OF + 40 kg Urea-N/ha). SOM= soil organic matter and Avail. P = available phosphorus. According to Duncan's Multiple Range Test, means in a column with the same alphabet are not statistically different at a 5% probability.

Variation in the selected soil properties, as affected by organomineral fertilizer, at inception and end of the study

At week 1, the soil pH of OMF3 (4.93) was significantly higher ($P<0.05$) than that of OMF1 (4.75) which was statistically similar to that of OMF2 (4.80) (Table 3). However, at the end of week 5, the pH of OMF2 (4.65) and OMF3 (4.75) were statistically similar and both significantly higher than that of OMF1 (4.48). The available P of both OMF2 and 3 was significantly higher than the control both at week 1 and 5.

Monitoring of soil properties treated with organomineral fertilizer on a weekly time scale

Table 4 reveals a significantly higher ($P\leq0.05$) pH for OMF2 (except at week 1 and 2) and OMF3 compared to the control (OMF1) through the weeks. At week 2, however, there was no significant difference among the treatments. The soil pH was highest at week 2 and began to gradually decline through week 5. There was increase in pH with increase in temperature between weeks 2 to 4. There was no significant difference in $K_{(-0.5)}$ (cm s^{-1}) and $K_{(-2)}$ (cm s^{-1}) among the treatments across the weeks of sampling (Table 4). However, in $K_{(-0.5)}$ dipped sharply from week 2 unlike $K_{(-2)}$ that had a mild decline.

Comparisons of soil hydraulic conductivivty of the treatments at daily and sub-daily time scales

Figure 1 shows differences in K $_{(-0.5)}$ that exist between the treatments at both daily (e.g. Fig 1A), and at sub-daily sampling frequency (K $_{(-0.5)}$ assessment at both morning (Figure 1A) and noon (Figure 1B) same day. In most of the days where there were significant difference ($P\leq0.05$) in $K_{(-0.5)}$, the plot treated with organomineral fertilizer (OMF2 and OMF3) were higher in $K_{(-0.5)}$ than the control. The higher significant difference in K occurred on days 1 to 3 (between OMF3 and OMF2), day 4 (among OMF3 and OMF2 and the control) and on days 8 and 11 where either OMF2 or OMF3 were higher than the control.

Table 4. Selected properties of soil of the study at weekly time scale.

TREATMENT		**Week 1**	**Week 2**	**Week 3**	**Week 4**	**Week 5**
OMF1, FERT.1 & 2	**Temp. (^{0}C)**	26.5	29	31	30	29
OMF1	**pH**	4.75b	5.38a	5.13c	5.03b	4.48b
OMF2		4.80ab	5.40a	5.23b	5.18a	4.65a
OMF3		4.93a	5.43a	5.33a	5.20a	4.75a
OMF1	**$K_{(-0.5)}$ (x 10^{-4}cm s^{-1})**	15.97a	2.22a	2.13a	3.14a	1.76a
OMF2		8.03a	2.38a	1.05a	2.72a	2.42a
OMF3		13.92a	2.09a	2.38a	1.88a	2.01a
OMF1	**$K_{(-2)}$ (x 10^{-4}cm s^{-1})**	6.89a	6.69a	7.01a	5.50a	3.86a
OMF2		5.61a	6.28a	6.33a	4.88a	3.55a
OMF3		8.08a	7.56a	6.48a	3.86a	3.86a

OMF1, OMF2 and OMF3 = (0 tons/ha OF + 0 kg Urea-N/ha), (2.5 tons/ha OF + 40 kg Urea-N/ha) and (5 tons/ha OF + 40 kg Urea-N/ha). According to Duncan's Multiple Range Test, means in a column with the same alphabet are not statistically different at a 5% probability.

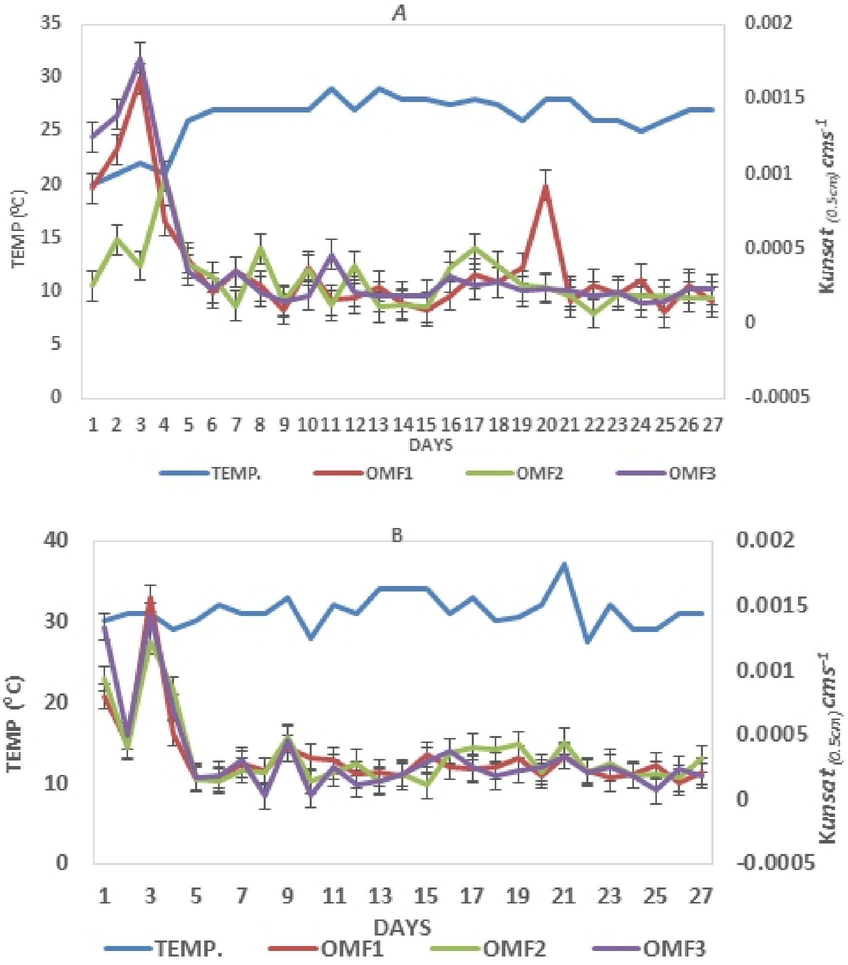

Figure 1: A-B. Daily/Sub-daily sampling of soil $K_{(0.5cm)}$ treated with organomineral fertilizer. OMF1, OMF2 and OMF3 = (0 tons/ha OF + 0 kg Urea-N/ha), (2.5 tons/ha OF + 40 kg Urea-N/ha) and (5 tons/ha OF + 40 kg Urea-N/ha). A – Morning; B - Afternoon

On sub-daily monitoring basis, more significant differences ($P \leq 0.05$) in $K_{(-0.5)}$ occurred in the morning while OMF3 was significantly higher than OMF1 only on the first day of the experiment at noon indicating the limited days of dominance of OMF3 over other treatments. When this is considered with the results of the weekly sample in view, where there was no significance difference at all (Table 3), it implies that variation in near saturated hydraulic conductivity is limited under this experimental condition but occurred closer to the time of application of the OMF than later in both morning and noon assessment. When the treatment was compared together, it was rare to see any significant difference at noon compare to when the assessment was carried out in the morning.

Figures 2a – c, where $K_{(-0.5)}$ dynamics was considered for each treatment separately, shows that at higher rate (OMF3), $K_{(-0.5)}$ was higher in the morning but at relatively lower rate (OMF 1 and OMF2), it was higher at noon over the limited days that there were significant differences.

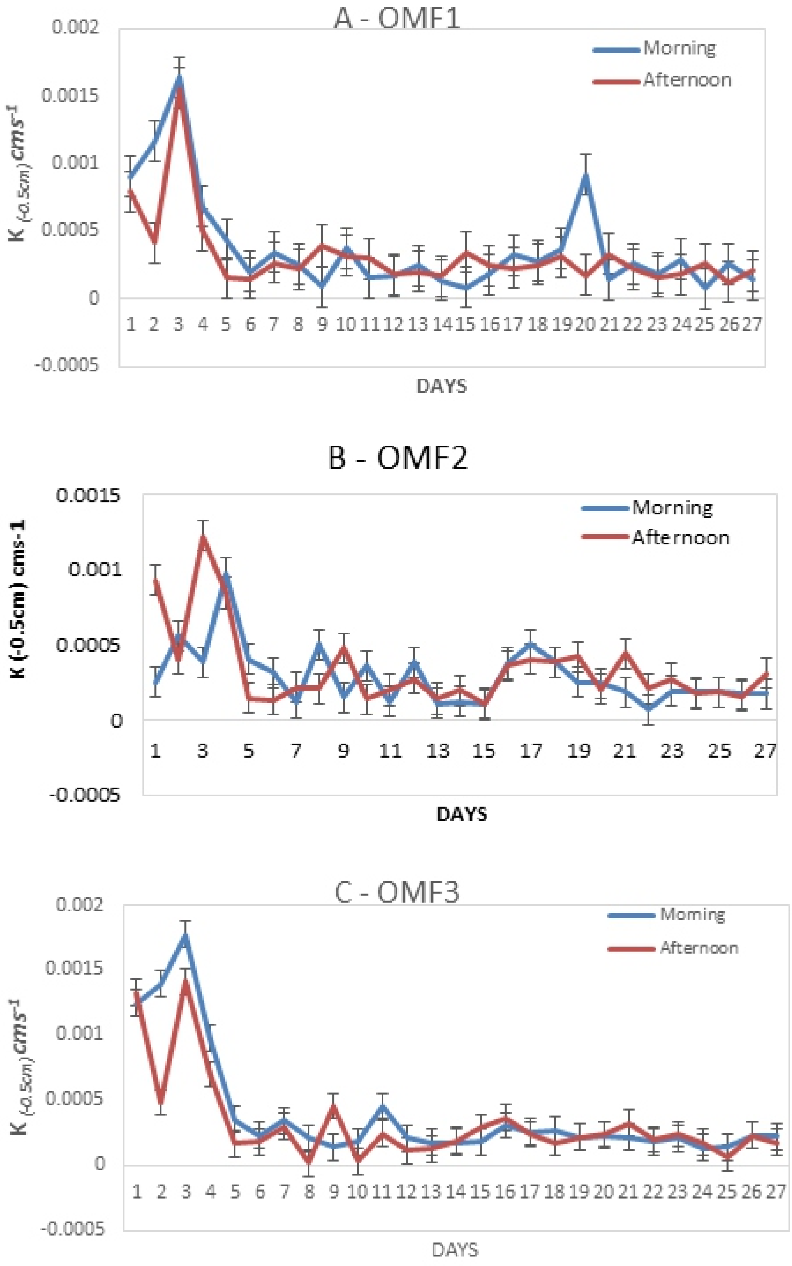

Figure 2: A – C. Comparison of $K_{(0.5cm}$ of the treatments at sub-daily time scale, that is, morning verses noon. A – Control, B – organomineral fertilizer at 40 kg Urea-N/ha + 2.5 ton/ha OF, C - organomineral fertilizer at 40 kg Urea-N/ha + 5 ton/ha OF.

Comparisons of $K_{(-0.5cm)}$ *between daily and weekly and at sub-daily time scale*

Various rates of OMF resulted in temporal variability of $K_{(-0.5)}$ (Fig. 3a, b and c). The figures also reveal the trend in K in response to organomineral fertilizer application overtime. The declining trend in $K_{(-0.5)}$ was made obvious by daily sampling, when sampling was more frequent compared to weekly sampling. Furthermore, there was a mild underestimation of K under more coarse weekly monitoring compared to the daily and sub-daily monitoring (Figs. 3); this is more obvious with OMF2. The deployment of both low and high sampling frequencies of $K_{(-0.5)}$ demonstrated that high-frequency monitoring appears to be more accurate (or informative) in interpreting the temporal variability of $K_{(-0.5)}$. The high frequency monitoring at daily and sub-daily basis (Figures 1 - 3) also revealed the importance of acquiring data on K in the first few days following application of such amendments so as to have all-range understanding of response of the parameter to the amendments.

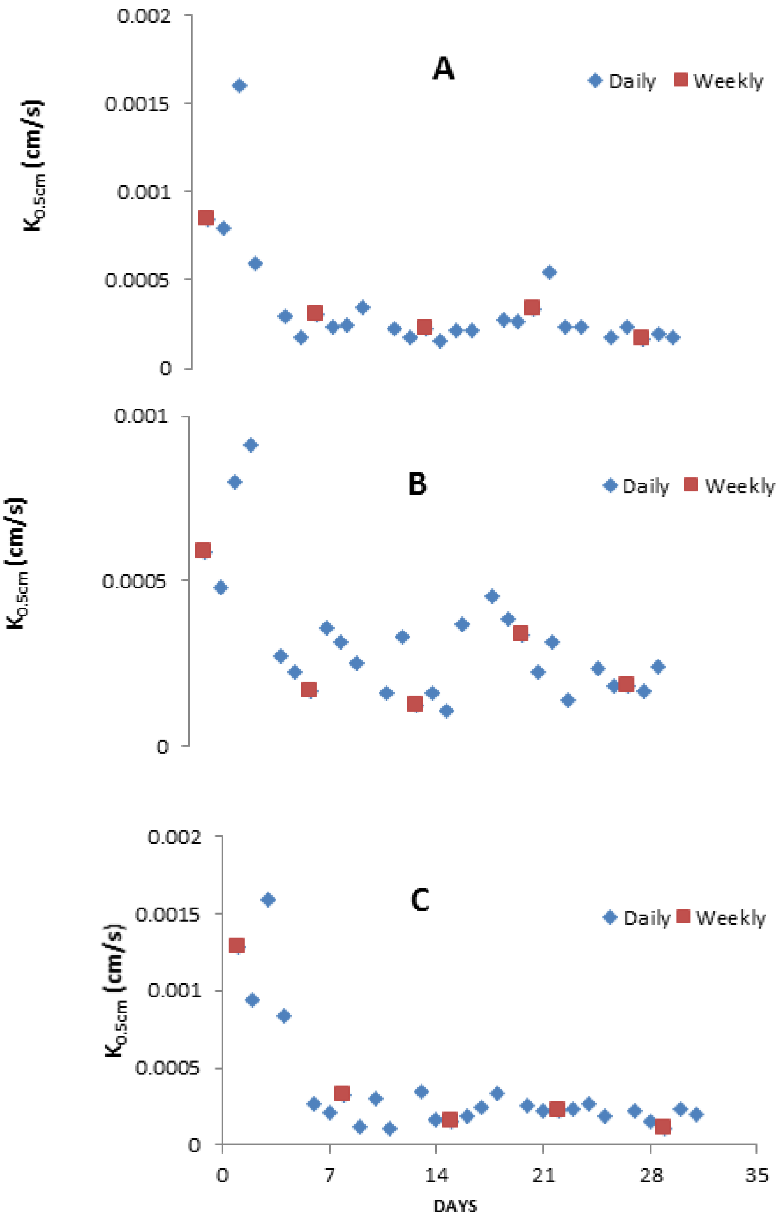

Figure 3: A - C. Comparison of $K_{(0.5cm)}$ of the soil treated with organomineral fertilizer at daily and weekly time scale. A – Control, B – organomineral fertilizer at 40 kg Urea-N/ha + 2.5 ton/ha OF, C - organomineral fertilizer at 40 kg Urea-N/ha + 5 ton/ha OF.

DISCUSSION

Properties of the soil before imposing the treatments

The bulk density of the sandy loam soil was 1.56 gcm^{-3} and it was not above the critical value of 1.63 gcm^{-3} above which plant growth and root establishment are limited (De-Geus, 1973) but high enough (above 1.2 gcm^{-3}) to impair root elongation and reduce soil aeration according to Reynold *et al.* (2003). The pH ($CaCl_2$) was within the medium pH range (5.5 – 5.9) (Adepetu *et al.,* 2014). The SOM of 1.55% was within the medium classification (1.5%) but below the critical value of 2.0% as classified by Adepetu (1990) for Nigerian soils. The soil's available phosphorus of 8.3 mg kg^{-1} fell below the critical value of 10 mg kg^{-1} reported by Adeoye and Agboola (1985), and Adepetu (1990) for Nigerian soils.

Variation in the selected soil properties, as affected by organomineral fertilizer, at inception and end of the study

The higher significance in pH of soil amended with the OMF compared to the control might be due to the addition of organic fertilizer (OF) component of the OMF (Wang *et al.,* 2019). The gradual decrease in soil pH over time might be due to leaching of basic cations during intermittent irrigation to maintain the soil at 75% FC (Thomson *et al.,* 1993; Atere and Olayinka, 2012; Aula *et al.,* 2016). The significantly higher available P of both OMF2 and 3 than the control could be linked to the addition of OF which might have supplied phosphorus to the soil system. Chen *et al.* (2021) reported that OF increases phosphorus availability in the soil.

Monitoring of soil properties treated with organomineral fertilizer on a weekly time scale

The significant difference in the order of OMF3>OMF2>OMF1, might be due to the effect of organic fertilizer in the OMF as it has influence on SOM. This supports the findings of Wang *et al.* (2019) and Zhang *et al.* (2019) who reported that the application of OF could reduce soil acidity through their buffering capacity. This relationship has also been reported by several authors who indicated that introduction of organic matter positively affected soils of low pH (Wang *et al.* 2009; Tu *et al.,* 2018; Akinde *et al.,* 2020). The gradual decline in pH from week 2 to week 5 may likely be related to changes in SOM over time.

Dlamini *et al.* and Zhang *et al.* (2016) reported that soil pH could impact on the decaying of SOM through the hydrolysis and protonation processes that controls the solubilization, complexation, sorption, and desorption of organic materials on mineral surfaces. Conversely, increasing SOM results in an increase in microbial respiration producing more carbonic and organic acids which could be responsible for the temporal decrease in pH. The increase in pH relative to temperature between weeks 2 to 4 agrees with Ou *et al.* (2017) and Tu *et al.* (2018) who reported that climate (e.g temperature) is a major determinant of soil physicochemical property (e.g. soil pH) which also impacts organic residue input and decay. The absence of significant difference in $K_{(-0.5)}$ (cm s^{-1}) and $K_{(-2)}$ (cm s^{-1}) among the treatments across the weeks of sampling may be an indicator that weekly monitoring may not be sufficient to fully track near saturated K dynamics in soil (Tijani *et al.*, 2023).

Comparisons of soil hydraulic conductivivty of the treatments at daily and sub-daily time scales

The dominance of $K_{(-0.5)}$ in soil treated with OMF, which tend to increase as the rate increases, appears a direct response to the OMF applied and its influence on SOM content. Soil organic matter improves soil porosity and water holding capacity of the soil (Libohova *et al.,* 2018; Qui *et al.,* 2022). Soil organic matter also increase soil granulation with associated improvement in soil porosity. This corroborates the report of Nwite *et al.* (2012) who reported a reduction in soil bulk density resulting in an improved soil structure and increase in infiltration upon the addition of OMF. All these properties influence soil hydraulic conductivity.

When the three level of OMF were compared together, occurrence of variation at sub-daily time scale closer to the time of application of the OMF, couple with rare occurrence of significant difference at noon compare to when the assessment was carried out in the morning; indicates that time of sampling and frequency of sampling should be considered in the assessment of K in response to application of amendments. This may also explain the reason for divergent results from researches conducted on unsaturated K. This is in line with the observation earlier raised by Tijani *et al.* (2023) on near saturated hydraulic conductivity, where biochar-based fertilizers, urea and organic fertilizers were used as soil amendments. Eusufzai and Fujii (2012) and Akinde *et al.* (2020) linked the high hydraulic conductivity they observed in their study to high SOM content. Therefore, the presence of OMF, which can be related to SOM, might have led to significant increase in K for the aforementioned days.

When the dynamics of $K_{(-0.5)}$ was considered for each treatment, higher significant $K_{(-0.5)}$ that occurred at noon could have been impacted by higher temperature experienced in the noon (Shao *et al.,* 2015). This observation is validated by the findings of Hopmans and Dane (1983) and Gao and Shao (2015) who reported an increase in K with an increase in temperature and linked the increased K to decrease in water viscosity as temperature increases. Shao *et al.* (2015) also reported that temperature dependence on soil hydraulic conductivity could have been effected by water properties, such as surface tension, kinematic viscosity and density of water, and soil particles (expansion of soil particles altering soil pore characteristics).

Comparisons of $K_{(-0.5cm)}$ between daily and weekly and at sub-daily time scale

The declining trend in $K_{(-0.5)}$ was made obvious by daily sampling, when sampling was more frequent compared to weekly sampling. The spike in K at the early staged can be related to SOM that had been reported to increase soil porosity and water holding capacity (Qui *et al.*, 2022) while the decline with time could be due to reduction in porosity due to reduction in SOM, as a result of OF decomposition, as reported by Fageria (2012). The deployment of both low and high sampling frequencies of $K_{(-0.5)}$ revealed under estimation (particularly for OMF2) by weekly or low sampling resolution. This demonstrated that high-frequency monitoring appears to be more accurate (or informative) in interpreting the temporal variability of $K_{(-0.5)}$. The high frequency monitoring at daily and sub-daily basis also revealed the importance of capturing K in the first few days of application of the amendment if the whole range of K will be understood when such amendments are imposed. This is important in understanding soil moisture fluxes and associated risk or merit in soil management relative to soil use in terms of water uptake, nutrients, contaminant and pollutant transfer. This highlights the significance of this monitoring approach in fluid permeability in soil, as reported by Das Gupta *et al.* (2006) who opined that determination of temporal variability in soil hydraulic properties (including unsaturated K and volumetric moisture content) can improve long-term hydrologic, environmental, and climate prediction models. Zhou *et al.* (2008) studied and also found temporal variability of K (at vary matric potentials of -0.2, -0.15 and -0.1 m) of different four soil series. Nishiwaki, and Horton (2020) also found temporal variability of soil K as affected by combinations of physical and biological disturbances (pedoturbations) on the soil. It is therefore, reasonable to state that such high-resolution monitoring would be required for K dynamics variability to make it easier to adequately synthesize pertinent data (Bah *et al.,* 2012; Blackford *et al.,* 2017).

CONCLUSION

This study primarily examined the effect of OMF on near soil saturated K dynamics. There was significance difference between the treatments on few days (both at daily and sub-daily time scale) which was not captured under coarse weekly sampling frequency. The study also showed that K was affected by temperature. The high frequency sampling revealed a spike in flow of water in the immediate days that follow application of the amendment which underscored the importance of given consideration to these few and critical days if predictive models, management decisions etc., are to capture the whole range of $K(_{0.5cm})$ in soil. The OMF improved soil pH and available P. There is therefore the need to pay adequate attention to sampling frequency and immediate commencement of sampling in near unsaturated K study and data interpretation if its full dynamics is to be understood and managed.

FUNDING

Not applicable

CONFLICT OF INTEREST/ COMPETING INTERESTS

There are none to declare

AUTHORS' CONTRIBUTIONS

F. O. T. – conceptualization, supervision and writing, **A. S. O.** – investigation, statistical analysis and writing, **F. A.** – investigation, **B. P. A.** – statistical analysis and writing and **D. J. O.** – supervision

COMPLIANCE WITH ETHICAL STANDARD

The work does not require approval by (bio)ethical committee.

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