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PREDICTION OF SOIL WETTING PATTERN FOR THREE SOIL TYPES UNDER DRIP IRRIGATION

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Abstract:-

This study was carried out by identifying and selecting three soil types around the University of Agriculture, Makurdi, Nigeria to determine their physicochemical properties. Drip Irrigation is considered as one of the most efficient irrigation systems, provided the system is designed to meet the soil and plant condition. Information on wetting patterns under point source drip emitters is a prerequisite for the design and operation of the drip systems. This is to ensure precise placement of water and fertilizer in the active root zone. The objective of this study was to develop models that can help to determine the wetting radius (r), wetting depth (z) from surface point drip irrigation of three soil types (clay loam, sandy loam and sandy clay loam). Water was applied to each soil type using drip irrigation set up at a constant flow rate of 1.3 l/hr. The maximum duration of water application was 10 hrs. At intervals of 30 minutes, there was excavation to monitor the wetted radius and depth. The field data was subjected to statistical analysis using SPSS version 22.0 to formulate the models that relates the duration, flow rate, volume and hydraulic properties to wetted radius and depth. Results show that lateral water movement was highest in the clay loam while vertical movement was highest in sandy loam. The highest wetted depth in clay loam, sandy loam and sandy clay loam were 17, 26, and 25 cm while the wetted radius were 26, 24, and 22 cm, respectively. Models for the three soil types were developed, the R^2 values for the three soils were between 0.7and0.9 which are close to 1. The ANOVA shows that the models were statistically significant as the P values are less than 0.05. The results obtained showed that the wetted depth and wetted radius of these soil types are influenced by the flow rate, duration and volume of water application within the range under consideration and can fit into irrigation of vegetable crops.

Keywords:- *Drip irrigation, wetting pattern, clay loam, sandy loam, sandy clay loam and efficiency*

INTRODUCTION

Trickle irrigation, also called drip or daily flow irrigation, is the most recent method of water application to the soil for crop growth. It is the frequent slow application of water to the soil through mechanical devices called emitters or applicators located at selected points along the water delivery lines (Subbaiah, 2013). In order to produce "more crop per drop", growers in semi- arid regions currently explore irrigation techniques using less fresh water (Provenzano, 2007). A proliferation of models for stimulating infiltration from point source have been developed, examples are the steady state solutions, non-steady linearized solutions, quasilinearization approximation solution. These models were based on the assumption of a point source and certain forms for the physical properties of soil and water content distribution and their applications are limited to simulation of water movements under drip irrigation systems under simple boundary conditions. However, they are generally computationally intensive, requiring extensive soil property data and involving parameterization and fine spatial and temporal discretization which could result in errors and too complicated for routine use (Subbaiah, 2013). The study was carried out by identifying and selecting three soil types around the University of Agriculture, Makurdi to determine their physicochemical properties. Furthermore, field investigation was carried out to measure infiltrated depth and their corresponding seepage radii, which are relevant for the development of the models relating infiltrated depth and radius. Drip irrigation (Fig. 1) systems are designed to transport water from source, to a crop, through a delivery network of pipes and water devices. The general goal of drip irrigation system design is to provide irrigation water efficiently and uniformly to a crop, to help meet the evapotranspiration (ET) needs. At the same time, the desired water content is maintained at a depth of the root zone, which will increase the crop yield and quality (Lamm et al., 2007; FAO, 2002a & b).

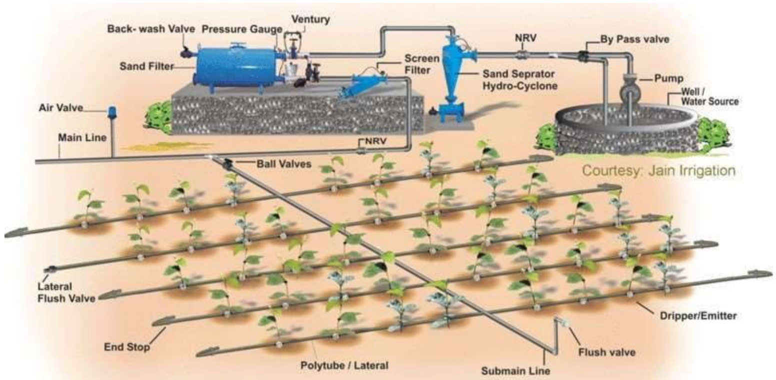


Figure 1: Drip irrigation layout and its components

Source: Lamm *et al.* (2007)

A simple empirical model is usually more convenient for system design than a dynamic model. Further investigations into the wetting patterns from a surface point source can help refine general design criteria because direct wetting measurements are site specific (Li et al., 2004). Changes in the wetted surface radius and the vertical wetted depth were monitored during irrigation and the results showed that the increase in the wetted surface radius and the vertical wetted depth with increasing volume applied can be represented by a power function with power values of about 0.3 and 0.45, respectively. Soil wetting patterns under surface and subsurface micro-irrigation have been measured and analysed theoretically by a number of authors (Cote et al., 2003; Skaggs et al., 2004; Gardenas et al., 2005; Wang et al., 2006). Water has a tendency to move vertically rather than horizontally. Water moves in soils as a result of the matric potential (directly related to water content) and gravitational potential (tendency of the water to move downward). In dry soils, matric potential is dominant compared to gravitational potential. As soil gets wetter, gravitational potential dominates the matric potential. The higher the application rate, the larger is the influence of gravity and, as a result, the narrower the wetted area (Roth, 1974). The radius of wetted bulb at any depth, *d*, and time, *t,* (Rw) is expressed heuristically as;

$$R_w = \frac{\pi}{2} r_w \left(r_w / r_{w_0} \right)^2 \qquad 1$$

Where,

r_{w0}= the radius of circular area of entry of water into the soil (cm) at the surface, $Rw = wetted\ radius,$ when time t tends to be large whose further increase can be considered negligible ($drw/dt = 0$ as $t \rightarrow \infty$). Rw is measured from the vertical axis through the dripper. Maximum depth of wetting front below the emitter is generally observed due to availability of maximum opportunity time equal to duration of irrigation. The time needed for the water to reach the root zone depth is controlled mainly by infiltration of the soil. This neglecting all other effects for drip irrigation, the depth of wetting front at any time,' t' is expressed as;

$$d = (t_i/T)^b RD_{max} \qquad 2$$

Where,

T = the irrigation application time in min; RD_{max} = the maximum depth of root zone, t = the time at which depth is to be calculated.

The radius of the pool formed on the ground surface is calculated from equation 3 and the radius of water pool (*Rw*) at any depth (*d*) can be calculated by taking the infiltration opportunity time at that depth;

$$Rw^2 = 0.955Q/a\ (2t^b + 3^b) \qquad 3$$

Where,
Q = emitter flow rate in L/h, a = area of water entering into the soil cm^3, b = radius of water pool formed on the ground surface.

Materials and Methods

Study Location

This study was carried out in Federal University of Agriculture, Makurdi in the capital city of Benue State, Nigeria. The State lies between latitudes 7^o 45’ and 7^o 52’ N of the equator and longitude 8^o 35’ and 8^o 41’ E of Greenwich Meridian (Egboramy, 1989). It has a population of 421,924 according to Census, (2006) and most of the people live in this high density flood plains. The primary occupation of the people is Agriculture hence the appellation “Food Basket of the Nation” some of the crops grown are potatoes, cassava, soya beans, guinea corn, groundnut and yam, etc. The State shares border with five States, namely Nasarawa to the North, Taraba to the North East, Cross River to the South, Enugu to the South East and Kogi to the West. There is also a short international boundary between the States and the Republic of Cameroon along Nigeria’s South East border.

Sample Collection and Analysis

The physical and chemical properties of the soil which are the preliminary investigation in order to select the different soil types were carried out by collecting soils randomly in six sites, within the university using an essential tool for gardeners called stainless steel blade (Model 9APH2) as shown in Plate 1. In each site which measures 7 by 7 m, samples were collected from five different points at depths of 0-15 cm and 16-30 cm. The samples were immediately tied in polythene bags to avoid loss of moisture. On getting to the laboratory, the samples were air dried and sieved through a-2 mm diameter sieve and assigned laboratory numbers. The physicochemical analysis were carried out at the Nasarawa State University Agronomy Research Laboratory, using standard laboratory procedures.

Plate 1: Gardeners stainless steel blade

Site Preparation

The experimental sites were cleared of weeds and shrubs and then slightly ploughed to 1.5 m depth and harrowed to about 0.3 m to thoroughly mix the profile and eliminate any compacted layer, this also brought the soil to an ideal planting condition. The global positioning system (GPS) of the experimental plots indicated that the site of clay loam is located at N $07^0 47.508^1$, E $008^0 37.224^1$ at an elevation of 100m, and from the map pointer at SW $1^{\varepsilon}_{\varepsilon}$, sandy loam located at N $07^0 47.730^1$, E $008^0 36.994^1$ at an elevation of 105 m, and from the map pointer at SW $4^{\varepsilon}_{\varepsilon}$ and sandy clay loam located at N $07^0 47.737^1$, E $008^0 37.158^1$ at an elevation of 99 m, and from the map pointer at SE $22^{\varepsilon}_{\varepsilon}$

Field Layout

The irrigation system, which is a complete gravitational drip irrigation unit is made up of a plastic tank of 200.0 litres placed 1.0 m above the ground level supplying water to the whole system.

The field layout consist of a mainline connecting the source of water with the sub-main, both made of PVC pipes. The sub-main was linked to two laterals. The lateral has factory-fitted emitters or drippers with fitted filaments which regulated the emission of water directly to the ground surface. It is manufactured by NAAN irrigation Israel, and has a wall thickness of 0.90 mm and 12.0 mm diameter. The emitters are fitted at 30.0 cm interval and each discharges at a fixed flow rate of 1.3 litres per hour. The setup is as shown in Plate 2;

Plate 2: Irrigation line setup

Field Investigation
The irrigation system as shown in Plate 2, was set up on each soil type (clay loam, sandy loam and sandy clay loam). This is to determine the configuration of their wetted radius on the surface, as well as at different depth of 0.0 cm, 5.0 cm, 10.0 cm, 15.0 cm, 20.0 cm, 25.0 cm, 30.0 cm and 35.0 cm intervals from the surface at the same discharge rate. Water was discharged to the sub main from the source through the main line with a control valve, this was discharged at the different emitter location with a filament fitted at the drippers, which regulated the discharge to 1.3.0 litres per hour. The water level was constantly replenished to make sure that, water was conducted under constant and low pressure to the network of closely spaced outlets. A coordinate system of the wetted soil was established on the profile between 30.0 min. to 10.0 hrs. of irrigation, with the centre of the soil surface directly under the emitter. At the end of every 30.0 min, three points of the lateral line around the emitter that were wetted were excavated to expose the vertical soil profile as shown in Plate 3 (a) (b) & (c), respectively and the distance of the wetted front was measured horizontally and vertically downwards at the above mentioned depths.

(a)

(b)

(c)

Plate 3: Representation of the wetted bulbs of clay loam (a), sandy loam (b) and sandy clay loam (c)

Method of Data Analysis

All the soil physical and chemical characteristics as obtained from the Laboratory analysis were appraised. There was also a descriptive analysis of the wetting pattern of the three soil types used.

The field data collected were subjected to data analysis using SPSS 22.0 version and Microsoft, about two third of the data was used to generate multiple linear regression models which was used to estimate the regression coefficient of the models. The remaining one third was used to validate the generated models. The calculated data from the models were compared to the observed using correlation analysis and three errors; MAD, MES and RMSE. Analysis of variance (ANOVA) was also employed to analyse the data.

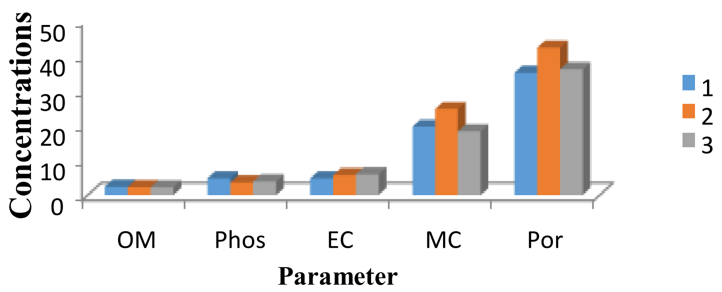
Results and Discussions

Laboratory Analysis of the Soil Samples:

The mean results of physico-chemical parameters

The physico-chemical parameters analysed in the laboratory are shown in Tables 1-3. The variation in concentration of physicochemical and hydraulic parameters, are shown in Figures 2 and 3, respectively. Table 4 displays particles size distribution of the soil samples under investigation.

Figure 2: Variations in soil physicochemical and hydraulic parameter



OM =Organic matter, Phos. =Phosphorus, EC =Electrical conductivity, MC =Moisture content, Por. =Porosity.

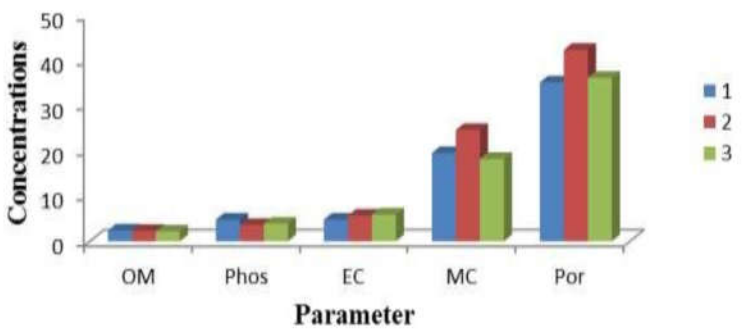


Figure 3: Variations in oil physicochemical and hydraulic parameters.

OM =Organic matter, Phos. =Phosphorus, EC =Electrical conductivity, MC =Moisture content, Por. =Porosity.

Statistical results of physico-chemical and hydraulic parameters

The Physico-chemical and hydraulic properties of the soil samples are presented in Table 5, showing the statistics of three replicates of Organic carbon, Organic matter, Nitrogen, Phosphorus, Electrical conductivity, Sodium absorption Ratio, Field capacity, Hydraulic conductivity and Moisture content. The correlation matrix of their parameters, with *correlation being significant at ($p < 0.05$) at 2- tailed, is shown in Table 6.

Physico-chemical parameters

These three soil types are considered to be suitable for drip irrigation, considering their sand and silt components in Table 6. Sand and silt composition of all the plots exceeded 60 % and 2.5 %, respectively. Mubarak *et al,* (2009) suggested that soil plot having these compositions can be subjected to drip irrigation since it will give good wetting front. From Table 7, there are slight differences between values obtained at the two depths considered. For instance, pH, organic carbon, organic matter, Sodium Absorption Ratio (SAR) and field capacity have no significant differences in their properties both for the three locations and between the two depths considered. This may point to the fact that if clay loam is suitable for any particular irrigation type with respect to any of these properties, sandy loam and sandy clay loam will also be suitable for such irrigation techniques. However, parameters like phosphorus, nitrogen, electrical conductivity, hydraulic conductivity (HC) and moisture content exhibited some significant difference in the two depths. Though SAR and HC are considered to be important while studying suitability of any soil for irrigation (Hu et al., 2009), the change and variation in this particular scenario do not make the sandy loam and sandy clay loam unsuitable. Other parameter considered important in this research is total porosity which in turn will determine the effective porosity of the soil (Lado and Hur, 2009). Sample from sandy loam also have higher porosity and EC and therefore will be able to withstand the release of more water either by higher irrigation frequency or bigger emitter size when the conceived drip irrigation is set up.

Table1: Physicochemical and hydraulic parameters of clay loam (Site 1)

	Physico-chemical Parameters																			Hydraulic Parameters	
Depth (cm)	H_2O pH	$CaCl_2$ pH	O.C %	O.M %	N %	AVAIL P (ppm)	K (ppm)	Ca (ppm)	Na (ppm)	Mg (ppm)	E.A Mq /100 g	E.C.E.C	B.S %	SAR Mq/ 100 g	F.C %	E.C (U/cm)	TDS	M.C %	B.D	HYD. COND.	T. POR. %
0-15	6.49	5.83	1.40	2.41	0.56	4.86	0.27	3.11	0.12	0.48	0.83	4.81	83	0.09	0.9	2200	1460	19.8	1.70	0.34	36
15-30	6.58	5.86	1.38	2.37	0.56	4.52	0.24	2.98	0.10	0.50	0.67	4.49	85	0.07	1.0	1430	980	18.6	1.72	0.34	35
0-15	6.16	5.61	1.35	2.32	0.35	4.73	0.30	3.10	0.09	0.52	1.50	5.51	73	0.07	1.2	2190	1420	20.0	1.73	0.35	35
15-30	5.98	5.48	1.37	2.36	0.40	4.81	0.28	3.14	0.11	0.47	1.20	5.20	77	0.08	1.1	2030	960	20.8	1.80	0.35	32
0-15	6.52	5.98	1.41	2.43	0.28	4.31	0.32	3.11	0.14	0.39	1.00	4.96	80	0.08	0.9	2010	940	20.6	1.68	0.40	37
15-30	6.48	6.01	1.35	2.32	0.35	3.96	0.26	3.21	0.16	0.40	1.00	5.03	80	0.12	0.8	1980	980	20.4	1.66	0.38	37
0-15	6.30	5.78	1.34	2.30	0.14	3.86	0.30	3.06	0.24	0.41	0.83	4.84	83	0.18	1.0	2100	960	19.6	1.68	0.30	37
15-30	6.23	5.63	1.42	2.44	0.14	4.56	0.32	3.08	0.30	0.43	0.83	4.96	83	0.22	1.2	2000	940	19.4	1.67	0.30	37
0-15	5.82	5.36	1.32	2.27	0.28	4.32	0.82	3.13	0.23	0.42	0.67	4.73	86	0.17	0.9	2100	890	19.7	1.70	0.34	36
15-30	5.98	5.47	1.36	2.34	0.28	3.82	0.30	3.16	0.21	0.46	0.67	4.80	86	0.16	0.8	2120	980	19.6	1.68	0.33	37

Table2: Physicochemical and hydraulic parameters of sandy loam (Site 2)

	Physico-chemical Parameters																			Hydraulic Parameters	
Depth (cm)	H_2O pH	$CaCl_2$ pH	O.C %	O.M %	N %	AVAIL P (ppm)	K (ppm)	Ca (ppm)	Na (ppm)	Mg (ppm)	E.A Mq /100 g	E.C.E.C	B.S %	SAR Mq/ 100 g	F.C %	E.C (U/cm)	TDS	M.C %	B.D	HYD. COND.	T. POR. %
0-15	6.63	5.98	1.22	2.09	0.56	3.87	0.36	4.20	0.09	0.62	0.83	6.10	86	0.06	1.2	2350	970	19.9	1.82	0.76	31
15-30	6.51	5.84	1.25	2.25	0.63	3.86	0.38	4.10	0.10	0.58	0.83	5.99	86	0.07	1.0	2370	960	19.7	1.67	0.77	37
0-15	6.45	6.01	1.30	2.24	0.49	4.01	0.41	4.09	0.15	0.49	1.00	6.14	84	0.10	1.1	2340	1300	19.2	1.78	0.92	33
15-30	6.38	5.82	1.31	2.25	0.42	3.89	0.39	3.92	0.14	0.50	1.00	5.95	83	0.09	0.9	2310	1320	19.0	1.70	0.92	36
0-15	6.32	5.92	1.22	2.10	0.28	3.73	0.32	4.03	0.16	0.49	0.50	5.50	91	0.11	1.2	1600	1400	18.9	1.70	0.77	36
15-30	6.36	5.96	1.18	2.03	0.28	3.64	0.40	4.10	0.12	0.48	0.50	5.60	91	0.08	1.3	1600	1380	18.6	1.62	0.96	39
0-15	6.40	5.98	1.23	2.12	0.14	3.56	0.43	4.12	0.11	0.53	0.67	5.86	88	0.07	1.2	1900	1000	18.8	1.70	0.84	36
15-30	6.46	5.96	1.32	2.27	0.14	3.62	0.38	4.05	0.10	0.54	0.67	5.74	88	0.07	1.1	2400	700	18.7	1.72	0.84	35
0-15	6.61	6.11	1.20	2.06	0.21	3.82	0.38	4.06	0.14	0.49	0.50	5.57	91	0.10	0.9	2200	800	19.0	1.63	0.90	38
15-30	6.48	6.01	1.21	2.08	0.21	3.90	0.40	4.09	0.15	0.50	0.50	5.64	91	0.10	0.9	2280	500	19.2	1.62	0.90	39

Table3: Physicochemical and hydraulic parameters of sandy clay loam (Site 3)

	Physico-chemical Parameters																			Hydraulic Parameters	
Depth (cm)	H_2O pH	$CaCl_2$ pH	O.C %	O.M %	N %	AVAIL P (ppm)	K (ppm)	Ca (ppm)	Na (ppm)	Mg (ppm)	E.A Mq /100 g	E.C.E.C	B.S %	SAR Mq/ 100 g	F.C %	E.C (U/cm)	TDS	M.C %	B.D	HYD. COND.	T. POR. %
0-15	6.63	5.98	1.22	2.09	0.56	3.87	0.36	4.20	0.09	0.62	0.83	6.10	86	0.06	1.2	2350	970	19.9	1.82	0.76	31
15-30	6.51	5.84	1.25	2.25	0.63	3.86	0.38	4.10	0.10	0.58	0.83	5.99	86	0.07	1.0	2370	960	19.7	1.67	0.77	37
0-15	6.45	6.01	1.30	2.24	0.49	4.01	0.41	4.09	0.15	0.49	1.00	6.14	84	0.10	1.1	2340	1300	19.2	1.78	0.92	33
15-30	6.38	5.82	1.31	2.25	0.42	3.89	0.39	3.92	0.14	0.50	1.00	5.95	83	0.09	0.9	2310	1320	19.0	1.70	0.92	36
0-15	6.32	5.92	1.22	2.10	0.28	3.73	0.32	4.03	0.16	0.49	0.50	5.50	91	0.11	1.2	1600	1400	18.9	1.70	0.77	36
15-30	6.36	5.96	1.18	2.03	0.28	3.64	0.40	4.10	0.12	0.48	0.50	5.60	91	0.08	1.3	1600	1380	18.6	1.62	0.96	39
0-15	6.40	5.98	1.23	2.12	0.14	3.56	0.43	4.12	0.11	0.53	0.67	5.86	88	0.07	1.2	1900	1000	18.8	1.70	0.84	36
15-30	6.46	5.96	1.32	2.27	0.14	3.62	0.38	4.05	0.10	0.54	0.67	5.74	88	0.07	1.1	2400	700	18.7	1.72	0.84	35
0-15	6.61	6.11	1.20	2.06	0.21	3.82	0.38	4.06	0.14	0.49	0.50	5.57	91	0.10	0.9	2200	800	19.0	1.63	0.90	38
15-30	6.48	6.01	1.21	2.08	0.21	3.90	0.40	4.09	0.15	0.50	0.50	5.64	91	0.10	0.9	2280	500	19.2	1.62	0.90	39

Table 4: Particles size distribution of the soil samples

Site	Depth (cm)	Sand (%)	Silt (%)	Clay (%)	Textural Class
1	0 - 15	60.8	5.4	33.4	Clay Loam
	16 - 30	60.6	3.4	34.0	
2	0 - 15	77.3	3.4	19.4	Sandy loam
	16 - 30	77.0	3.6	19.4	
3	0 - 15	74.2	5.4	20.4	Sandy clay loam
	16 - 30	74.2	5.4	20.4	

Table 5: Physicochemical and hydraulic properties of the soil samples

Site	Depth (cm)	pH	OC (%)	OM (%)	N (mg/g)	P (mg/g)	EC (µs/cm	SAR (Meq/100 g)	FC (%)	HC (m/day)	MC (%)	Total Porosity (%)
1	0 – 15	6.3 ± 0.4	1.4 ± 0.5	2.4 ± 0.1	0.6 ± 0.0	4.8 ± 1.0	4.8 ± 0.7	0.14 ± 0.3	1.1 ± 0.2	0.35 ± 0.1	19.5 ± 1.2	35.1 ± 2.4
	16 -30	5.9 ± 0.4	1.4 ± 0.6	2.4 ± 0.4	0.3 ± 0.1	4.4 ± 1.1	4.5 ± 0.3	0.18 ± 0.0	0.9 ± 0.3	0.33 ± 0.1	20.1 ± 1.4	34.9 ± 2.1
2	0 – 15	6.4 ± 0.4	1.3 ± 0.5	2.2 ± 0.0	0.5 ± 0.2	4.8 ± 0.3	5.7 ± 0.4	0.13 ± 0.0	1.4 ± 0.2	1.86 ± 0.4	24.6 ± 3.0	42.3 ± 3.0
	16 -30	6.5 ± 0.6	1.3 ± 0.2	2.3 ± 0.5	0.5 ± 0.2	3.6 ± 0.1	4.7 ± 0.2	0.07 ± 0.0	1.2 ± 0.3	1.98 ± 0.3	22.3 ± 0.4	41.6 ± 0.8
3	0 – 15	6.5 ± 0.3	1.3 ± 0.2	2.2 ± 0.1	0.3 ± 0.0	3.9 ± 0.2	5.9 ± 0.3	0.07 ± 0.0	1.2 ± 0.0	0.78 ± 0.2	19.0 ± 0.9	37.0 ± 2.1
	16 -30	6.4 ± 0.2	1.2 ± 0.2	2.1 ± 0.2	0.2 ± 0.0	3.6 ± 0.2	5.9 ± 0.3	0.10 ± 0.0	1.1 ± 0.1	0.92 ± 0.1	18.2 ± 1.8	36.1 ± 2.2

Mean with similar superscripts along same column are not significant difference (p< 0-.5) while mean with different superscripts along same column have significant difference.

Table 6 presents inter-elemental correlation among the parameters tested. Both negative and positive correlation existed. For instance, pH exhibited negative correlation with other parameters except phosphorus, bulk density and moisture content though the correlation are not so significant. Correlation between hydraulic conductivity and percentage organic matter is a strong significant one and this may be interpreted that increased organic matter in a soil sample may lead to reduced HC; Franzluebbers (2002) attributed this to higher clay content of organic matters which can seal up the pores in the soil samples. Similarly, bulk density and HC also exhibited strong significant correlation which may also be as a result of aforementioned points. And also that high bulk density can be as a result of well parked soil particles, reduced soil pores and therefore less HC.

Table 6: Correlation matrix for soil parameters

	pH	OC	OM	N	Pho	Pot	Cal	Sod	Mag	EC	SAR	FC	HC	MC	TP	BD
pH	1															
OC	-0.14	1														
OM	-0.12	**0.99***	1													
Nitr	-0.08	0.06	0.11	1												
Pho	0.19	**0.53***	0.52	0.13	1											
Pot	-0.08	-0.17	-0.16	-0.31	-0.07	1										
Cal	0.30*	-0.60	**-0.57***	-0.01	**-0.49**	0.22	1									
Sod	-0.18	0.30	0.27	-0.27	0.35	0.16	-0.20	1								
Mag	-0.13	-0.41	-0.39	0.57*	-0.21	-0.28	0.37*	-0.30	1							
EC	0.21	-0.24	-0.22	0.19	0.03	0.05	**0.64***	0.14	**0.46***	1						
SAR	-0.18	0.35	0.33	-0.21	0.37	0.14	-0.29	**0.92***	-0.25	0.10	1					
FC	-0.43	-0.17	-0.18	0.30	-0.18	-0.34	-0.04	-0.10	**0.64***	0.19	-0.13	1				
HC	-0.17	-0.38	**-0.40***	0.29	-0.06	-0.26	0.08	0.13	**0.66***	**0.40***	0.08	0.72	1			
MC	0.02	0.08	0.07	0.23	**0.54***	-0.26	-0.27	0.37	0.29	0.28	0.38*	0.39	0.67*	1		
TP	-0.19	-0.29	-0.30	0.02	0.00	-0.24	-0.16	0.34	0.28	0.06	0.30	0.43*	0.77*	**0.58***	1	
BD	0.18	0.31	0.32	-0.02	0.02	0.25	0.14	-0.32	-0.30	-0.06	-0.30	**-0.43***	**-0.78***	**-0.58***	-1.00	1

Table 7: Correlation of depth regression for clay loam

		Wetd depth (cm) (Z)	Vw	Qw	t	Ks	δθ
Pearson Correlation	Wetd depth (cm) (Z)	1.00	0.05	0.05	0.05	-0.96	-0.95
	Vw	0.05	1.00	0.97	0.97	0.00	-0.01
	Qw	0.05	0.97	1.00	1.00	-0.01	-0.01
	t (hr)	0.05	0.97	1.00	1.00	-0.01	-0.01
	Ks	-0.96	0.00	-0.01	-0.01	1.00	0.95
	δθ	-0.95	-0.01	-0.01	-0.01	0.95	1.00
Sig. (1-tailed)	Wetd depth (cm) (Z)		0.17	0.19	0.19	0.00	0.00
	Vw	0.17		0.00	0.00	0.47	0.46
	Qw	0.19	0.00		0.00	0.46	0.45
	t (hr)	0.19	0.00	0.00		0.46	0.45
	Ks	0.00	0.47	0.46	0.46		0.00
	δθ	0.00	0.46	0.45	0.45	0.00	
N	Wetd depth (cm) (Z)	341.00	341.00	341.00	341.00	341.00	341.00
	Vw	341.00	341.00	341.00	341.00	341.00	341.00
	Qw	341.00	341.00	341.00	341.00	341.00	341.00
	t (hr)	341.00	341.00	341.00	341.00	341.00	341.00
	Ks	341.00	341.00	341.00	341.00	341.00	341.00
	δθ	341.00	341.00	341.00	341.00	341.00	341.00

Z = Depth; Vw = Volume of Water;Qw = Flow rate;t = time;Ks = Hydraulic Conductivity;δθ = Porosity

Effect of Duration on Wetted Depth and Wetted Radius

Figures 4 and 5 show the relationship between duration of irrigation, wetted radius and wetted depth, respectively. Ali and Nasiri, (2012) reported that relationship exists between wetted width and wetted depth which is mainly determined by fractions of clay, loam and silt in the soil. From Figure 4, more radii are covered in clay loam soil and the least were covered by sandy clay loam soil with lowest clay percentage. Freddie et al., (2007) also reported a similar result and the reason attributed to such occurrence was the fact that soils with high clay content have more micro pores per unit volume than sandy soil and the more the pores, water is likely to move more horizontally (sideways) due to capillary action than vertical movement which is governed by gravity. Therefore, in a soil with higher clay content, the width to depth ratio of water distribution will be bigger as compared to sandy soil if same volume of water is applied. This assertion was also supported by Mostafa, (2014), who suggested that the reason why lateral water movement is more in clay soil maybe attributed to the fact that lateral movement is affected by micro pores while that of vertical movement is affected more by total porosity of the soil and that may explain why vertical movement of water will be more in sandy soil than clay while lateral will be more in clay soil than sandy soil. The observation in Figure 5 supported this where vertical water movement is more in sandy loam soil than other soil samples with higher clay percentage. To support this, Li et al., (2004), highlighted that vertical distribution of water is governed by gravitational action which in turn is governed by inter-particle pores in the soil. The pores are larger in sandy soil and water tends to infiltrate more. However, lateral movement in soil is governed by capillary action which is being determined by intra-particle pores. The pores are said to be more in sandy than clay soil and therefore, irrigation water is expected to travel wider than deeper in clay soil than sandy soil if the same quantity of water is applied to both soil types for the same duration. Ali and Nasir, (2012), then concluded that drip irrigation for clay soil will have more impact on shallow rooted crops planted over a wide area of land and that if drip irrigation is to be set up on sandy soil; deeper rooted crops can be considered since the water is expected to infiltrate deeper.

Analysis of field data

Figures 4 and 5 show the variation of the effect of duration of water application in wetted radius and depth within the soil types.

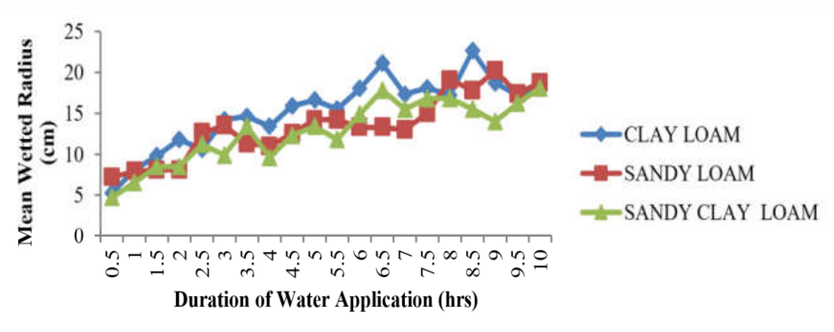


Figure 4: Variation of wetted radius with duration of water application

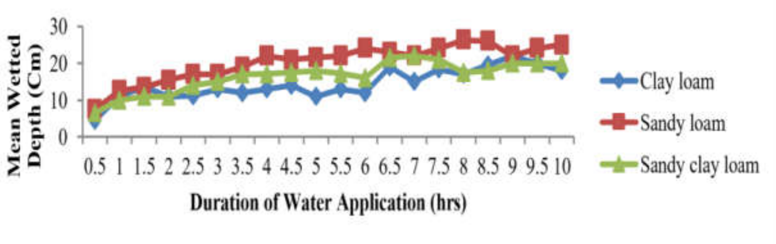


Figure 5: Variation of wetted depth with duration of water application

Statistical implication of field investigation

The coefficient value of 90 % generally indicates a very satisfactory model performance according to, Mallikarjuna et al., (2009). For this work 95 % confidence interval was used to measure the ability of the model to reproduce the observed. The R values gave a satisfactory fitness of the models between 0.741-0.966 for the data of all the three soil types indicating that they are close to 1, showing a good fitness of the models. The R^2 shows the relationship between the independent variables, that is, the duration of water application, the volume of water applied, the rates of water applied, the hydraulic conductivity, the porosity with the dependent variables which are depth and radius we observed that the R^2 values for clay loam is between (0.7-0.9), sandy loam (0.7-0.8) and sandy clay loam (0.7-0.8) are close to 1 showing that the models are statistically significant, adequate for the wetted depth and radius data. Also from the ANOVA for the three soil samples, the significant levels of the models are less than 0.05 ($P<0.05$) which implies that the duration, volume and rates of water applied and the hydraulic properties had significant effect on the radius and depth. The sign of their coefficient gives the direction of the effect, the positive values means that an increase in the dependent variables will produce an increase in the independent variable, while a negative sign means that as the independent variable increases the dependent variable will decline.

Conclusions and Recommendations

Conclusion

The prediction of soil wetting pattern for clay loam, sandy loam and sandy clay loam under point source drip irrigation was studied to develop model to relate flow rate, duration of water application with wetted depth and radius. The three experimental plots used for this work are suitable for drip irrigation based on the values of their physicochemical and hydraulic properties. Sandy loam soil exhibited better hydraulic properties and will therefore conduct water faster, hence, more water can be released and the plot can also be planted with crop with higher reference evapo-transpiration (ET_e). There is no significant difference between the parameters of soil samples taken from depth 0-15 cm and from samples taken from depth 16.0 – 30.0 cm. Therefore crops that can extract water or nutrient up to 30.0 cm depth can be established on the soils. This work has also shown that the wetted depth and wetted radius of these soil types are influenced by flow rate and time within the range under consideration. As expected, the size of the wetting pattern in both depths and radius increased with the volume of water applied. It moved faster at the beginning of the water application, and slowed down with increase in volume of water applied, as the wetting pattern moved away from the source. The wetted radius in clay loam tends to be larger and smaller in sandy loam and sand clay loam, respectively. It is therefore observed that clay loam soil will have more impact on shallow rooted vegetable crops planted over a wide range of land. Deeper rooted vegetable crops are better on sandy loam since water was found to have infiltrated deeper. The experimental data also indicated that the rate of discharge and the hydraulic property of the soil had a remarkable effect on the shape of the wetted soil zone. As the depth increases the hydraulic properties reduces.

Recommendations

It is however recommended that;

1. SAR, percentage magnesium and sodium of the plots should be considered if repeated drip irrigation will be carried out on these plots as this may lead to salt build up and solidity.
2. Further work can be carried out with specific crops in other to optimize the results.
3. More soil types to test further predictive capability of rate and time of application can be done.

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