UNIVERSITY OF KWAZULU-NATAL

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MASINDE MULIRO UNIVERSITY OF SCIENCE AND TECHNOLOGY

Technology for Development

EFFECT OF SOIL TEXTURE ON SOIL WATER MOVEMENT UNDER MOISTUBE IRRIGATION

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Moistube Irrigation (MTI)

- Moistube irrigation (MTI) is a new technology which originated in China – developed in 2008
  - Trials in China, UAE, Morocco (Green Engineering Mission)
- The system uses semi-permeable membrane

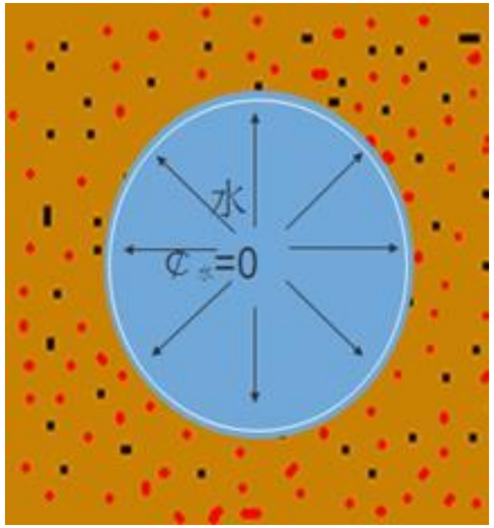
Moistube structure

(Envirogrower, 2017; Yang, 2016)

Water Flow Mechanism

- The discharge from Moistube varies with;

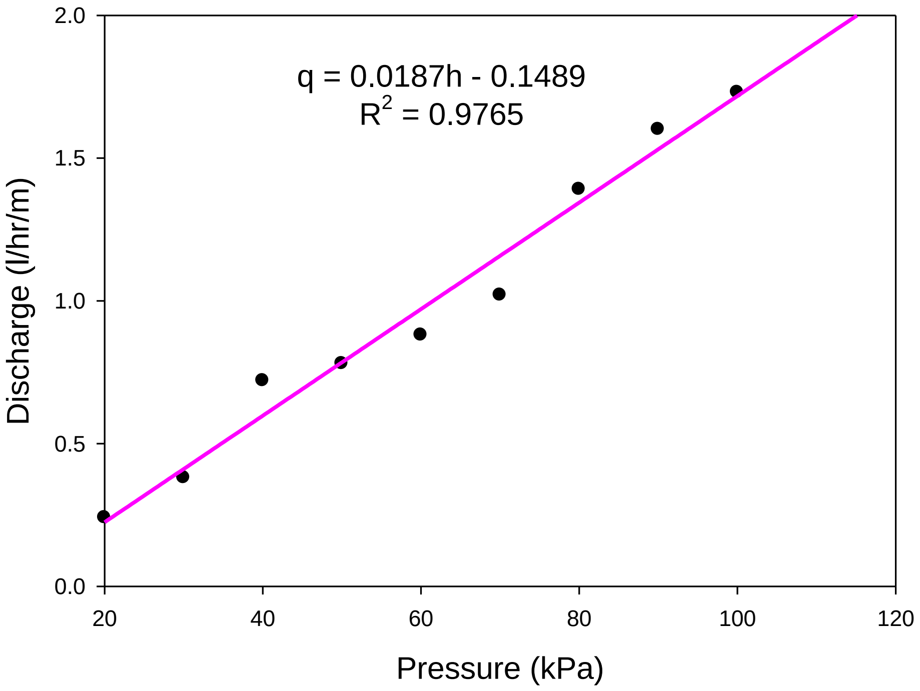
1) System pressure
2) Soil water potential



Ȼ water≥ Ȼ soil. large volume of water seepage

Ȼ water> Ȼ soil, less volume of water seepage

Ȼ water=Ȼ soil, no water seepage



- The effect of soil water potential is weak (< 48 hours)

(Niu, et al., 2013, Yang, 2016, Niu et al., 2017; Kanda, et al., 2018)

Crop Response



1) Tomato

- Relatively same yield, 38% water savings and WUE (↑13 – 26%), than drip irrigation

2) Cabbage

- No significant improvement in yield compared to drip irrigation

3) Maize

- Yield significantly less in MTI than subsurface drip (SDI)
- WUE not significantly different between SDI and MTI

Xue, et al., 2013; Lyu, et al., 2016; Zhang, et al., 2017; Sun et al., 2018)

Soil Water Dynamics

- It depends on;
  - Soil characteristics
  - System flow rate
  - Crop characteristics
- The soil water distribution is required for optimum design of subsurface irrigation systems
- The suitable Moistube placement depth for tomato and sunflower are 10 and 20 cm respectively

(Kandelous and Šimůnek, 2010; Subbaiah, 2013; Tian, et al., 2016; Niu et al., 2017)

Research Objective

- To determine the effect of soil texture on the soil water dynamics under MTI

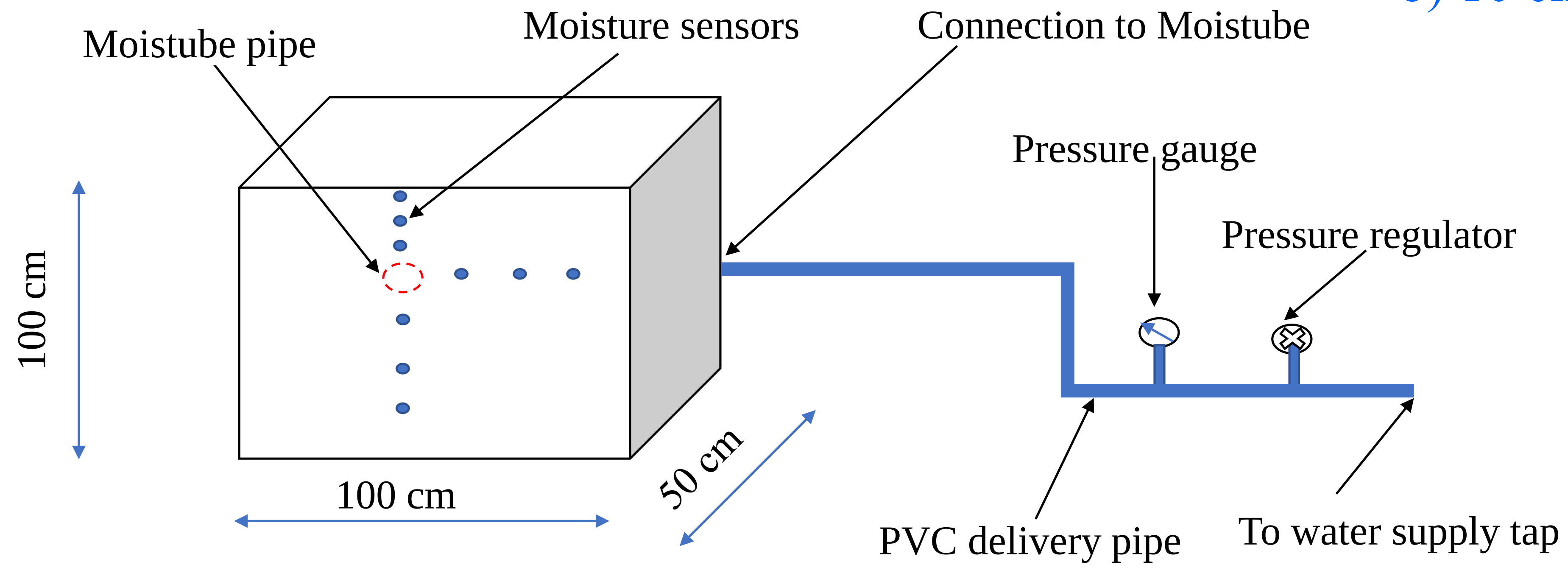
Methodology

- This study was accomplished using;

1) Laboratory experiments and

2) HYDRUS 2D/3D model

- Pressure head = 60 kPa
- Moisture sensor locations:
  - a) 5 cm, 10 cm, 15 cm ↑
  - b) 10 cm, 20 cm, 30 cm → & ↓



Lab experiment

Numerical Simulation

- MTI is simulated in HYDRUS 2D/3D using 2D form of Richard's Equation

$$\frac{\partial \theta}{\partial t} = \frac{\partial}{\partial x}\left[K(h)\frac{\partial h}{\partial x}\right] + \frac{\partial}{\partial z}\left[K(h)\frac{\partial h}{\partial z} + K(h)\right]$$

(Skaggs et al., 2004)

θ = Volumetric water content [L^3 L^{-3}], h =soil water pressure head [L K = unsaturated hydraulic conductivity [LT^{-1}]; t = time [T]; and x = horizontal spatial coordinate [L], and z = vertical spatial coordinate (L)

Numerical Simulation …

- Model set-up requires specification of soil hydraulic parameters in the van Genuchten Equation

$$\theta(h) = \begin{cases} \theta_r + \frac{\theta_s - \theta_r}{(1+|\alpha h|^n)^m} & h < 0 \\ \theta_s & h \geq 0 \end{cases}$$

(Skaggs et al., 2004)

$$K(h) = K_s S_e^l \left[1 - (1 - S_e^{1/m})^m\right]^2$$

$$S_e = \frac{\theta - \theta_r}{\theta_s - \theta_r} \quad , m = 1 - \frac{1}{n}$$

θ = Volumetric water content [$L^3\ L^{-3}$], h =soil water pressure head [L], S_e = effective saturation, θ_s = saturated water content [$L^3\ L^{-3}$]; θ_r = residual water content [$L^3\ L^{-3}$]; K = unsaturated hydraulic conductivity [LT^{-1}]; K_s = saturated hydraulic conductivity [LT^{-1}]; and α, m, n and l = empirical coefficients

Numerical Simulation …

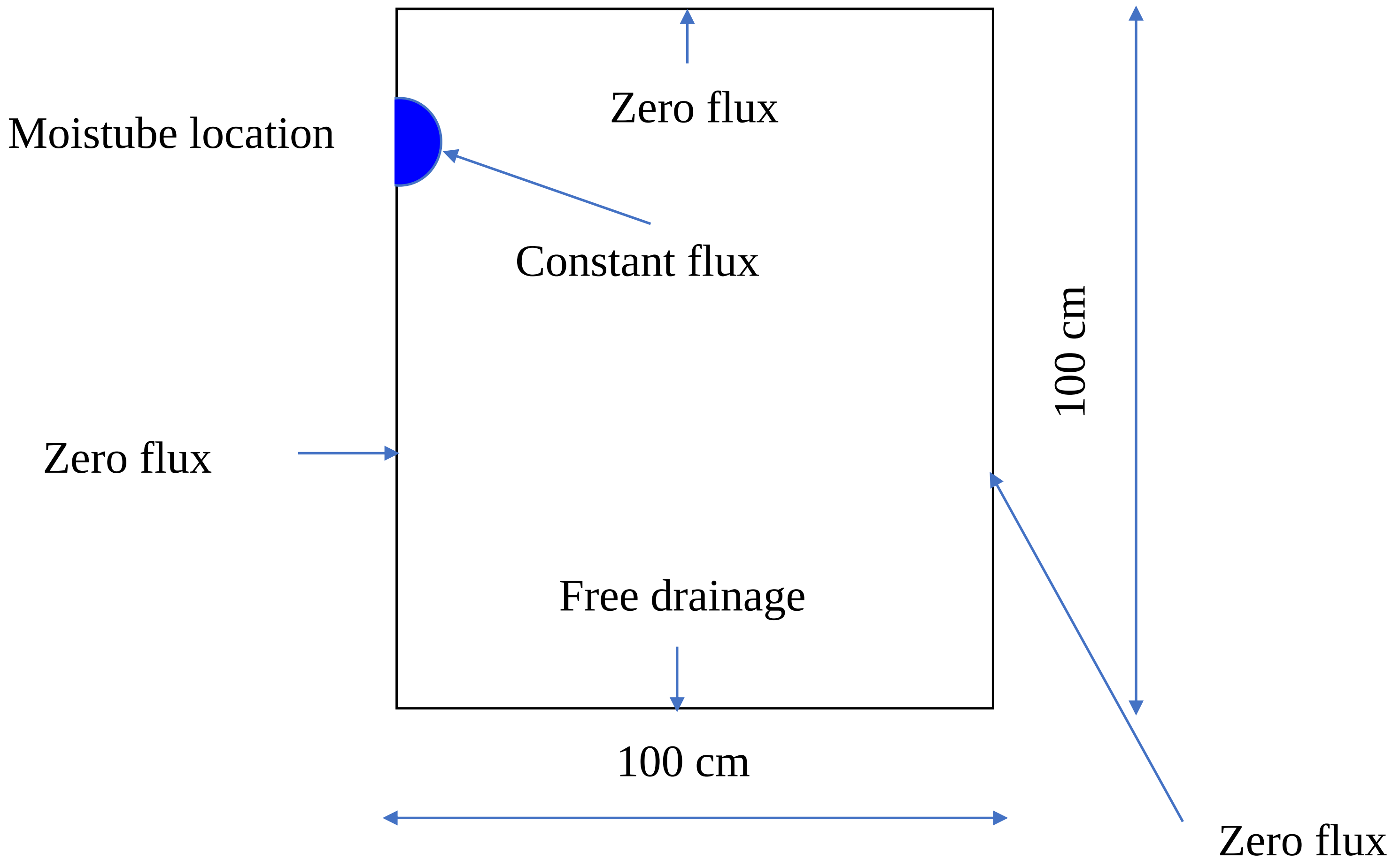
- Soil hydraulic parameters were estimated using ROSETTA (Schaap, et al 2001)

Table : Soil hydraulic parameters (van Genuchten-Mualem model)

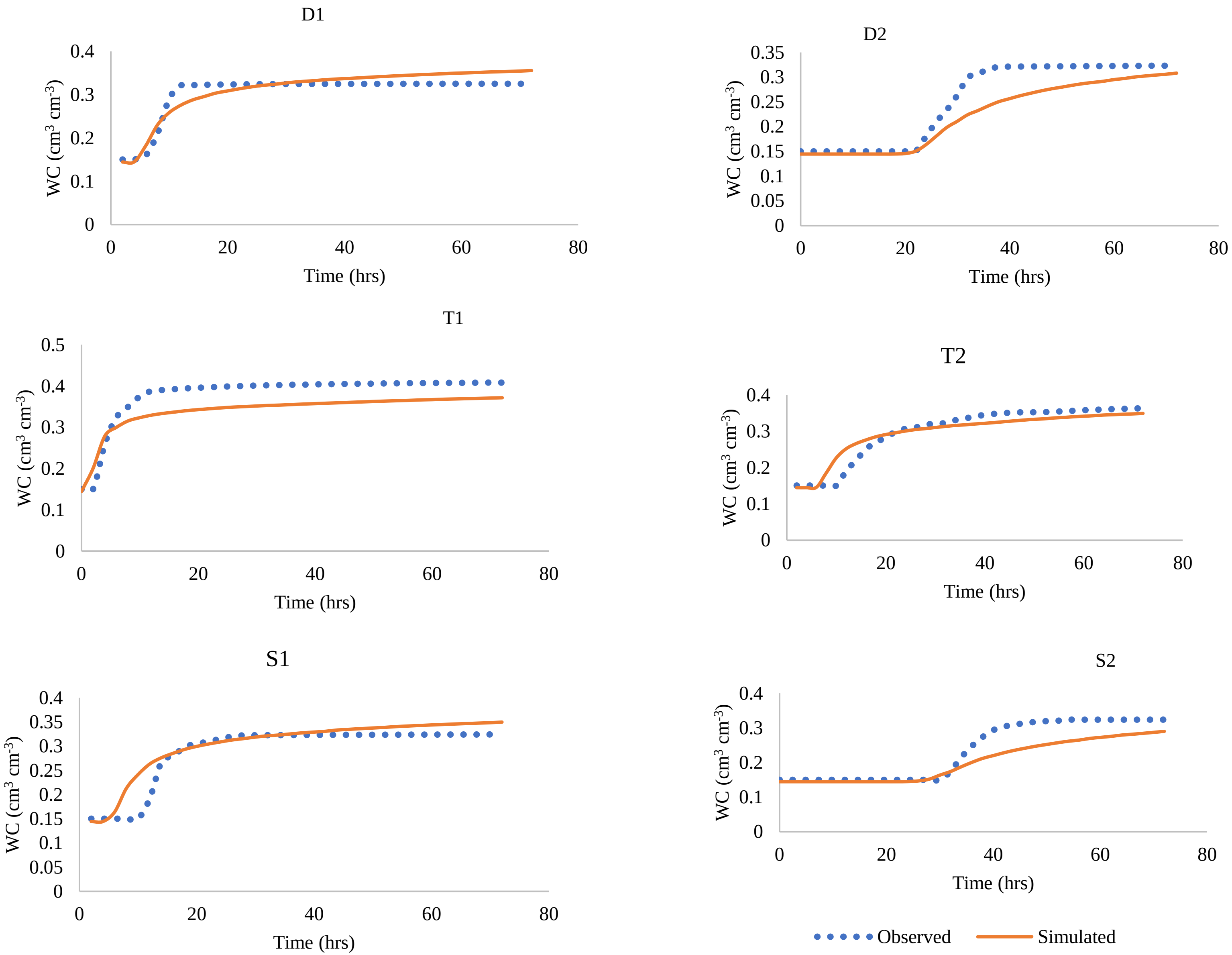
Texture class	θ_r (cm^3 cm^{-3})	θ_s (cm^3 cm^{-3})	α (cm^{-1})	n	Ks (cm day^{-1})	l
Sandy clay loam	0.0736	0.461	0.0216	1.4102	42.32	0.5
Loam	0.0635	0.3977	0.0108	1.4915	18.42	0.5
Clay loam	0.0911	0.4796	0.0176	1.3593	10.31	0.5
Clay	0.1042	0.52783	0.0221	1.2963	6.28	0.5

Numerical Simulation …

- Boundary Conditions



Results – Soil water contents at Observation Points



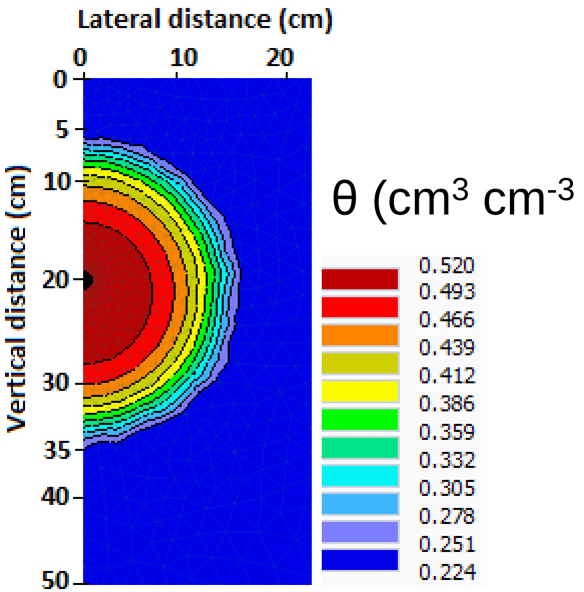
R^2 = 0.871 – 0.956
RMSE = 0.021 – 0.042 cm^3/cm^3
PBIAS = 2.2 – 13.4%

D1&D2 = 10 cm & 20 cm downward
T1&T2 = 10 cm & 20 cm upward
S1& S2 = 10 cm & 20 cm lateral

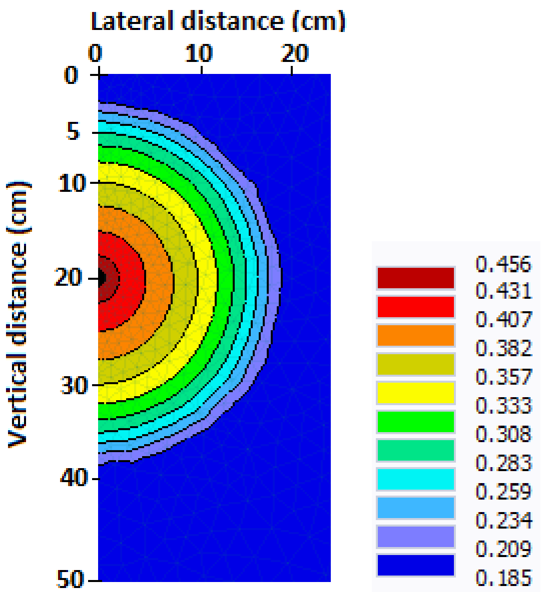
Observed and simulated soil water contents (sandy clay loam)

Soil Water Distributions

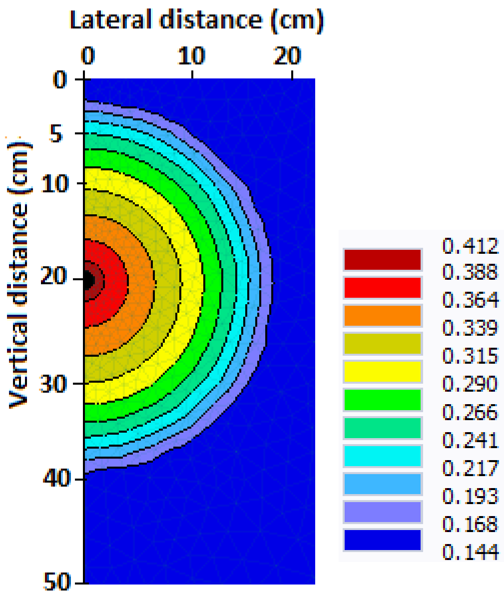
After 24 hours



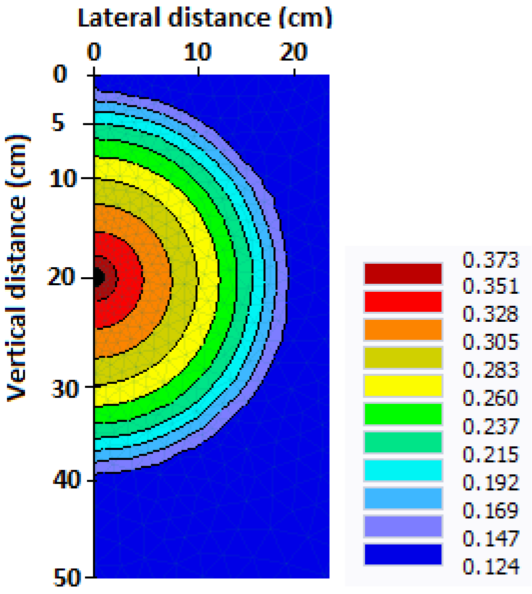
Clay



Clay loam



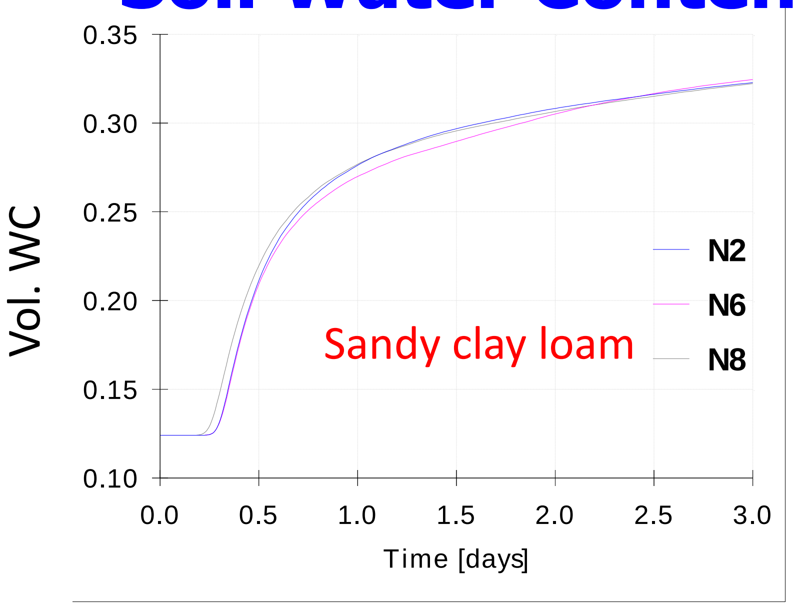
Loam

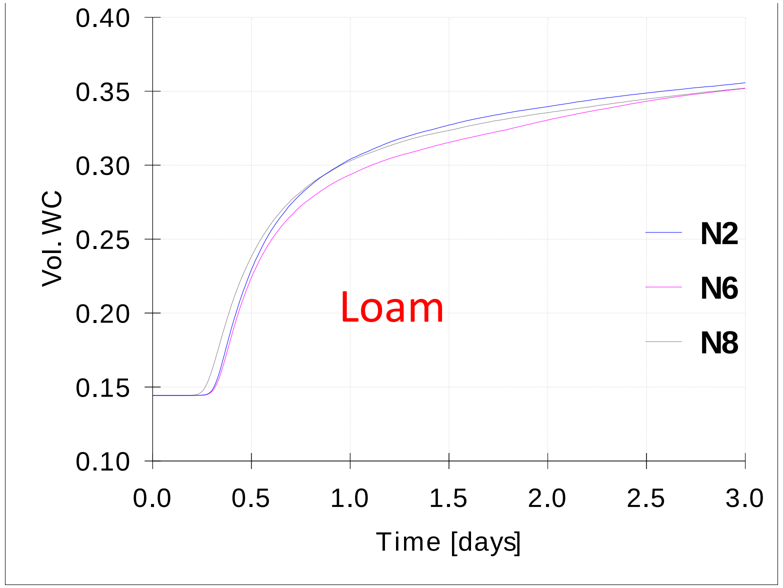


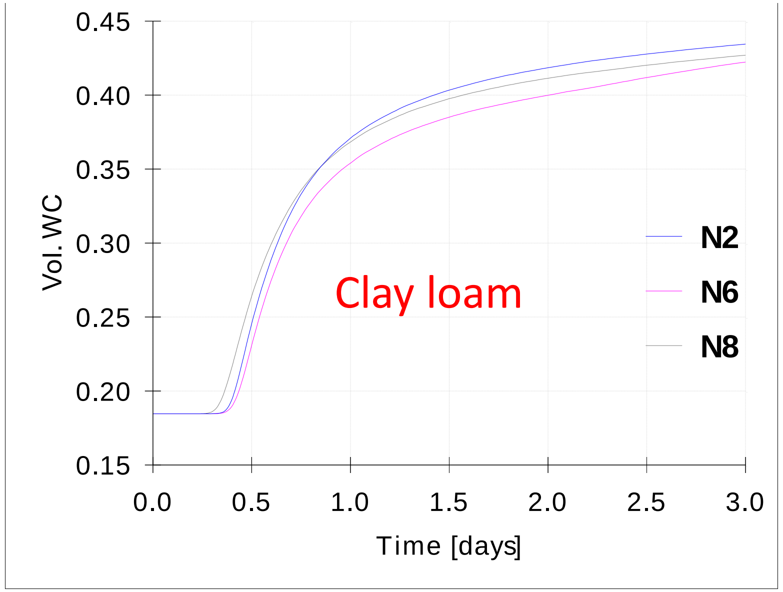
Sandy clay Loam

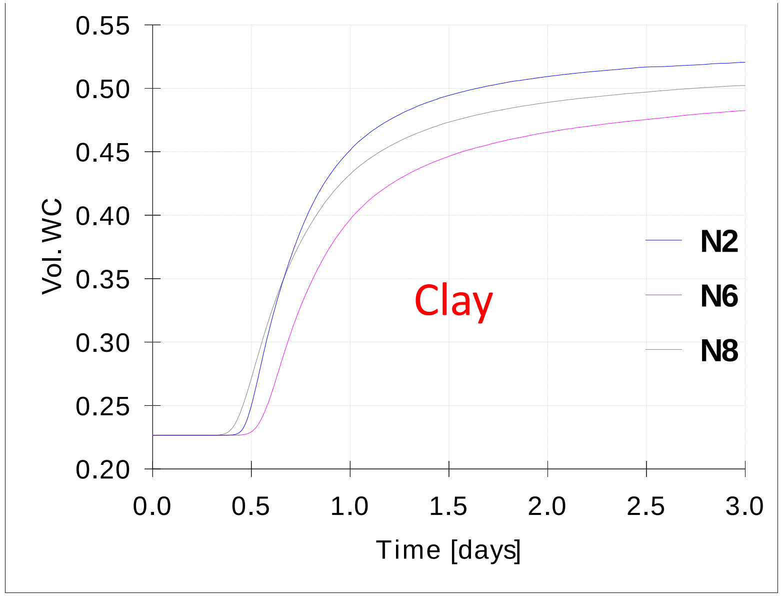
- Lateral movement was similar in all the soil textures
- Soil wetting pattern was symmetrical in clay
- Downward movement slowest in clay
- No significant difference between downward movement in all the soil textures

Soil Water Content at Observation Points









N2 = 10 cm downwards
N6 = 10 cm upward
N8 = 10 cm laterally

- The water contents were lower in the upward directions in all the soil texture
- The water content in each soil texture were not significantly different in the 3 directions

Soil Water Distributions …

- The average water contents within the 10 cm radii (after 24 hours) were 0.43, 0.29, 0.36 and 0.28 in clay, loam, clay loam and sandy clay loam respectively.

Soil Water Distributions …

- Based on the soil water distribution;
  - The MTI installation depth could be shallower in coarse textured soils to minimize drainage losses
  - Fine textured soils could benefit from deeper installation depths
- Niu et al., (2013) established that a suitable Moistube installation depth was between 15 and 20 cm in clay loam

Conclusion

- Soil texture influences the soil water movement under MTI
- The wetted volume was symmetrical in clay
- Potential drainage loss in medium and coarse textured soils
- The effect of root water uptake need to be investigated

Moistube tapes