



Research Article

Design of a Drip Irrigation System for a Pineapple Orchard at the Federal University of Technology Owerri (F.U.T.O), School Farm

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ABSTRACT

The aim of this research paper is to design a drip irrigation system for a Pineapple orchard in the Federal University of Technology Owerri school farm. This work takes into account the preliminary studies of the study area (general relief, topography and soil nature), water quality and quantity assessment (water sample collection, testing and analysis), soil and field analysis (moisture content test, infiltration tests and grain-size analysis) and climatic influence on the area to make resolute conclusions on the parameters required for the design of the drip irrigation system. With reference to the peak consumptive use of pineapple (1.928mm/day) and peak potential evapotranspiration (4.794mm/day) obtained from application of empirical formulas; the drip irrigation system designed comprises of 48 laterals (Inside Diameter of 10mm, 1104 emitters, Discharge of 0.012L/S, and Friction Loss of 13.44m), 1 submain (Inside Diameter of 28mm, Discharge of 0.56L/S and Friction Loss of 3.65m) and 1 mainline (Inside Diameter of 42mm, Discharge of 0.57L/S and Friction Loss of 0.02m) with an actual emission uniformity of 85%.

Keywords:

Irrigation, Drip Irrigation, Design, Pineapple

INTRODUCTION

Irrigation is the controlled application of water artificially to the soil for the purpose of supplying the moisture needs and requirements of the crop(s) for production and optimum performance in the field or farm. Drip irrigation is the frequent, slow application of water either directly into the land surface or into the root zone of the crops, (James, 1988), according to A.M Michael, 1991, drip irrigation is a method of watering plants with a volume of water approaching the consumptive use (CU) of the plants. It is the slow even application of low pressure water to the soil and plants using plastic tubing placed directly at the plants root zone (Malheur Experiment Station, 2006). Irrigation therefore provides the necessary requirements and needs of plants for regular production and performance as regards water availability in farm with dependence on nature. Changes in frequency, occurrence and intensity of rainfall are of great importance and concern to agriculture both in arid and humid regions respectively. The shortfalls that accrue in the course of various seasons in the year provides a big hinge on which irrigation is needed to satisfy all year round crop production for optimal output and higher productivity in the field/farm. In this work, pineapple is considered as the plant in the field.

MATERIALS AND METHOD

- Time of irrigation = 5hours per plot
- Allowable desirable pressure falls between 10- 20% for drip systems
- Area to be irrigated = 2 hectares (4 plots of 50m x 100m)
- Spacing of each pineapple sucker = 2m x 2m
- Emission Uniformity for point source emitters 80-90%, (Schwab et al, 1993)
- Coefficient of Variation, $C_v = 0.10$, (Schwab et al, 1993)
- Number of emitters per pineapple sucker = 1
- Pipe type; Poly Vinyl Chloride (PVC)

Design Procedure

- 1) Determination of evapotranspiration, for each month for the crop, consumptive use of crop for each month and the peak consumptive use for plant.
- 2) Determination of emitter discharge or volume of water required per emitter for plant.
- 3) Determination of system operating pressure and minimum pressure required to maintain the desired emission uniformity (E.U)
- 4) Determination of pressure variation, ΔH in each lines of the drip system.
- 5) Determination of the laterals, submain and main line sections and pump selection.

Study Area

The study area is the FUTO school farm, located on Latitude 5.27.N and Longitude 6.55.E, with an area of 2 Hectares (200m x 100m). The watershed enjoys mean monthly temperatures ranging from 25-31 degrees centigrade, relative humidity of about 70%-85%, with annual rainfall of about 2250mm-2750mm, (Wikipedia, 2001 and NIMET, 2008). The study area falls within the tropical rainforest/rainfall belt region, with thick underbrush and woody vegetation, (Ibe and Uzoukwu, 2001), the area is predominated by sandy soil with little proportions of silt and clay, thus accounting for low carbon and nitrogen contents, (Nnaji et al., 2011). The slope of the area of consideration falls between 1%-2%.

Methods

In designing this system, certain tests need to be carried out to ascertain various parameters, such tests are as follows; water quality test and assessment, grain-size analysis and moisture content tests and Infiltration tests and field analysis.

Design Information

The following form the basic guidelines for the design of the drip irrigation system;

RESULTS/DESIGN CALCULATIONS**Table 1.0: Grain-Size Analysis**

| SIEVE | WEIGHT OF CAN (g) | WEIGHT OF CAN PLUS SAMPLE (g) | WEIGHT OF DRY SIEVED SAMPLE (g) | PERCENTAGE RETAINED (%) | PERCENTAGE PASSING THROUGH SIEVE (%) |
|-------|-------------------|-------------------------------|---------------------------------|-------------------------|--------------------------------------|
| 2.000 | 19.5 | 19.6 | 0.1 | 0.1 | 99.9 |
| 1.180 | 19.6 | 22.8 | 3.2 | 1.8 | 98.1 |
| 0.850 | 19.5 | 30.7 | 11.2 | 6.3 | 91.8 |
| 0.600 | 19.2 | 53.3 | 34.1 | 19.0 | 72.8 |
| 0.425 | 19.5 | 74.7 | 55.2 | 30.8 | 42.0 |
| 0.300 | 19.4 | 47.4 | 28.0 | 15.6 | 26.4 |
| 0.150 | 19.7 | 52.2 | 32.5 | 18.2 | 8.2 |
| 0.075 | 17.6 | 29.8 | 12.2 | 6.8 | 1.4 |
| PAN | 19.0 | 21.5 | 2.5 | 1.4 | - |

Table 2.0: Moisture Content Test

| DESCRIPTION OF SAMPLE | SAMPLE A | SAMPLE B | SAMPLE C | SAMPLE D |
|--------------------------------------|----------|----------|----------|----------|
| Weight of wet plus moisture cans,(g) | 78.2 | 84.2 | 76.7 | 75.8 |
| Weight of the moisture can, (g) | 22.7 | 23 | 21.7 | 20 |
| Weight of wet soil sample, (g) | 55.5 | 61 | 55 | 55.8 |
| Weight of dry soil plus can (g) | 73.2 | 75.6 | 69.9 | 67.5 |
| Weight of dry soil sample, (g) | 56.5 | 52.6 | 48.2 | 47.5 |
| Weight of removed moisture(g) | 5 | 8.6 | 6.8 | 8.3 |
| Moisture content (%) | 9.01 | 14.05 | 12.36 | 14.87 |

Table 3.0: Infiltration Test Results

| TIME ELAPSED (mins) | Level before filling (cm) | | Level after filling (cm) | | Depth of flow (cm) | | Average inflow rate(cm/hr) | | Accumulated Infiltration(cm) | |
|---------------------|---------------------------|--------|--------------------------|--------|--------------------|--------|----------------------------|--------|------------------------------|--------|
| | PLOT 1 | PLOT 2 | PLOT 1 | PLOT 2 | PLOT 1 | PLOT 2 | PLOT 1 | PLOT 2 | PLOT 1 | PLOT 2 |
| 0 | 0 | 0 | 12 | 12 | 0 | 0 | 0 | 0 | 0 | 0 |
| 5 | 6.4 | 6.9 | 12 | 12 | 5.6 | 5.1 | 67.2 | 61.2 | 5.6 | 5.1 |
| 10 | 6.9 | 7.4 | 12 | 12 | 5.1 | 4.6 | 61.2 | 55.2 | 10.7 | 9.7 |
| 15 | 7.7 | 7.9 | 12 | 12 | 4.3 | 4.1 | 51.6 | 49.2 | 15 | 13.8 |
| 25 | 6.7 | 6.2 | 12 | 12 | 5.3 | 5.8 | 31.8 | 34.8 | 20.3 | 19.6 |
| 45 | 4.3 | 4.6 | 12 | 12 | 7.7 | 7.4 | 23.1 | 22.2 | 28 | 27 |
| 60 | 6.6 | 7.1 | 12 | 12 | 5.4 | 4.9 | 21.6 | 19.6 | 33.4 | 31.9 |
| 75 | 6.6 | 7.2 | 12 | 12 | 5.4 | 4.8 | 21.6 | 19.2 | 38.8 | 36.7 |
| 90 | 6.6 | 7.2 | 12 | 12 | 5.4 | 4.8 | 21.6 | 19.2 | 44.2 | 41.5 |
| 110 | 5.9 | 6 | 12 | 12 | 6.1 | 6 | 18.3 | 18 | 50.3 | 47.5 |
| 130 | 5.8 | 6 | 12 | 12 | 6.1 | 6 | 18.3 | 18 | 56.4 | 53.5 |

Water Quality Assessment

The chemical quality of water determines the suitability for irrigation use, the most important characteristics of irrigation water are the total concentrations of soluble

salts, properties of sodium, toxic elements and carbonate concentrations plus magnesium (USDA, 1954,1974,1976).

Table 4.0 Water Sample Analysis Results

| PARAMETERS | SAMPLE A | SAMPLE B | SAMPLE C |
|------------------|----------|----------|----------|
| Ph | 5.7 | 5.4 | 5.55 |
| Turbidity | 2 | 3 | 2.5 |
| Color | <5 | <5 | <5 |
| Salinity, mg/l | 18.8 | 16.5 | 17.65 |
| Acidity, mg/l | 90 | 75 | 82.5 |
| Calcium,mg/l | 7.2 | 6.8 | 7 |
| Sodium, mg/l | 12.4 | 11.6 | 12 |
| Magnesium, mg/l | 8 | 7.5 | 7.75 |
| Chloride, mg/l | 12 | 10 | 11 |
| Nitrate, mg/l | 2.5 | 4.5 | 3.5 |
| Sulphate, mg/l | 4 | 8 | 6 |
| Manganese, mg/l | 0.1 | 0.2 | 0.15 |
| Silica, mg/l | 8 | 10 | 9 |
| Iron, mg/l | 0.15 | 0.05 | 0.1 |
| Total Hardness | 18 | 17 | 17.5 |
| Temperature,°C | 26.5 | 29 | 27.75 |
| Alkalinity, mg/l | 10 | 5 | 7.5 |

Evapotranspiration And Consumptive Use Of Pineapple

In determining the evapotranspiration and consumptive use of pineapple we apply Blaney-Morin model, (Duru, 1984);

$$E_{TP} = R_f(0.45T + 8)(520 + R^{1.31})/100 \quad (1)$$

$$C_U = K E_{TP} \quad (2)$$

Where E_{TP} = Potential Evapotranspiration (mm/day), R_F = Radiation Factor

R = Average relative humidity

K = Crop Factor, which with growth stage of the plant.

Evapotranspiration And Consumptive Use Results For Pineapple

| MONTH | E_{TP} (mm/day) | C_u (mm/day) | K | R (%) | T | R_F |
|-----------|-------------------|----------------|------|---------|------|--------|
| JANUARY | 4.794 | 1.918 | 0.40 | 65 | 28.2 | 0.0819 |
| FEBRUARY | 3.969 | 1.786 | 0.45 | 73.2 | 29.3 | 0.7710 |
| MARCH | 4.237 | 1.907 | 0.45 | 76.6 | 29.3 | 0.0885 |
| APRIL | 4.068 | 1.907 | 0.46 | 77.0 | 29.2 | 0.8590 |
| MAY | 3.809 | 1.790 | 0.47 | 79.2 | 28.3 | 0.8630 |
| JUNE | 4.003 | 1.921 | 0.48 | 66.2 | 21.7 | 0.8590 |
| JULY | 2.988 | 1.494 | 0.50 | 86.0 | 26.4 | 0.8450 |
| AUGUST | 3.006 | 1.503 | 0.50 | 86.4 | 26 | 0.8590 |
| SEPTEMBER | 4.017 | 1.928 | 0.48 | 68.0 | 21.2 | 0.8530 |
| OCTOBER | 3.539 | 1.663 | 0.47 | 81.2 | 27.5 | 0.8570 |
| NOVEMBER | 3.708 | 1.669 | 0.45 | 77.2 | 29.0 | 0.0790 |
| DECEMBER | 4.124 | 1.649 | 0.40 | 71.0 | 28.1 | 0.0787 |

PEAK CONSUMPTIVE USE OF PINEAPPLE = 1.928mm/day.

PEAK POTENTIAL EVAPOTRANSPIRATION = 4.794mm/day.

Discharge Per Emitter/Volume Of Water Required Per Plant

Since an emitter is placed at the plant root zone, the discharge is as follows;

$$V = (\text{peak } E_{TP} \times \text{Spacing}) / \text{Emission Uniformity} = 9.073 \text{ L/day}$$

Each stand is irrigated once a day for 5hours, therefore volume of water per stand per hour is given by;

$$V = 9.073/5 = 1.814\text{L/hr}$$

$$\text{Emitter discharge, } q = Kh^x \quad (3)$$

Obtaining average operating pressure, $H = (q/k)^{1/x}$, where $k = 0.151$ and emitter discharge exponent, $x = 0.63$, $H = 51.73\text{KPa}$, converting to meters, $H = 5.27\text{m}$.

Minimum discharge of emitter in the farthest lateral, coefficient of variation, $C_v = 0.10$,

$$Q_{\text{MIN}} = EU(Q_{\text{AVG}})/100(1 - 1.27(C_v/n^{0.5})), \quad (4)$$

number of emitter per plant = 1, so $Q_{\text{MIN}} = 1.77\text{L/hr}$

Minimum head in farthest lateral is given by, $H_{\text{MIN}} = (Q/K)^{1/x} = 50.07$, converting to meters, thus $H_{\text{MIN}} = 5.10\text{m}$

Pressure variation $\Delta H = 2.5 (H_{\text{AVG}} - H_{\text{MIN}}) = 5.27 - 5.10 = 0.17\text{m}$

Maximum allowable inlet pressure in section, $H_{\text{MAX}} = H_{\text{AVG}} + \Delta H = 5.27 + 0.17 = 5.44\text{m}$.

Table 5.0 Values Of The Design Components

| LATERALS | SUBMAIN | MAINLINE |
|---|---|---|
| -discharge per emitter=1.814L/hr -number of emitters per lateral=23 -total discharge per lateral = $23 \times 1.814 = 41.72\text{L/hr}$ Converting to L/s=0.012L/s -lateral length = 46m -head pressure= 5.4m From Wu and Gittlin chart L/H = 8.5m,thus pipe inside diameter is 10m -friction loss= $KLQ^{1.75}D^{-4.75} = 0.28\text{m}$ $K=7.89 \times 10^{1.75}$ for water Total friction loss= $48 \times 0.28 = 13.44\text{m}$ | Number of submain = 1 Length of submain=96m Operating pressure = 5.44m Discharge, $Q_{\text{SUB}} = 41.72 \times 48 =$ 2002.66L/hr Converting to L/s=0.56L/s Slope of design area is 1-2% Inside Diameter, D= 28mm Friction loss= $KLQ^{1.75}D^{-4.75} = 3.65\text{m}$ | Number of mainlines=1 Length of mainline=3m Maimum inlet pressure=5.44m, Take 6m $Q =$ discharge of lateral + discharge of submain= $41.72 + 2002.66 = 2044.38\text{L/hr}$ Conerting to L/s=0.57L/s Inside diameter= diameter of submain X 1.5=42m Friction loss= $KLQ^{1.75}D^{-4.75}$ $= 0.02\text{m}$ |

Total friction loss in the system= $13.44 + 3.65 + 0.02 = 17.11\text{m}$

Total Least amount of water required to irrigate each plot = $41.72 + 2002.66 + 2044.38 = 4088.76\text{L/hr}$

For 5hours= $4088.76 \times 5 = 20443.80$ Liters

A 1.5-2.0 Horsepower sumo pump is okay for pumping of water into a storage tank.

Table 6.0 Design Summary

| LINE | NUMBER OF EACH | INSIDE DIAMETER(MM) | NUMBER OF EMITTERS | DISCHARGE (L/S) | FRICION LOSS (M) |
|----------|----------------|---------------------|--------------------|-----------------|------------------|
| LATERALS | 48 | 10 | 1104 | 0.012 | 13.44 |
| SUBMAIN | 1 | 28 | | 0.56 | 3.65 |
| MAINLINE | 1 | 42 | | 0.57 | 0.02 |

Actual Emission Uniformity of the system, $EU = 100[1 - 1.27C_v/(n^{0.5})]Q_{\text{MIN}}/Q_{\text{AVG}} = 85\%$

CONCLUSION

Though the school farm enjoys a long period of rainfall, shortfalls and unequal intensity of rainfall amount guarantee the water requirements of the pineapple covering for evaporation and transpiration losses. The drip irrigation system consisting of 48 laterals, 1 submain and 1 main line, will therefore be a solution in solving the shortfalls of climate in the school farm.

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