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Development of Gravity Drip Irrigation System in Agricultural and Bio-Environmental Engineering Demonstration Farm, Auchi Polytechnic, Auchi

Ahanmisi Edeki [α] & Ajayi Asishana Stanley [σ]

Abstract- Agriculture is known to accounts for about 70 – 80% use of available water in the world. However, dwindling water availability has made it necessary to improve on the way water is used in Agriculture. Rainfall is the single most important factor affecting crop production. The objective of this study is to develop a gravity drip irrigation system for selected vegetable crops. This study was carried out in Auchi Polytechnic, which is located between latitude 7^0 10' and 7^0 20' north of the equator and longitude 6^0 16' and 6^0 36' east of the Greenwich Meridian with an altitude of 207m. Field preparation was done by clearing, ploughing and harrowing. PVC pipes were laid, 2 mm holes was made at distance of 30 cm on the 6 m PVC pipes. Components of drip irrigation system consist essentially of main line, sub mains, laterals and emitters. The main line delivers water to the submains and the submains to the laterals. The set up was tested to determine the uniformity of water emission from the drip emitters into the field, maize, pepper, tomatos was used as the test crops and there was uniform growth observed across the entire field. The low cost drip system developed in this study showed a high level of efficiency and uniformity of water emission across the entire study area.

I. Background of the Study

Agriculture accounts for about 70 – 80% use of available water in the world (Duhrkoop*et al.*, 2009). However, dwindling water availability has made it necessary to improve on the way water is used in Agriculture. In other to make water available to farmers throughout the season to ensure food security (Keller and Bliesner, 1990). The increased competition for water among agricultural, industrial and domestic consumers creates the need for continuous improvements in techniques for judicious use of water in crop production. Efficient water use is becoming increasingly important and alternative water application methods such as drip and sprinkler irrigation may contribute substantially in making the best use of the scarce available water for crop production (Keller and Bliesner, 1990, Ewemoje*et al.,* 2006).

Irrigation is the artificial application of water to the soil or plant, in the required quantity and at the time needed, is a risk management tool for agricultural production. The risk of yield reduction due to drought is minimized with irrigation. Irrigation is widely carried out through surface, sub-surface and pressurized systems, characterized by the mode of transport of the water onto the point of application (Keller and Bliesner, 1990). When water is applied on the surface, a considerable amount is lost through evaporation, run off and deep percolation making it less efficient.

Field application efficiency in most traditional irrigation methods is still very low, typically less than 50 % (sprinkler irrigation) and often as low as 30 % (surface irrigation). Excessive application of water generally entails losses 2 because of surface run-off from the field and deep percolation below the root zone within the field. Both run-off and deep percolation losses are difficult to control under furrow irrigation system, where a large volume of water is applied at a single instance. An alternative water application method such as the drip irrigation method allow for much more uniform distribution as well as more precise control of the amount of water applied and also decreases nutrient leaching. Drip irrigation is defined as "the slow, frequent application of small volumes of irrigation water to the base or root zone of plants" (Smeal, 2007). More widespread adoption of this technology in recent years began in the late 1960s to early 1970s. Advantages of drip irrigation system include: less water loss, reduction in weed growth, less labour requirements, minimal evaporation compared to other watering methods, less usage of fertilizer, reduced soil erosion, equitable water distribution and higher crop production (Coelho and Or, 1999; Assouline, 2002; Wang *et al.* 2006).

Rainfall is the single most important factor affecting crop production (Rukuni and Carl 2004). The smallholder farming sector have been experiencing decreasing crop yield due to; the erratic rainfall patterns, non-uniform water requirement in all the growth stages, sensitivity of crops to water stress, competing use of water among different sectors due to climate change (Howell, 1980).

To address all these issues there is the need to develop an irrigation (drip irrigation) system that meets the water use and uniform water requirement of crops especially vegetables, to improve yield and production. Based on the problem above, this project is significant in the following ways: it will bring about maximum use of available water and no water being available to weeds,

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maximum crop yield, high efficiency in the use of fertilizers, less weed growth and restrictions of the population of potential hosts, low labour and relatively low operation cost, no soil erosion, improved infiltration in soil of low intake, readily adjustable to sophisticated automatic control, no runoff of fertilizers into ground water, less evaporation losses of water as compared to surface irrigation, improvement of seed germination and decreased to tillage operations. The objective of this study is to develop a low cost gravity drip irrigation system for selected crops (Coelho and Or 1999; Assouline, 2002; Wang *et al.* 2006).

Africa's regions with extensive periods of drought and inadequate rainfall contribute to the continent"s food shortage problem. While nature cannot be controlled, society does have the ability to develop and practice more efficient water usage techniques in order to improve water supply management. One type of technology that may contribute to the improvement of water supply management and the associated food crisis is drip irrigation. Drip irrigation systems (DIS) have discharge points or sufficiently small holes in sections of hose such that filtration is a primary concern (Benami *et al.,* 1984). These systems commonly use low flow rates and low pressures at the emitters and are typically designed to only wet the root zone and maintain this zone at or near an optimum moisture level. Hence, there is a potential to conserve water losses by not irrigating the whole field. Obvious advantages of drip irrigation include a smaller wetted surface area, minimal evaporation and weed growth, and potentially improved water application uniformity within the crop root zone by better control over the location and volume of water application (Benami*et al.,* 1984). Drip systems are also commonly designed to include fertigation and automation capabilities. In recent years, low-pressure drip irrigation (LPDI) systems have been developed for smaller farming areas. For many subsistence farmers, a standard pressurized system is too expensive and complicated, as pressurized systems are intended for large areas of land, and therefore do not match the needs of small subsistence farming (Phocaides, 2007, Ascough and Kiker, 2002).

Drip systems are commonly categorized according to either their physical structure or their placement in the field (e.g. surface, subsurface or suspended). The physical structures may be either: Flexible thin-walled drip (or trickle) tape made of polyethylene where the emitter is formed in the join, or the emitter is joined to the inside of the tape or drip (or trickle) tube where the structure is a thicker walled polyethylene pipe into which the separately formed emitter is inserted, welded, glued within, or attached externally to the hose. A major benefit of drip is the ability to apply small amounts of water at high frequency intervals. This provides the opportunity to maintain the soil moisture at a specified moisture content and changes the focus of irrigation scheduling away from "irrigating at a frequency which does not affect output quantity/quality" to "irrigating on a schedule which maximizes output quality/quantity". This change in emphasis may produce benefits depending on the specific crop response to moisture stress. However, where the crop is relatively insensitive to moisture stress and when the available moisture content is high the benefits of more frequent irrigation are likely to be minor if present at all. Hence, many researchers (Hanson and Patterson, 1974; Wendt *et al*., 1977; Bucks *et al*., 1981) have found that drip irrigation does not increase yield compared to other application systems where both the volume and timing of the water applied for evapotranspiration is non-limiting. Drip systems provide not only the potential to irrigate more frequently but also the ability to more readily maintain specific moisture deficits at a level below field capacity either for part or all of the irrigation season. Irrigating to maintain a specified root zone soil moisture deficit provides the opportunity for increased soil moisture storage from rainfall during the irrigation season (Bustan and Pasternak, 2008).

The potential water application efficiency of drip irrigation systems is often quoted as greater than 90% (Keller and Karmeli, 1975; Jensen, 1983). However, as with all irrigation systems, the ability to achieve high levels of efficiency is a function of the design, installation and management practices. Losses of water in drip irrigation systems principally occur through evaporation from the soil surface, surface run-off and deep drainage. Evaporation losses are generally small in subsurface irrigated systems due to a limited wetted surface area. Run-off losses are also normally small due to the low application rates. However, excessive watering periods and the use of shallow subsurface drip on low infiltration soils (e.g. sodic soils) can result in appreciable tunneling of flows to the surface creating surface ponding and the potential for localized run-off (Oriola, 2009, Polak*et al*., 1997).

II. Materials and Methods

a) Design Concept

The concept underlining the design is to develop a drip irrigation system that is cheap to rural farmers using low cost, readily available materials and adopting low technology which will require no special skills and will be adaptable to local environmental conditions in rural areas. The system should also be able to perform the following:

- Apply water to meet peak crop water requirement
- Maintain application and uniformity efficiencies at optimum levels
- Provide an energy and water efficient system to keep initial capital and operating cost as low as possible

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b) Study Selection and Field Preparation

This study was carried out in Auchi Polytechnic, which is located between latitude 7^0 10' and 7^0 20' north of the equator and longitude 6^0 16' and 6^0 36' east of the Greenwich Meridian with an altitude of 207m.

Field preparation was done by clearing the field and preparing seed beds as shown in plate 1-3.Components of drip irrigation system consist essentially of main line, submains, laterals and emitters. The main line delivers water to the submains and the submains to the laterals. The emitters which are attached to the laterals distribute water for irrigation. The mains, submains and laterals are usually made of black polyvinyl Chloride (PVC) tubing. The emitters are also usually made of PVC materials. PVC material is preferred for drip system because it can withstand saline irrigation water and is also not affected by chemical fertilizers (Isrealson, *et al.,* 2002).

In this design the following specifications was used as adapted from Evans, (2011):

Length of ridge (lateral) = 1 m
Width of a ridge = 50 cm = 0.5 m
Area of a ridge =10 x 0.5 = 5 m^2
Depth of a ridge = 0.5 m
Centre to centre of a ridge =1 m
Operating pressure H =10 m
Slope of lateral line =1 %
No. of emitter = 10 = 17 spaced at 30 cm equally along the lateral line 0.6.

The laterals were laid with caution to ensure that there will be a uniform flow and distribution of water from each drip hole. Levelling instruments was used to get a good level of pipe placement on the field in the trenches.

The field preparation was carried out as explained in the headings below:

Site Clearing and Ploughing: Land clearing was carried to rid the land of debris, grasses, shrubs, stumps, stones etc. The land was previously cultivated with cassava, care was taken to do a proper work of uprooting left over stems after harvest. The land was plough to a depth of 30 cm using a tractor mounted mould board plough as shown in plate 1 and 2.

Plate 1: Clearing and stumping operation at the research site

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Plate 2: Primary tillage operation at the site with a tractor mounted disc plough

Plate 3: Prepared field after harrowing (secondary tillage)

III. Installation of Drip Lines and Erection of Water Platform

The water storage tank was positioned on a raised platform high enough to allow the water flow into the field by gravity, this is shown in plate 4 – 7.

Construction of Concrete Platform: The site work began with the erection of a concrete platform (stand) for the 3, 000 litres water tank. Plates 4 – 6 shows the procedures for creating form work, pouring of concrete and installation of tank.

Installation of drip lines: There was a need for a plumber to install the drip lines. The plumber was mobilized with funds to secure the materials needed and to be installed subsequently and this was done in close supervision of the researchers.

Plate 4: Form work prepared for the platform

Plate 5: 3, 000 litres tank placed on the concrete platform

Plate 6: Installation of pipes from the tank to underground laterals

Plate 7: Buried ¾ inch laterals

a) Design procedures

Capacity of drip system

Drip irrigation system is generally not recommended to operate for more than 1.5 - 2.0 hours at a stretch to avoid losses of water through leaching. The equation to estimate Capacity of Drip System is:

$$Q = A \times CU \times \frac{T}{(\eta_a \times t)} \quad (1)$$

where,

Q = Capacity of drip system, lph

A = Total cultivated area, m^2

T = Irrigation interval, days

η_a = Water application efficiency (in fraction)

t = Duration of each irrigation, h

Discharge required per plant (Qp) can simply be estimated by dividing the drip capacity (Q) by the number of plants (n) in the area Qp = Q/n (Evans, 2011) *b) Length of main, submain and lateral lines*

Length of main, submain and lateral lines can be calculated with the help of length, width and total number of equal sized blocks in a field, as follows:

Length of main line = width of block (if number of block i.e. NB = 1, in small fields)

Length of main, submain and lateral lines

- Total length of main line (Lm) = (NB-1) x width of block (if NB>1)
- Length of submain line (Ls) = width of block (Bw)
- No submain if NB = 1
- Total length of submain = Ls X NB
- Length of lateral line (LL)= Length of block (BL)
- Total length of lateral = LL X NB X NR

Where, NR = Number of plant row per block

Number of drippers and laterals

In orchard and vegetables crops (Evans, 2011)

- Drippers are installed close to each plant
- Laterals are placed along each row of plant
- Number of laterals is taken equal to the number of plant rows

Number of laterals and drippers

$$NLS = LS \div S \qquad (2)$$

Where,

NLS = Number of laterals per submain
LS = Length of sub main pipe, m
S = Spacing between two rows of laterals, m

In large fields total number of laterals is estimated by multiplying the laterals per submain and the number of submain used

NL = LM ÷ S If NB =1
NL = NLS x Ns if NB >1

Where,

NL= Total number of laterals
LM = Length of main pipe, m

Numbers of plants per lateral are estimated by dividing the length of lateral pipe by the spacing between two plants(Evans, 2011)

$$NPL = LL \div PS \qquad (3)$$

Where,

NPL =Number of plants per lateral
LL =Length of lateral pipe, m
PS =Spacing between two plants, m

Number of drippers per plant is estimated as follow:

$$QP = Q \div (NL \times NPL) \qquad (4)$$

NDP = QP ÷ q

Where,

QP =Discharge required per Plant, lph
Q = Drip Capacity lph
NL= Total Number of laterals
NPL = Number of Plants per lateral
NDP = Number of Drippers per plant
q = Dripper discharge, lph

Total Number of Dripper required is estimated using the equations

NDL = NDP x NPL
ND = NDL x NL
NP = NPL X NL

Where,

NDL = Number of drippers per lateral
ND = Total number of drippers
NP = Total number of Plants
NL= Total Number of laterals
NPL = Number of Plants per lateral
NDP = Number of Drippers per plant

In close growing field crops

In close growing field crops the whole area needs to be wetted

Drippers are used to act as a line source of water rather than a point source

In case of closely spaced field crops large number of drippers are required

Installation and operation of such a large number of drippers may pose problems

Therefore, emitting pipes or laterals within built drippers placed at 30 to 40 cm along the lateral pipes better suit such a situation(Evans, 2011).

In close growing field crops in close growing crops, the spacing between two drippers, laterals and number of drippers per lateral are estimated by taking into consideration the movement of water front with time in vertical and horizontal direction in the soil

In close growing field crops Spacing between two drippers and laterals in a closely spaced field crop were estimated by using the relationship, allowing 20 % of overlapping of coverage's of two adjacent drippers (James, 1988, Evans, 2011).

$$r = 0.9\left[(3 \times q \times t \times 10^{-3}) \div 2(\theta_f - \theta_i)\right]^{\frac{1}{3}} \qquad (5)$$

Where,

r = Wetted radius, m
θi = Initial moisture content of soil, per cent
θf = Final moisture content of soil, per cent

Emitter spacing is kept equal to twice the wetted radius

SE =2 x r

Where,

r = Wetted radius, m
SE = Emitter spacing, m

Number of emitters per lateral may be estimated by dividing the length of lateral by the emitter spacing

Total number of emitters are then estimated by multiplying the emitters per lateral with number of lateral

$$NEL = \frac{L}{SE} \quad (6)$$

$$QL = NEL \times q \quad (7)$$

$$QS = \frac{Q}{NS} \quad (8)$$

$$NLS = \frac{QS}{QL} \quad (9)$$

$$NL = Q \div QL \text{ if } NB = 1$$

$$NL = NLS \times NS \text{ if } NB > 1$$

Where,

NEL = Number of emitters per lateral
L = Length of Lateral, m
SE = Emitters spacing, m
q = Emitter discharge
Q = Drip Capacity or designed discharge
NLS = Number of Lateral per sub-main
NL = Total numbers of Laterals
QS = sub main discharge, lph
QL = lateral discharge, lph

Number of fittings and accessories

- Common PVC fittings are elbow, reducer, tee, straight connector, end cap and gate valve
- Accessories for laterals includes gate valve, tee, joiner, elbow, end caps and grommet takeoff etc
- All these components are available in 4, 10, 12, 16 and 20 mm sizes
- These takeouts/ starter and rubber grommet are used for taking out laterals lines from submain/ main line

c) Capacity of sub-main, lateral and main pipe

- The capacity of each lateral pipe can be estimated by multiplying the dripper discharge to number of drippers per lateral
- Capacity of sub main pipe can be estimated by multiplying the lateral capacity to number of laterals per submain
- Capacity of main line and control head can be estimated by multiplying the submain discharge to number of sub mains placed on it
- Qm = Qs x Ns
- Diameter of lateral pipe
- Lateral pipe is selected such that the head loss in lateral pipe is limited within 10 per cent of the operating pressure available at the head of the lateral
- Expected head loss in different diameter pipes are estimated and that smallest diameter pipe is selected in which the head losses are within 10 per cent of the operating pressure
- Lateral pipes having 10, 12, 16 and 20 mm internal diameter with wall thickness varying from 1 to 3 mm are used in drip irrigation system.

First a smaller diameter lateral pipe should be selected to reduce the total cost of system and the friction losses are estimated by using Equation

$$h = \frac{\left[789000 \times \left(\frac{Q}{N_1}\right)^{1.75} \times l \times F_d\right]}{d^{4.75}} \quad (10)$$

and then elevation head is added to this. If the variation in total friction losses are found within 10 % of the operating pressure then selected diameter is accepted.

Where,

Q = Capacity of drip system, lps
h = Frictional loss in lateral pipe, m
Fd = Factor for multiple outlet (Based on number of outlets)
d = Diameter of lateral pipe, mm

d) Laying of pipe in the field

The laterals were laid with caution to ensure that there will be a uniform flow and distribution of water from each drip hole. Levelling instruments were used to get a good level of pipe placement on the field in the trenches. As indicated in plate 8.

Plate 8: Installation of the emitting points and the perforated 1 inch pipe

e) Calibration of flow in PVC pipes (tied and untied)

To obtain a uniform flow of water from the laterals with a length of 6m, the pipes were calibrated to determine their uniformity of emission. To calibrate the pipe for uniformity of flow from 5 drip holes of 2mm diameter each per lateral of 6m x 4 = 24m, end cap fixed a tone end, elbow fixed at the other and join ted to a pipe of height 0.6m. This was connected to the main pipe through the elbows to supply water from the storage tank to the main laterals through the dripholes. Collector cans was used to collect water from the drip holes. The collector cans were placed on a leveled surface which was checked with a leveling device (spirit level), to ensure even distribution of water in the drip holes. The water collected from different drip lines at 5, 10, 20 and 30 minutes was measured using a measuring cylinder to check uniformity of water flow from each drip hole. The laterals are designated by numbers while the emitters are designated by letters A – I as shown in Table 1 – 4 and a plot of the uniformity distribution is shown in figure 1.

Table 1: Millilitres of water emitted in 5 minutes

Lateral/Emitter	A	B	C	D	E	F	G	H	I
1	5.0	5.0	6.0	7.0	5.0	6.0	5.0	4.5	4.8
2	4.5	4.5	4.4	4.7	5.1	4.6	4.3	4.4	4.9
3	5.2	5.2	6.2	7.2	5.2	6.2	5.2	4.7	5.0
4	4.7	4.7	4.6	4.9	5.3	4.8	4.5	4.6	5.1
5	5.4	5.4	6.4	7.4	5.4	6.4	5.4	4.9	5.2
Average	5.0	5.0	5.5	6.3	5.2	5.6	4.9	4.6	5.0

Table 2: Millilitres of water emitted in 10 minutes

Lateral/Emitter	A	B	C	D	E	F	G	H	I
1	7.7	7.7	8.7	9.7	7.7	8.7	7.7	7.2	7.5
2	7.9	7.9	7.8	8.1	8.5	8.0	7.7	7.8	8.3
3	8.3	8.3	9.3	10.3	8.3	9.3	8.3	7.8	8.1
4	7.6	7.6	7.5	7.8	8.2	7.7	7.4	7.5	8.0
5	8.6	8.6	9.6	10.6	8.6	9.6	8.6	8.1	8.4
Average	8.0	8.0	8.6	9.3	8.3	8.7	8.0	7.7	8.1

Table 3: Millilitres of water emitted in 20 minutes

Lateral/Emitter	A	B	C	D	E	F	G	H	I
1	15.4	15.4	17.4	19.4	15.4	17.4	15.4	14.4	15.0
2	15.8	15.8	15.6	16.2	17.0	16.0	15.4	15.6	16.6
3	16.7	16.7	18.7	20.7	16.7	18.7	16.7	15.7	16.3
4	15.2	15.2	15.0	15.6	16.4	15.4	14.8	15.0	16.0
5	17.3	17.3	19.3	21.3	17.3	19.3	17.3	16.3	16.9
Average	16.1	16.1	17.2	18.6	16.6	17.4	15.9	15.4	16.2

Table 4: Millilitres of water emitted in 30 minutes

Lateral/Emitter	A	B	C	D	E	F	G	H	I
1	25.0	25.0	30.0	35.0	25.0	30.0	25.0	22.5	24.0
2	22.5	22.5	22.0	23.5	25.5	23.0	21.5	22.0	24.5
3	26.2	26.2	31.2	36.2	26.2	31.2	26.2	23.7	25.2
4	23.6	23.6	23.1	24.6	26.6	24.1	22.6	23.1	25.6
5	27.2	27.2	32.2	37.2	27.2	32.2	27.2	24.7	26.2
Average	24.9	24.9	27.7	31.3	26.1	28.1	24.5	23.2	25.1

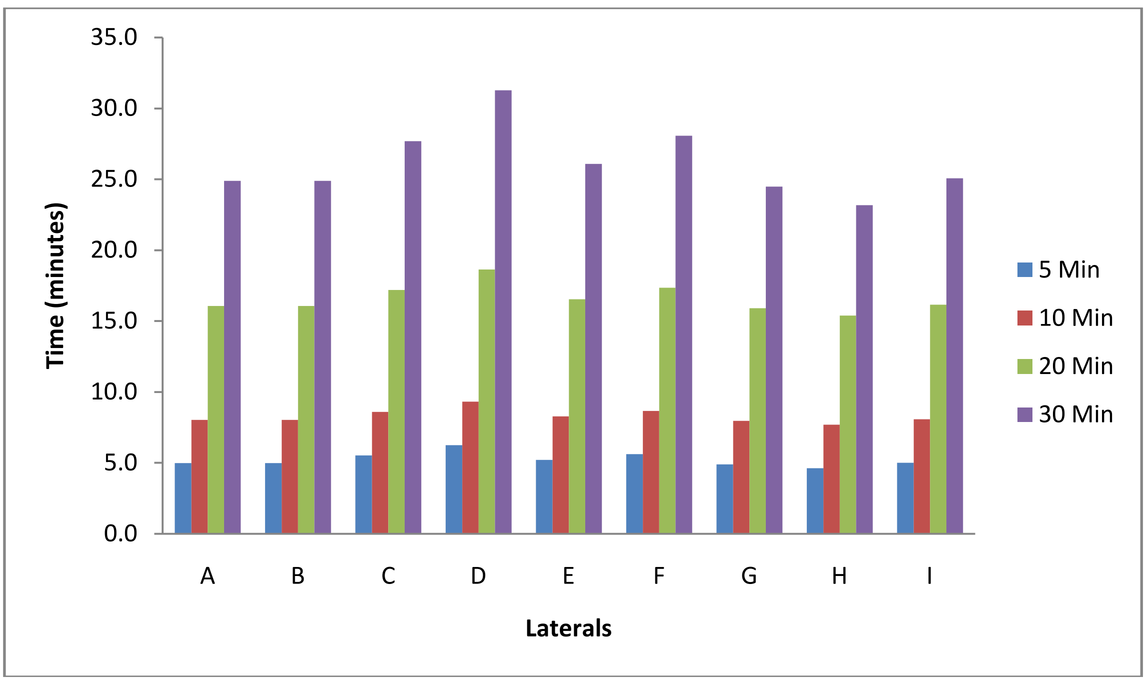

Figure 1: Average values of emitter uniformity

The results above shows a steady increase in the litres of water emitted with time. Unless there is a blockage in any of the emitters during long time operation, they are quite efficient in the uniform distribution of water over the land. Water quality and filtration are probably the most serious concerns when considering drip irrigation. In order to discharge very low flow rates, the diameter of the emitter orifices must be very small. This results in the emitters being blocked very easily by even the smallest contaminants in the water supply. Of particular concern are suspended solids, such as silt and sand, minerals that precipitate out of solution, such as iron or calcium, and algae that may grow in the water. Virtually every drip irrigation system must include a filtration system adequate to prevent plugging of the emitters. A system with poor quality water and poor filtration simply will not function reliably enough to warrant the maintenance requirements needed to keep it in operation. One will think that the emitter close to the main line along the lateral will yield more litres of water but as the water fills the lateral it discharges it at almost equal rate.

The hours of operation needed to meet the irrigation requirement will depend upon the flow rate of the emitting device, the irrigation interval, and the rate of consumptive water use by the crop. In no case should the total system be designed to operate more than 18 hours per day. This allows time for system maintenance, and excess capacity for catch-up in case of breakdowns. Nor should any zone be irrigated for more than 16 hours continuously, to allow some time for aeration of the crop root zone.

This low cost drip irrigation system can be an extremely versatile production tool in horticultural enterprises. It can stretch a limited water supply to cover up to 25 percent more acreage than a typical sprinkler system. It can reduce the incidence of many fungal diseases by reducing humidity in the crop canopy and keeping foliage dry. It allows automation of the irrigation system, reducing labor requirements. It delays the onset of salinity problems when irrigation water of marginal quality must be used.

This low cost system requires careful water treatment to prevent emitter blockage problems. Frequent inspection of the system is necessary to insure it is functioning properly. Improper design and component sizing can result in a system with poor uniformity of application and a much lower than expected application efficiency.

A properly designed and installed drip irrigation system will normally be substantially more expensive than a sprinkler irrigation system initially. However, the lower operating cost and higher efficiency of the drip system can justify the added expense very quickly in many horticultural production systems.

IV. Planting of Crops

The crops planted are Maize, Tomato, Pepper and Melon. The following headings shows the agronomic steps involved in the planting and the planted crops shown in plate 9 and 10.

a) *Amount of water to apply*

Amount of water to apply was calculated based on the various growth stages of the maize variety. Rooting depth (Dr), depletion factor (Df), field capacity (FC)and permanent wilting point (PWP) were considered, resulting in the following equation;

$$Amount\ of\ water\ to\ irrigate = Df \times (FC - PWP) \times Dr \times Wetteddiameter \quad (11)$$

Df was considered to be 50% and Dr based on the maize and the other crops planted, the rooting depth at each growth stage of the plant. Wetted diameter of the calibrated pipe was17cm.

b) *Calculation of Irrigation Requirements (The oritical/Ideal Flow)*

Depth of water applied (d)

Cylindrical volume of soil

Volume of water applied(V)=Wetted area (A)×Depth of water(d)

$$V = A \times d \quad (12)$$

Wet ted area was given as

$$A = \pi d^2/4$$

A=3.1428× (34^2/4)

A=908.038cm^2= (9080.38mm^2)

Volume of water applied considering the capacity of the storage tank which is 25 liters. Taking the number of drip holes on the lateral (16 drip holes); each drip hole is expected to release an amount of 1.56 liters, assuming a perfectly uniform application.

c) *Depth of irrigation water applying for 20.466 litres*

(25 litre container was used for the calibration but because the tap was fixed closed to the bottom of the container some of the water was left at the bottom by letting 20.466 litres be collected through the catching cans and this applies to all liters used for the calibrations throughout the calibration of the pipe for 30L, 35L, 45L and 50L respectively).

Volume of water applied (V)=20.466liters/16dripholes

V=1.28liters ×1000cm^3

V=1280cm^3 (per drip hole) Therefore depth(d) of water applied=V/A

d=1280cm^3/908.038cm^2

d=1.4cm= (14mm)

Depth of irrigation water applyingfor24.614litres

Volume of water applied(V)=24.614liters/16dripholes

V=1.54liters ×1000cm^3

V=1540cm^3 (per drip hole) Therefore depth (d) of water applied=V/A

d=1540cm^3/908.038cm^2

d=1.7cm= (17mm)

Depth of irrigation water applyingfor28.650litres

Volume of water applied (V)=28.650liters/16dripholes

V=1.8liters ×1000cm^3

V=1800cm^3(per drip hole) Therefore depth(d) of water applied=V/A

d=1800cm^3/908.038cm^2

d=2.00cm= (20mm)

Depth of irrigation water applyingfor36.851litres

Volume of water applied (V)=36.851liters/16dripholes

V=2.3liters ×1000cm^3

V=2300cm^3 (per drip hole) Therefore depth (d) of water applied=V/A

$$d = 2300cm^3/908.038cm^2$$

$$d = 2.3cm = (23mm)$$

Depth of irrigation water applyingfor40.982litres Volume of water applied(V)=40.982liters/16dripholes

$$V = 2.56liters \times 1000cm^3$$

$V = 2560cm^3$ (per drip hole) Therefore depth(d) of water applied=V/A

$$d = 2560cm^3/908.038cm^2$$

$$d = 2.9cm = (29mm)$$

Plate 9: Planted Maize crop

Plate 10: Cross session of the entire field

V. Discussion of the Results

The results above shows a steady increase in the litres of water emitted with time. Unless there is a blockage in any of the emitters during long time operation, they are quite efficient in the uniform distribution of water over the land. Water quality and filtration are probably the most serious concerns when considering drip irrigation. In order to discharge very low flow rates, the diameter of the emitter orifices must be very small. This results in the emitters being blocked very easily by even the smallest contaminants in the water supply. Of particular concern are suspended solids, such as silt and sand, minerals that precipitate out of solution, such as iron or calcium, and algae that may grow in the water. Virtually every drip irrigation system must include a filtration system adequate to prevent plugging of the emitters. A system with poor quality water and poor filtration simply will not function reliably enough to warrant the maintenance requirements needed to keep it in operation.

One will think that the emitter close to the main line along the lateral will yield more litres of water but as the water fills the lateral it discharges it at almost equal rate.

The hours of operation needed to meet the irrigation requirement will depend upon the flow rate of the emitting device, the irrigation interval, and the rate of consumptive water use by the crop. In no case should the total system be designed to operate more than 18 hours per day. This allows time for system maintenance, and excess capacity for catch-up in case of breakdowns. Nor should any zone be irrigated for more than 16 hours continuously, to allow some time for aeration of the crop root zone.

This low cost drip irrigation system can be an extremely versatile production tool in horticultural enterprises. It can stretch a limited water supply to cover up to 25 percent more acreage than a typical sprinkler system. It can reduce the incidence of many fungal diseases by reducing humidity in the crop canopy and keeping foliage dry. It allows automation of the irrigation system, reducing labor requirements. It delays the onset of salinity problems when irrigation water of marginal quality must be used.

This low cost system requires careful water treatment to prevent emitter blockage problems. Frequent inspection of the system is necessary to insure it is functioning properly. Improper design and component sizing can result in a system with poor uniformity of application and a much lower than expected application efficiency.

A properly designed and installed drip irrigation system will normally be substantially more expensive than a sprinkler irrigation system initially. However, the lower operating cost and higher efficiency of the drip system can justify the added expense very quickly in many horticultural production systems.

Conclusion

Drip or trickle irrigation refers to the frequent application of small quantities of water at low flow rates and pressures. Rather than irrigating the entire field surface, as with sprinklers, drip irrigation is capable of delivering water precisely at the plant where nearly all of the water can be used for plant growth. Because very little water spreads to the soil between the crop rows, little water is wasted in supporting surface evaporation or weed growth.

The low cost drip system developed in this study showed a high level of uniformity of water emission across the entire study area.

- The study should be repeated in the dry season when soil moisture content can be effectively monitored.
- Further studies should focus on the design performance criteria.
- There is the need to determine the long-term effects of the depth of pipe placement and depth of water application on maize growth and yield.
- Economic analysis should be under taken to determine cost and benefits of the effects of depth of pipe placement and depth of water application on maize performance.

Conflict of Interests

The authors have not declared any conflict of interests.

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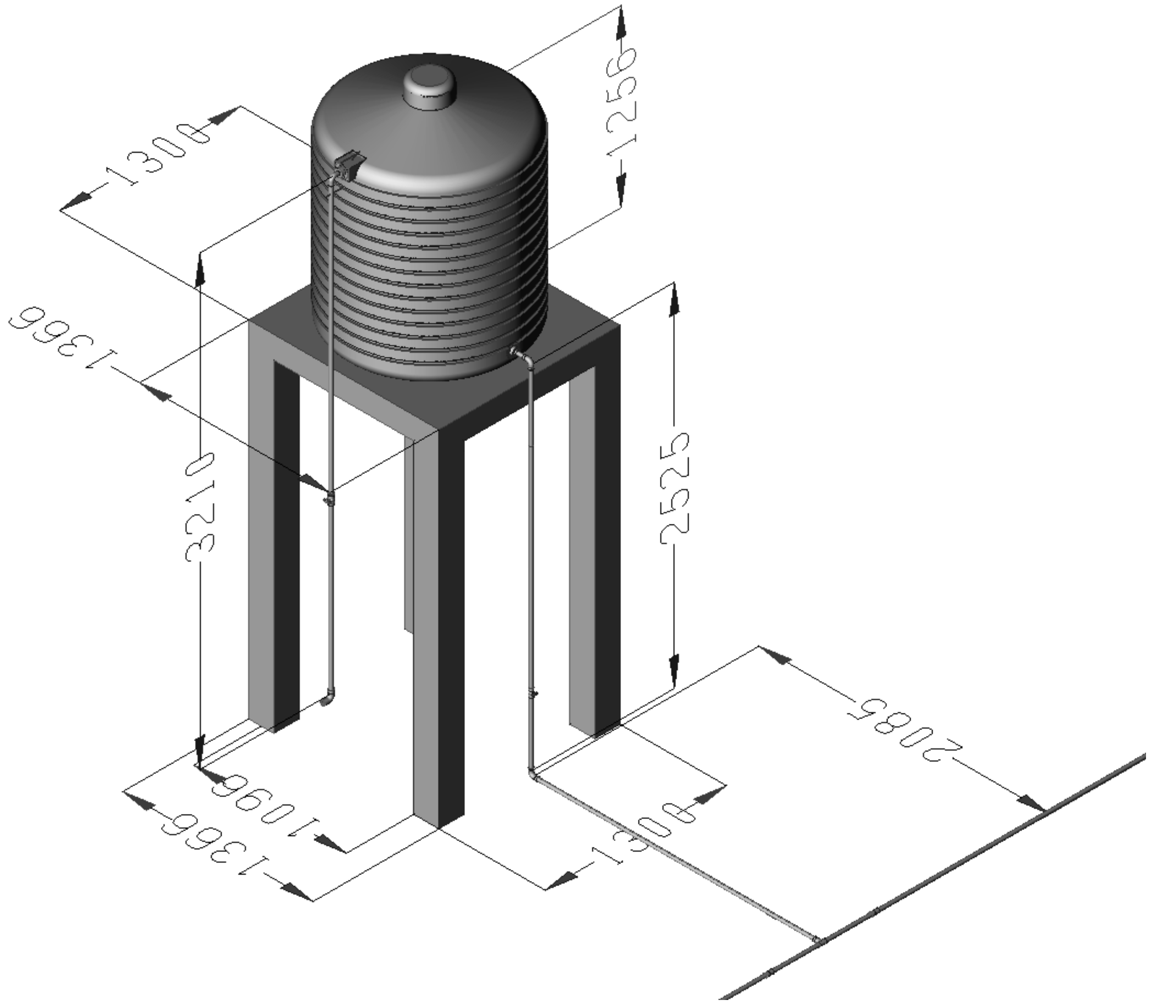
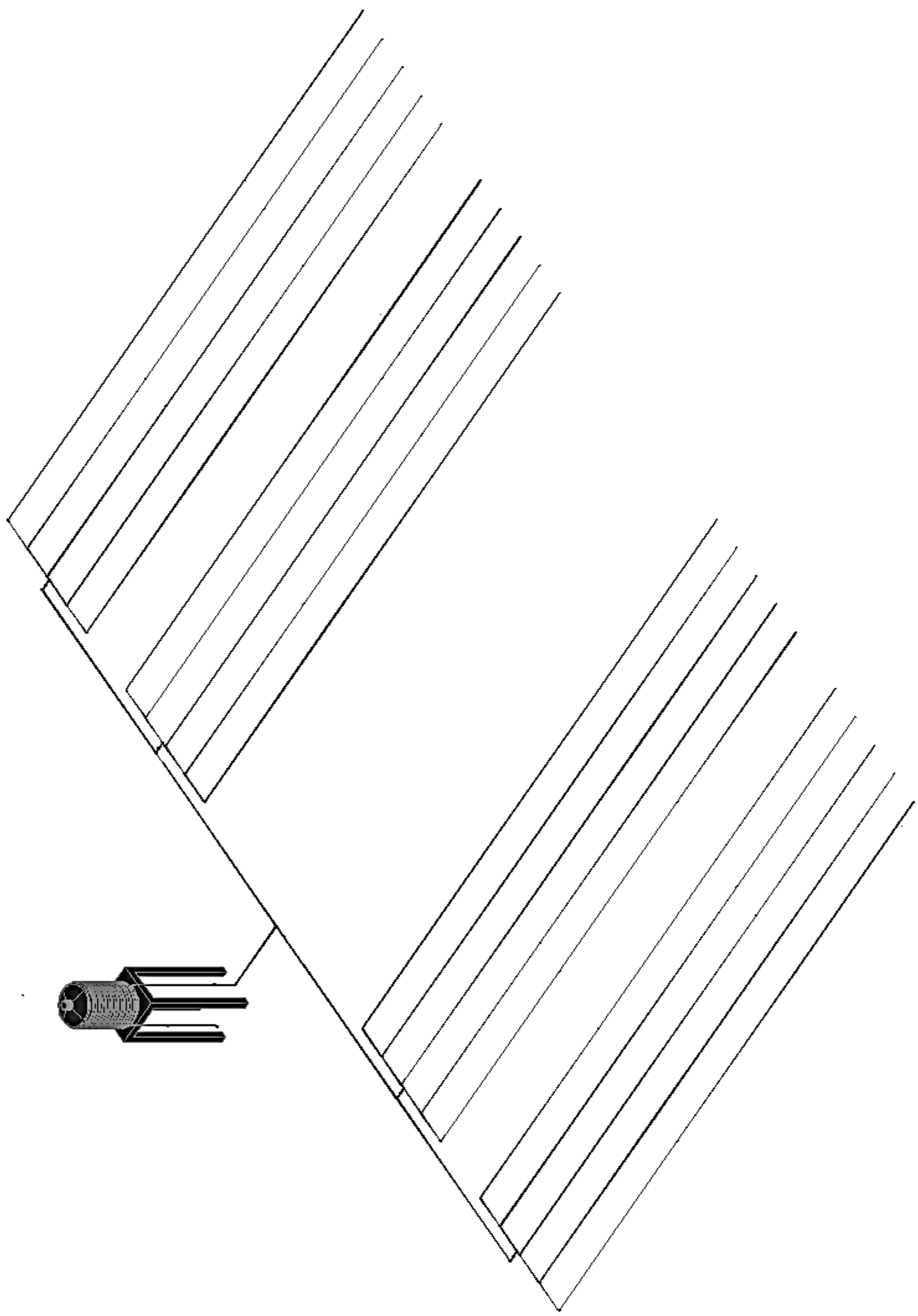
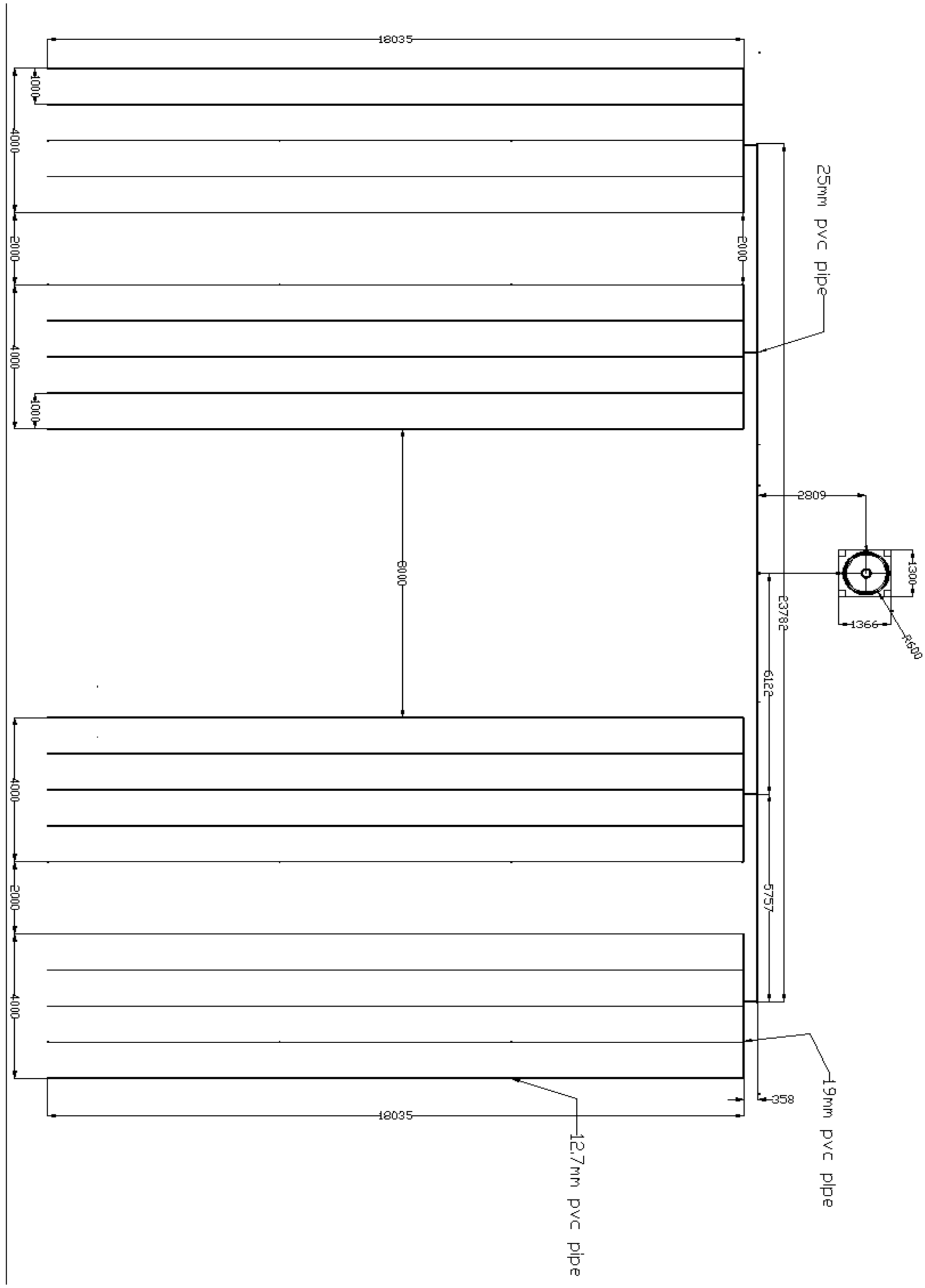
Appendix







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