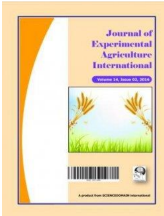

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Development of a Low-cost Drip Irrigation System

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The localized irrigation is the artificial application of water to the root zone of plants for the purpose of supplying the essential moisture requirement for plant growth. The system makes the production and availability of food crops, citrus and vegetables possible throughout the year on small and medium scale basis at an affordable cost. In places and periods of water scarcity, low-cost drip irrigation can be used for the economic growing of vegetables, citrus and food crops all –round the year. This paper aimed at developing a low-cost drip irrigation system to empower the small and medium scale farmers to produce crops during offseason at minimum operational cost with less human efforts. The field area of 126.4 m^2 was properly cleared, stumped, ploughed, harrowed and leveled. The leveling was carried out to allow unobstructed flow and evenly distribution of water to the root of plants. The system does not only reduce water loss but also conserve water during the period of scarcity. The controlled moisture available to the plant at low soil tension results in faster growth, higher yields, better quality and more environmentally and health friendly. The system improves the penetration of water into problematic soils and reduces substantially deep percolation and runoff losses. The system also saves water, money, time and makes provision for all- season farming. The topography of the field was flat with its suitable soil texture, texture, retention capacity and pump for this work was designed and selected to be 1 hp. The system was developed using a simple principle of water flow through gravity to drip out water at regulated interval to irrigate farmland. The drum has 214 litres capacity and 121 emitters. The total cost of production was estimated to be ₦50, 790 which is affordable by small and medium scale farmers.

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Keywords: Development; low cost; drip; irrigation; system.

1. INTRODUCTION

Drip irrigation is the artificial application of water to the root zone of plants most especially during the dry season to supplement insufficient soil moisture in order to quicken crop emergence, accelerate growth and development as well as enhancing crop yield [1]. Drip irrigation is necessary to provide enough water to fill the deficit arising from the depletion of soil moisture from the combined action of the two separate phenomena of evaporation and transpiration [2]. Irrigation is an age-old practice and in fact as old as man attempt at crop growing. The beginning of agricultural revolutionized the way of living of primitive man who was still then dependent only on hunting and food gathering, agriculture heralded the era of development of human civilization [3]. Early agriculture involves mainly food production change slowly to modern agriculture through a continuous evolution of agricultural technologies. This transformation gave a strong structural and economic base to the human and society for its existence and progress [4].

Human civilization grew up new natural resources and there are many records of the practice of irrigation from the river and from man-made canal tanks wells. Climate, soil and water are three basic natural resources that decide the nature, scope and extent of successful crop growing [5]. Climate decides the availability of water and the type of crop to be grown in a region while soil serves as a house of water and nutrient for plant [6]. Water vital for any life processes and there can be no substitute for it. There is the massive demand of water for industries, sanitation and recreational activities, domestic purposes which largely affect the availability of water for agricultural inadequacies of rainfall in most places, make agricultural water scarce [7]. In the united states the total amount of water that is used each year is utilized for the purpose of irrigation, water that is brought to farm, from a source of surface water such as lake or reservoir is usually done through a serve of canal, when the sources is ground water from a well the water is pump to the surface and transported to the farm via network of pipes, in both cases there are several ways that water can be lost in the process of irrigation and including evaporation, leakage and transpiration which is the loss of water that has been absorbed by nearly plant and weeds [8].

The effectiveness of rainfall, even in high rainfall areas is gain by his erratic occurrences and uneven distribution. Drought alternating with the flood in one or the other regions causes immense damage to crops production process. The main concern of productive agriculture is the effect and efficient supply of water and growing demand of crop production including remunerative cropping in modern time needs a systematic study of irrigation problem and method of efficient economic use of water since irrigation potential created and utilization that makes the situation more serious, on the other hand, when it is limited as compound to available water, the aim would be to minimize production per unit of land without water [9].

2. MATERIALS AND METHODS

The project was carried out at the demonstration plot of the Department of Agricultural and Bio-Environmental Engineering, The Federal Polytechnic, Ado- Ekiti. The topography of the soil was flat and the area was chosen for its suitable soil structure, texture, water retention capacity, loamy fertile soil, nearness to the water source (well) and availability of power supply to operate the electric water pump. The field area of 15.8 m x 8 m was earmarked, stumped, ploughed, harrowed and leveled. The leveling was carried out to allow unobstructed flow and evenly distribution of water to the root of plants.

The low-cost drip irrigation was developed to apply the correct quantity of water slowly and evenly to the root zone of plants to keep the level of moisture in the soil within the optimum range for healthy growth and minimum stress. The water pump was used to fill the storage tank with water. The valves connected to the drum were opened and water in the storage tank flow under gravity through the outlet into the mainline. The mainline received water from the storage tank and completely moved to the laterals. The water dripped out from the emitters on the laterals moved slowly and evenly to the root zone of the plant. Seven beakers were arranged at the nozzle of each emitter and the water collected was measured and the time of collection was recorded to determine the discharge from the emitter. To prevent the emitter from getting blocked, a piece of string threaded through the holes and knotted at each end, pulling the string back and forth on block and holes.

2.1 Description of Components

Storage tank: The tank was made of PVC. The capacity of the tank is 214 litres. PVC butterfly valves were fitted into the outlet to regulate the flow of water into the mainline from the tank.

Mainline: The mainline was made of PVC pipes. The main line is the pipe connecting the storage drum to the sub-main. The length is estimated to be 1.1 m. The main line received water from the storage drum and supplied to the sub-main.It has 25 mm diameter and has a six PVC T- joint attached to it, to which the dripper lines were well fitted.

Sub-main line: This is the pipe connecting the main line to the laterals. The length is estimated to be 6.8 m. The size of the pipe used is 19.05 mm. The pipe received water from the mainline and supplied to the laterals. The sub-main line carried eleven (11) laterals.

Laterals or Dripper lines: The dripper was connected to the mainline with 25 mm T-junction. Laterals were laid in the direction of the contours in order to improve the uniformity of water application. The length of each lateral is estimated to be 6.6 m. The spacing between the emitter is 0.6 m and the spacing between two laterals is 0.6 m. The total number of lateral is eleven (11) and each lateral carried eleven (11) emitters.The end plugs were used to block the pipes to prevent loss of water at the tail end.

Filter: This was installed for extensive filtering and also to remove sand, dirt and organic matter from surface water to prevent clogging of the emitters.

Emitters: Water was applied slowly and evenly to the root zone of plants through emitters. Eleven emitters were designed for each lateral. There were 121 emitters in all from where water drips out to irrigate the vegetable garden.

2.2 Description of Low-Cost Drip Irrigation

This is a simple and low-cost drip irrigation was designed for students' demonstration and dry season vegetable farming. The system has 214 litres volume of water storage tank with inlet and outlet at the base and top. The main line from the water source was connected to the inlet while the main line that distributes water to the sub-main line was connected to the outlet of the tank. Water was distributed to the laterals via the sub-main line. The laterals are linked to the sub-main line on which there are emitters. The water in the tank falls under gravity and applied directly to the root zone of plants.

2.3 Determination of number of emitter

Number of emitter per plant= = $\frac{\text{Area per plant} \times \text{Pw}}{Aw}$

Where:

Pw= percentage wetted area (%)
Aw= area wetted by one emitter (m^2)
Aw=$\frac{\pi d^2}{4}$

Where:

π=3.142

d= wetted diameter (m)

$$Aw = \frac{\pi d^2}{4}$$
$$= \frac{\pi 0.4370^2}{4}$$
$$= \frac{0.600025\ m^2}{4}$$
$$= 0.15m$$

2.4 Determination of Percentage Wetted Area

$$Pw = \frac{100 \times \text{Ns} \times \text{Se} \times \text{W}}{Sp \times Sr}$$

Where:

Ns = Distance between the plants within a row
Np = Number of emitters/plant
W =Wetted width (m)
Sr = Distance between plan rows or row spacing (m)
Sp = Distance between the plants within a row
Se = Distance between the emitters, which is the emitter spacing

Pw = $\frac{100 \times \text{Ns} \times \text{Se} \times \text{W}}{Sp \times Sr}$

Ns = 0.6m, Se = 0.6m, W = 0.6m, Sp =0.6m, Sr = 0.6m.

Se = Sp
Np = $\frac{0.6}{1}$
= 0.6 m.
Pw = $\frac{100 \times 0.6 \times 0.6 \times 0.6}{0.6 \times 0.6}$
= 60 % or 0.6
No of emitter / plant = $\frac{\text{Area per plant} \times \text{pw}}{Aw}$
= $\frac{0.25 \times 0.6}{0.15}$
= 1
: No of emitter/ plant = 1
Total number of emitters =11 × 11=121 emitters

2.5 Determination of Water Required from the Storage Drum

Drum capacity = $\frac{\pi D^2 H}{4}$

D = 0.56
H = 0.87m

Drum capacity = $\frac{3.142 \times 0.56^2 \times 0.87}{4}$
= 0.214m^3 or 214 litres

Water required from the storage tank = 0.214 m^3 or 214 liters

2.6 Determination of Emitter Discharge

Average emitter discharge = $\frac{\text{Water required from storage tank}}{\text{Total number of emitters}}$
= $\frac{0.214\ m^3}{121}$
= 0.00177m^3/30mim
= $\frac{0.00177\ m^3/mins}{30}$
= 0.000059m^3/mins or 0.059 liters/min

Amount of water discharge per minute through each emitter= $5.9 \times 10^{-5} m^3$/mins

2.7 Pump Design an Selection

Suction = 12.6m
Main = 3.4m
Sub main = 87.3 m
Q = $1.4347 \times 10^{-3} m^3$/s

2.8 Hazen William's Formula

$$Hf_s = \{\frac{1.4347 \times 10^{-3} \times 12.6^{0.54}}{(0.283 \times 100)(0.254^{2.58})}\}^{(1.85)}$$
$$= \{\frac{0.005637}{0.0021690}\}^{(1.85)}$$
$$= 5.853 \text{ m}$$

$Hf_m = \{\frac{1.4347 \times 10^{-3} \times 3.4^{0.54}}{(0.283 \times 100)(0.254^{2.58})}\}^{(1.85)}$

$= \{\frac{0.002779}{0.002169}\}^{(1.85)}$

= 1.5817 m

$Hf_s = \{\frac{1.4347 \times 10^{-3} \times 87.3^{0.54}}{(0.283 \times 100)(0.254^{2.58})}\}^{(1.85)}$

$= \{\frac{0.01603}{0.002169}\}^{(1.85)}$

= 40.473 m

Head loses in the fittings.

Socket = 30pcs

$hf_s = \frac{kv^2}{2g} = \frac{2.2 \times 1^2}{2 \times 9.81} \times 30$

= 3.364m

Elbow = 15pcs

$hf_e = \frac{kv^2}{2g} = \frac{2.2 \times 1^2}{2 \times 9.81} \times 15$

= 1.682 m

T- Joint = 3pcs

$hf_t = \frac{kv^2}{2g} = \frac{1.8 \times 1^2}{2 \times 9.81} \times 3$

= 0.2752m

Ball valve = 3pcs

$hf_b = \frac{kv^2}{2g} = \frac{0.2 \times 1^2}{2 \times 9.81} \times 3$

= 0.03058m

Foot valve = 1

$hf_f = \frac{kv^2}{2g} = \frac{1.55 \times 1^2}{2 \times 9.81} \times 1$

= 0.0790m

Union = 2pcs

$hf_u = \frac{kv^2}{2g} = \frac{0.4 \times 1^2}{2 \times 9.81} \times 2$

= 0.04077m

Adaptor = 3pcs

$hf_a = \frac{kv^2}{2g} = \frac{2.2 \times 1^2}{2 \times 9.81} \times 3$

= 0.3364 m

Total head loss $= hf_s + hf_e + hf_t + hf_b + hf_f + hf_u + hf_a + Hf_s + Hf_m + Hf_s$

= 3.3640 + 1.682 + 0.2752 + 0.03058 + 0.07900 + 0.04077 + 0.3364 + 5.833 + 1.5817 + 40.47

= 53.697565m

P = QρgH

= 1.435 × 10^{-3} × 1000 × 9.81 × 53.69765

= 755.921 W

$$P = \frac{745.7}{755.921}$$
$= 0.9861$ hp
$= 1.0$ hp

1.0 h pump selected.

2.9 Irrigation Layout

The purpose of irrigation layout is to transmit information from engineering plans to the irrigation field. This will locate the work and provide such lines and elevations as needed for the development of drip irrigation system. The detail of irrigation layout is shown in Fig. 1.

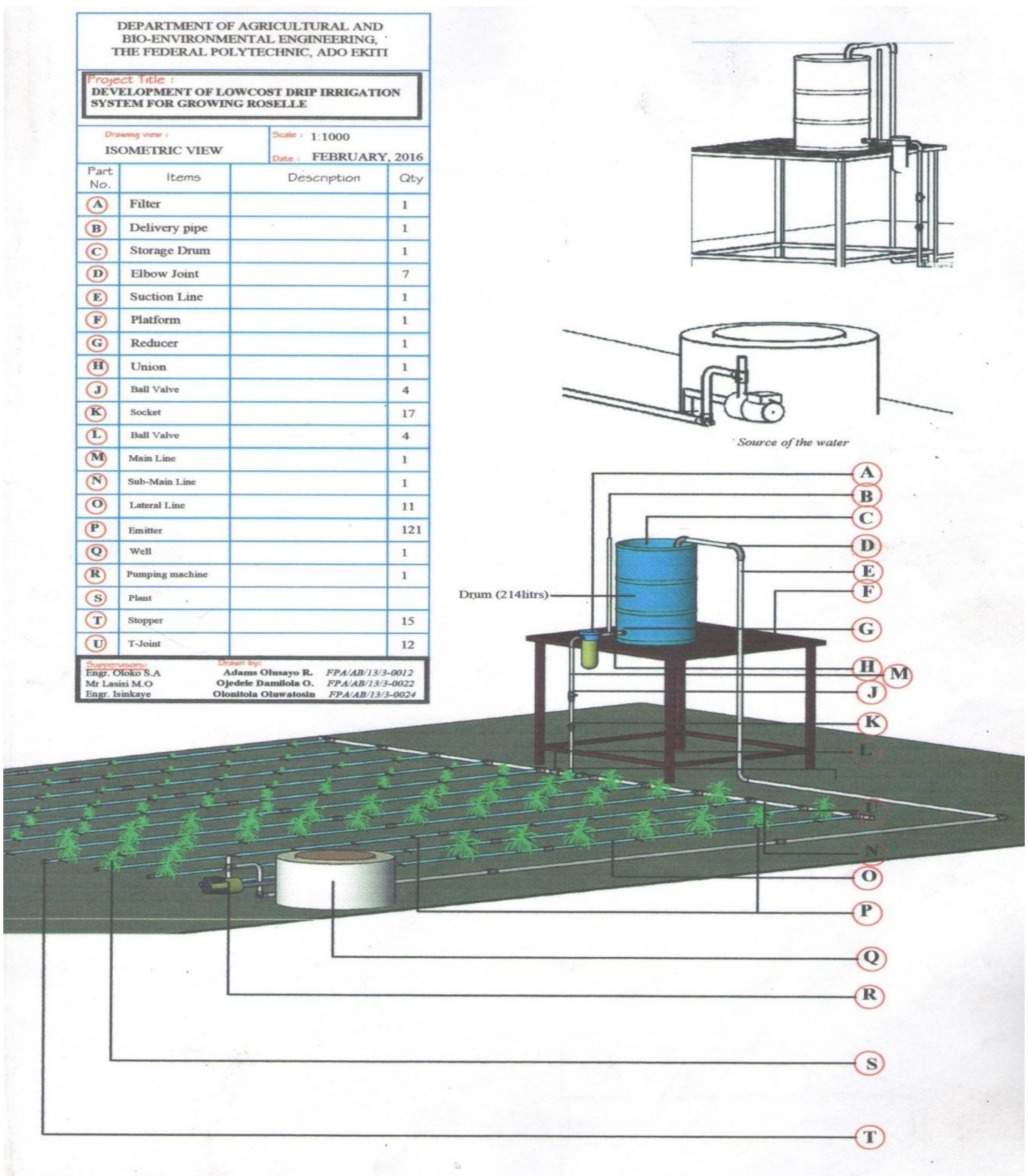

Fig. 1. Irrigation layout

2.10 Installation of Drip Irrigation System

A storage tank was placed on the raised platform that serves as the water reservoir which has a height of 0.87 m and diameter of 0.56 m which has the capacity of 214 litres of water. It was made of metal and was connected to the outlet for the passage of water. The surface water pump was well positioned and installed. The suction pipe was cut into the required length and immersed in the water source (well) and connected to pump through the inlet and another pipe was connected to the pump outlet which delivers water to the field. The stakes were inserted in the ground and extended twine between them to mark the locations for the main and sub-main pipes, ranging poles were inserted in the ground to determine spots for laterals and emitters. Pipes were cut to their required lengths using the pipe cutter and laid in their locations respectively. PVC primer and glue were applied to the inner and outer edges of the pipes and fittings. The soil was backfilled into the trenches to cover the main line. Figs. 2, 3 and 4 show the installation procedure of low-cost drip irrigation system.

3. RESULTS AND DISCUSSION

The drum was filled with clean water and control valve was used to control the flow of water from the drum to the delivery pipes. Water dripped out from the lateral to the emitters to irrigate the land.The field has a total number of 121 emitters at 0.6 m apart. Table 1 shows the results of calibration of emitters at 0.002, 0.0025 and 0.0030 m, respectively. The total average volume of water discharged at 0.002, 0.0025 and 0.0030 m are 0.0000308, 0.0000354 and 0.0000417 m^3 while the emitting rate are 0.00902, 0.01186 and 0.01228 m/hr, respectively. The functional efficiencies of emitters at 0.002, 0.0025 and 0.0030 m are 52.20, 60.00 and 70.68%, respectively. The size of an emitter is significant to the functional efficiency and therefore, the bigger the diameter of the emitter results in the higher in the functional efficiency. The adjustment of the emitter depends on the consumptive use of a particular crop. Fig. 5 reveals that controlled moisture available to the plant results in faster growth, higher yields and better quality.

Fig. 2. Installation of low-cost drip irrigation

Fig. 3. Germinated Roselle plant

Table 1. Calibration of emitters

Lateral line	0.002m	0.0025m	0.0030m
Line 1	0.000032m^3	0.000038 m^3	0.000044 m^3
Line 2	0.000030m^3	0.000036 m^3	0.000043 m^3
Line 3	0.000031 m^3	0.000036 m^3	0.000043 m^3
Line 4	0.000031 m^3	0.000036 m^3	0.000042 m^3
Line 5	0.000032 m^3	0.000035 m^3	0.000042 m^3
Line 6	0.000030 m^3	0.000036 m^3	0.000041 m^3
Line 7	0.000032 m^3	0.000036 m^3	0.000042 m^3
Line 8	0.000031 m^3	0.000035 m^3	0.000041 m^3
Line 9	0.000030 m^3	0.000034 m^3	0.000041 m^3
Line 10	0.000031 m^3	0.000034 m^3	0.000040 m^3
Line 11	0.000029m^3	0.000033m^3	0.000040m^3
Mean	*0.0000308m^3*	*0.0000354m^3*	*0.0000417m^3*

Fig. 4. Matured Roselle plant

Fig. 5. Roselle fruit

4. CONCLUSION

The system makes the production and availability of food crops, citrus and vegetables possible throughout the year at an affordable cost. The system can be used for the economic growing of vegetables, citrus and food crops all - around the year in places and periods of water scarcity. The system does not only reduce water loss but also conserve water during the period of scarcity. The controlled moisture available to the plant at low soil tension results in faster growth, higher yields, better quality and more environmentally and health friendly. The system improves the penetration of water into problematic soils and reduces substantially deep percolation and runoff losses. The system also saves water, money, time and makes provision for all- season farming. Periodic flushing of the lines, strainers and filter should be carried out to prevent clogging and blocking of emitters.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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