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Design and Evaluation of Drip Irrigation System for Date Palm Plantations in MAUTECH, Yola, Adamawa State, Northeastern Nigeria

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ABSTRACT

Irrigation using dripping system is more efficient method for saving the available water and labor. The research is aimed at design and evaluating the drip irrigation system for the Date Palm Plantations in MAUTECH, Yola, Adamawa State, Northeastern Nigeria. The drip irrigation system was designed using locally available materials, installed and tested on an area of 400 m by 100 m dimensions in the research area. The result of the elevation survey using ProMark3 GPS System shows that the elevation across the research area gives a slope of 0.02% which moderately gives water flows by gravity through the pipes to the date palms. The particle size analysis result shows that the sediments on the research area ranges between sand to sandy loam, this type of sediments are suitable for the Date Palms. The result of the infiltration rate was estimated to be 208.27 mm/hr which is moderate for sediment absorption. The discharge of the drip was estimated as 2.265 l/s through the velocity of 1.82 m/s under the pressure head of 8.02 m. The water application uniformity is above 90% this suggests that the drip irrigation system was well designed. The performance evaluation of the drip irrigation system was carried out in the field after design process and the result shows that the emitters are discharging water effectively to the date palm plantations. However, some linkage problems were observed along the lateral pipes and were fixed to avoid water wastages.

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1. Introduction

The date palm is one of the most nourishing natural foods for human consumption and its moisture content ranges between 15 to 30 % [1]. Date palm is a drought resistant fruit and it has a root depth range between 1.5 to 2.5 m which enables easy groundwater abstraction [2,3]. Date palms are usually irrigated by the flood water, where there are abundant water sources, however, this is wasteful of water resources [4]. Using modern method of irrigation such as drip irrigation system will increase water use efficiency. [4] reported that drip irrigation system is one of the most effective ways to convey water directly to the plants which not only save water but also increases crop yield.

Drip irrigation is a micro irrigation method whereby water is applied to the root zone of plants in proportions so that no water is wasted through spillage and evaporation [1]. [5,6] stated that design of drip irrigation systems improves the irrigation application efficiency and economic return in the production process of crops under irrigation. The system uses, pipes, filters, emitters and ancillary device to deliver water to specific sites on the soil surface. Drip irrigation system enables uniform application of water to the plant and has efficiency of over 90% [7,8]. Drip irrigation systems require less energy than other methods of irrigation e.g. sprinkler irrigation system [8,9].

Drip irrigation systems have not been adopted in Yola northeastern Nigeria and hence it is important to introduce these types of irrigation system in order to minimize water wastage. With effective drip irrigation systems in these areas, it would be easy to produce enough dates which are food for the population. This may also provide a platform to educate the people on adopting the same projects in order to increase their food production and income through sales of the surplus dates. Most water is lost as it is conveyed from reservoir to farm land, distributed among farmers and applied to fields. Under this condition word wide irrigation efficiency is estimated to average less than forty percent (40%), which means that the bulk of water directed for agricultural never benefits crops Therefore, the desire for the efficiencies use of water for maximum output especially in Modibbo Adama University of Technology, Yola was the problem of water scarcity is imminent calls for improve water utilization. In this regard a project research which covers the design of drip irrigation system for irrigation of date palms in the research area will play a vital role in water utilization, for the dry season. This is the first time to practice this system of irrigation in this area. The design of drip irrigation systems are dependent on some parameters which include the crop to be irrigated, the type of soil, topography of the area, infiltration rate etc. The aim of the research was to design and evaluate the efficient drip irrigation system for irrigating date palms in Modibbo Adama University of Technology, date palm plantation farm Yola.

2. The study area

The study area (Figure 1) of this research project is Modibbo Adama University of Technology, (MAUTECH) Yola Northeastern Nigerian formerly known as Federal University of Technology, Yola was established in the year 1981, it has continued to grow since its establishment as center for teaching and research. It is located in Girei local government area of Adamawa state Northeastern Nigeria. It has a coordinate of longitude 12º.27’ 57” to 12º .29’ 55”E and latitude 9º 28’ 10” to 9º 29’ 59”N. The dimension of the research area is 400 m x 100 m which covers an area of 40,000 m^2. The temperature in the research area range from a minimum of 26.5°C to a maximum of 32.8 ºC. Rainfall ranges between 1,500 mm and 2,000 mm. August and September is the wettest month. A dry period is seen in January, February, March and December. On average, the coolest month is December and the hottest months are March, April and May (metrological department, school of environmental science MAUTECH, Yola). The main economic activities of the people of Yola Northeastern Nigeria is cattle rearing, business, fishing, and farming activities.

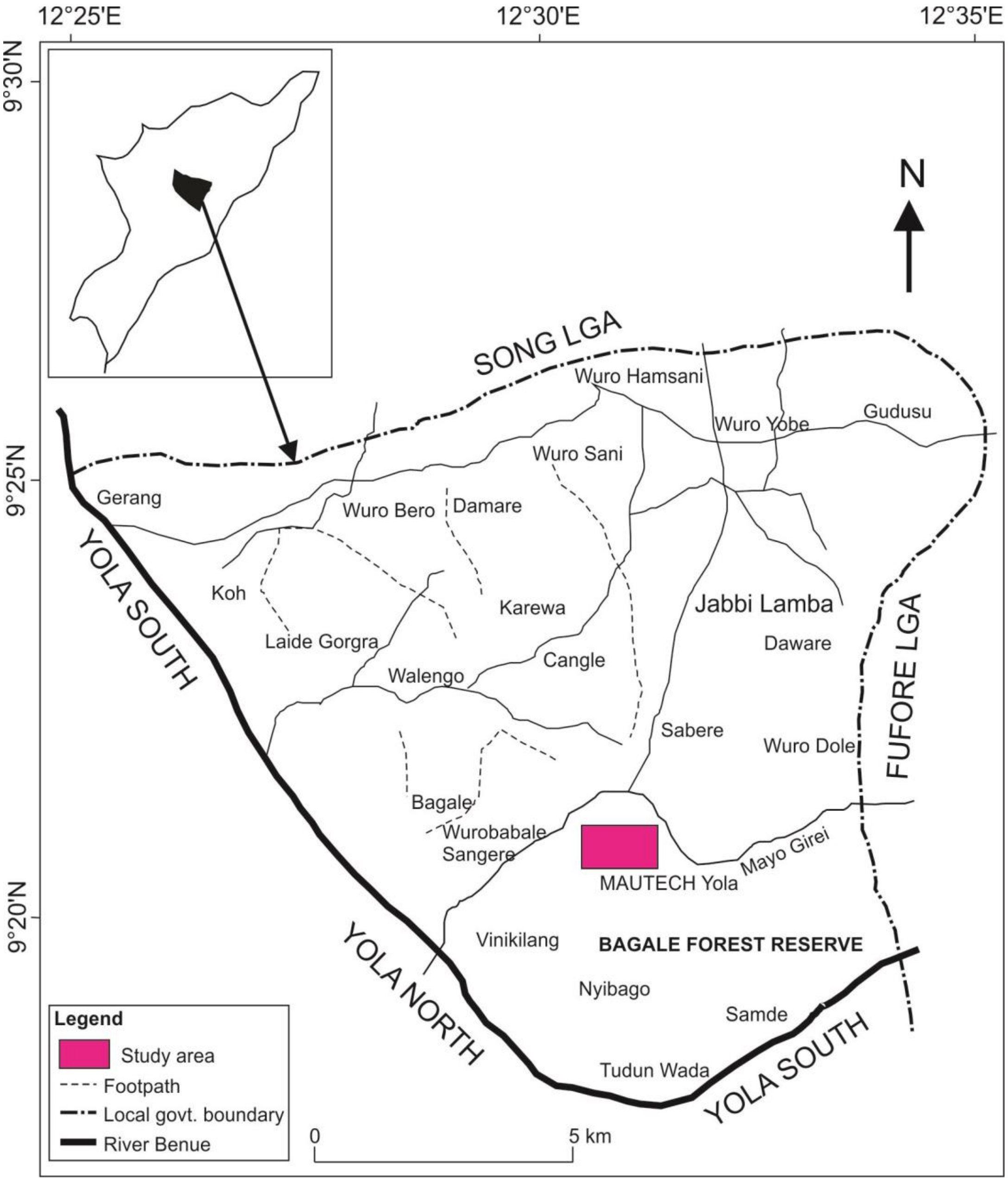

Fig. 1. Map of Girei Local Government Area Showing the Study Area [10].

3. Materials and method

3.1. Design parameters

The basic parameters considered for this design of drip irrigation system include: area to be irrigated, the climatic condition of the area, the type of soil in the research area, topography of the research area, plant spacing and number of plant required, selection of emitter type and emitter per plant, the infiltration capacity (maximum crop water requirement). The design of drip irrigation system consisted of selecting a system of pipes network to transmit water to the drippers at a suitable pressure.

3.2. Preliminary survey

The research area was visited to ascertain the factors that are crucial for the design process such as climatic factors, topography and soil. The climatic data of the research area was obtained from the meteorological station of the Department of geography, Moddobo Adama University of Technology, Yola and other information was acquired from the relevant websites.

3.3. Determining elevation across the floodplain

Elevation is very essential to design the drip irrigation system on the Date Palm farm area. Elevation was determined by using a wide range of survey instruments such as ProMark3 GPS system (Figure 2), which helps to fine the co-ordinate, and slope of the area [11,12]. The ProMArk3 GPS is attached to a cable wire and is connected to a receiver mounted on top of a masta and it continues to download information. A Rover was moved from one point to other by the operator for marking out a point on a surface. A receiver is mounted on top of the rover with cable wire connected to the GPS. The obtained data from the ProMark3 GPS system software was used to produce the topographic map of the study area using Golden Suffer 9 software.

Fig. 2. Determining elevation in the research area using ProMark GPS System.

3.4. Soil sampling in the research area

Ten samples of soil were collected at random in the field of the study area in five different points (A, B, C, D and E). This was achieved by auguring the soil to a depth of 0-15cm and 15-30 cm for every point and the sample was collected into a polyethylene bags for laboratory analysis.

3.5. Particle size distribution analysis

The soil sample was air dried for three days and after that it was been crushed and sieved through 2 mm. The particle sizes of soil that was analyzed include silt, sand and clay and this was achieved by the following procedures: 50g of air dry soil was taken and pass through 2 mm sieve in 500 ml bottle. 50 ml of 5% sodium hexametaphosphate was added. 100 ml of distilled water was also added. The sample bottle was shark at regular intervals for half an hour on shaking machine for preparing homogeneous solution [10,13]. The above soil sample solution was transferred to 1,000 ml glass measuring cylinder and the solution 1,000 ml was made by adding water (Figure 3). The entire solution was taken by the first reading using hydrometer as (H_1) and temperature (T_1) after 40 seconds. The solution was allowed to stay for 2 hours before taking the second reading Hydrometer reading (H_2) and Temperature (T_2). Table 1 shows the Bouyoucos hydrometer and thermometer reading for the soil samples.

Fig. 3. The particle size analysis in the laboratory.

Table 1
Bouyoucos hydrometer and thermometer reading for the soil samples.

SN	Depth (cm)	H1	T1	H2	T2
1	0-15	7	28	3.5	30
2	15-30	8	28	3	30
3	0-15	6	28	2	30
4	15-30	3.5	28	1	30
5	0-15	6	28	2	30
6	15-30	7	28	2	30
7	0-15	9	28	5	30
8	15-30	5	28	1	30
9	0-15	7	28	3	30
10	15-30	9	28	4	30

3.6. Determination of infiltration rate

Infiltration rate was determined in the field using double ring infiltrometer. A set of double ring Infiltrometer was derived into the soil to a depth of 20 cm by hammering with a wood plank placed on it to absorb the shock (Figure 4). Water was poured into the outer cylinder first, to prevent lateral water flow. Then water was also poured into the inner cylinder until it reaches the height of 3 cm to the top of the cylinder. Depth of water infiltrated was taken and recorded after every 5minutes for the first 30 minutes, and then 10 minutes for the next 60 minutes and then 15 minutes was maintained till the infiltration capacity was reached.

Fig. 4. Determining infiltration rate in the research area.

3.7. Design procedures

The important factor to consider in the overhead bucket design is the pressure. Pressure acted equally in the directions, and it was useful on occasion to refer to it as a 'head'. The relationship between head and pressure was easily derived from the certain depth of liquid. Bernoulli's equation might be expressed in heads as follows:

$$H = Z + \frac{V2}{2g} + \frac{P}{W} \quad (1)$$

where H = head (m), V = mean velocity of flow (m/s), Z = elevation at which the pressure is computed above datum, P = pressure = $\rho g\ h$ (N/m^2), g = acceleration due to gravity (m/s^2), ρ = density of water. The loss of head can be attributed to the frictional losses in the pipes (hf). The value of hf was calculated using the Darcy Weisbach equation

$$hf = \frac{4\,flv2}{2gd} \quad (2)$$

where f = frictional coefficient of the pipe, l = length of the pipe (m), v = velocity of flow (m/s), d = diameter of the pipe (mm).

3.8. Wetting patterns and area wetted by an emitter

The pattern was assumed by the water depend on the type of soil. The lateral movement of the irrigation water beneath the surface medium of a heavy textured is more pronounced than in the sandy soils. If the emitter rate exceeds the infiltration rate, ponds of water will form and will lead to a larger wetting volume of irrigation water. Simple field test was carried out in other to establish the area wetted by an emitter.

3.9. Numbers of emitter per plant and emitter spacing

Equation 3 was used to estimate the number of emitters required per plant.

$$\text{Emitter per plant} = \frac{\text{Area per plant x PW}}{\text{AW}} \quad (3)$$

where PW= percentage wetted area, AW = Area wetted by one emitter

The emitter spacing (Se) was estimated using equation 4.

$$\text{Se} = \frac{\text{SP}}{\text{NP}} \quad (4)$$

where Se = the distance between the emitters, SP = Distance between plants within a row, NP = Number of emitters per plant. After estimating Np, Sp and Se, the percentage wetted area (Pw) was checked to verify that it is within the recommended limits.

3.10. Pipe size determination

The pipe size was determined based on the peak irrigation water requirements and the maximum permissible head loss (less than 10%) of various pipe sizes. The commonly used lateral pipe sizes are 12, 16 and 20 mm inside diameter. Diameters of 25, 32 and 40 mm could also be used depending on the size of the irrigated land. For mainlines and sub-mains, PVC pipes of various sizes were used. However, the diameter of the pipes was determined using the equation below.

$$D = \frac{\sqrt{cfQ}}{v} \tag{5}$$

where D = initial estimate of diameter (mm), cf = unit conversion factor = 1274 for Q in Vs, D in mm, V in m/s, Q = peak flow, V = maximum allowable velocity (m/s).

3.11. Determination of crop water and irrigation requirements

The plant water requirement was computed using the formula below.

$$WR = 623 \times A \times Kc \times \frac{PET}{e} \tag{6}$$

where WR = water requirement by the plant, A = area of the plant's canopy, Kc = crop coefficient (plant factor) of the plant, PET = potential evapotranspiration rate (inches/day), e = application efficiency.

4. Results and discussions

Figure 5 shows the elevation and direction of flow on the study area. the area to be irrigated has a land mass of 4 acres ranging from 100 m to 400 m length with the breadth of 100 m. The interval between the contours is 0.4 m with a slope of 0.012 %. The elevation is higher in the eastern part of the research area and lower in the western part. The direction of flow is from the eastern part to the western part.

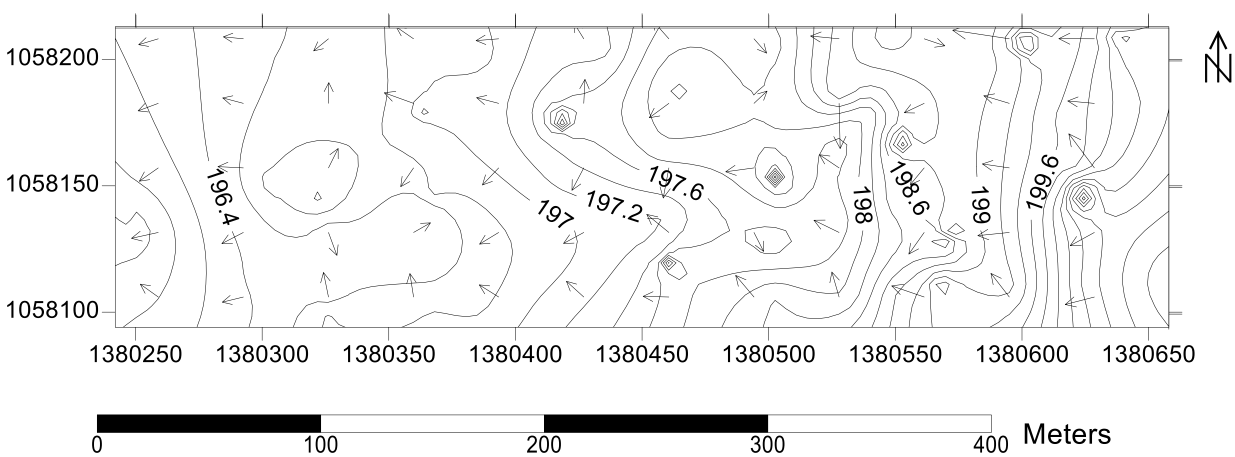

Fig. 5. Elevation and flow direction across the research area.

The particle size distribution (Table 2) in the research area ranges between sand and sandy loam, this type of soil is suitable for the date palm plantations. Sand and sandy loam soils allow free flow of water within the formation for an easy absorption by the plants.

Table 2
Results of particle size distribution analysis for the soil sample.

S/No	Sample	Depth	%Sand	%Silt	%Clay	Textural Class
1	A	0-15	86.80	6.20	7.00	Sandy Loam
2		15-30	84.80	9.20	6.00	Sandy Loam
3	B	0-15	88.80	7.20	4.00	Sand
4		15-30	93.80	4.20	2.00	Sand
5	C	0-15	88.80	7.20	4.00	Sand
6		15-30	86.80	9.20	4.00	Sandy Loam
7	D	0-15	82.80	7.20	10.00	Sandy Loam
8		15-30	90.80	7.20	2.00	Sand
9	E	0-15	86.00	7.20	6.00	Loamy Sand
10		15-30	82.80	9.20	80.00	Loamy Sand

The infiltration rate Figure 6 shows that soils have high intake rates at first but rates fall rapidly with elapsed time after irrigation. Finally intake rate comes to a steady state which is 2.00 mm/hr after approximately 3 hrs. This low rate may suggest that below the 30 cm depth of soil considered, it may contain soil with class other than the Sandy-loam, may be clay or clay-loam.

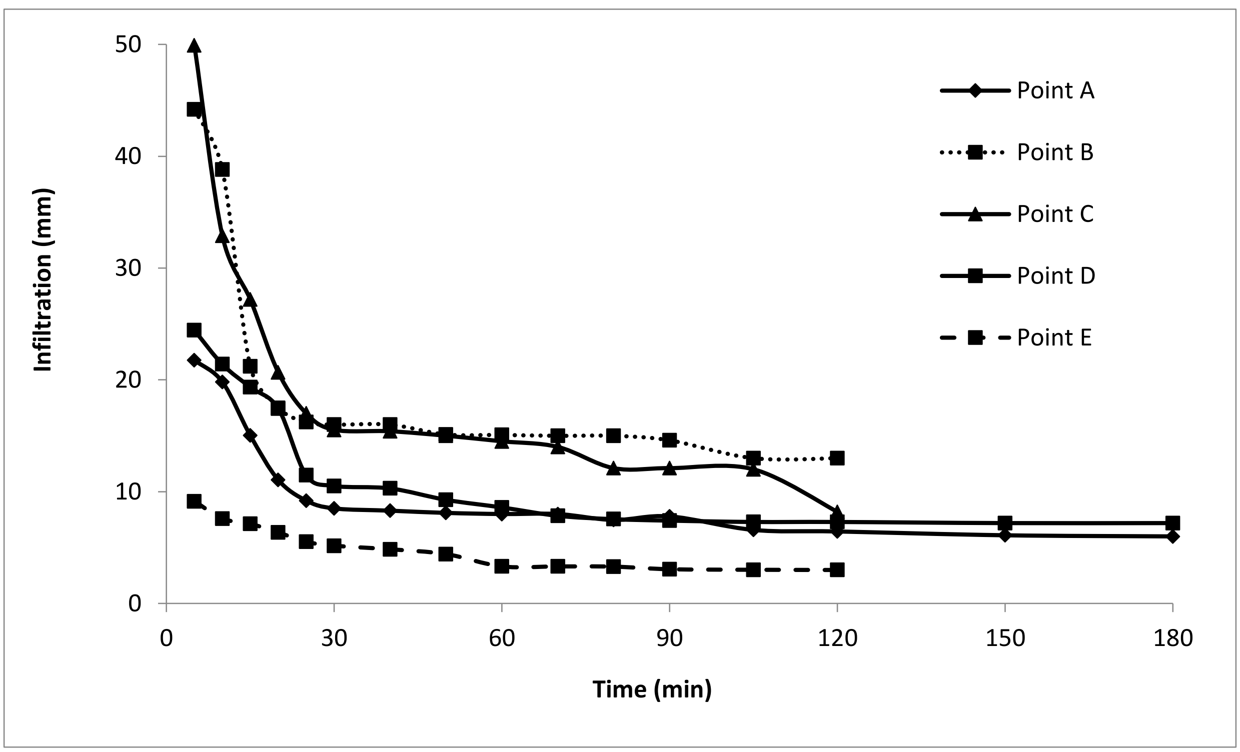

Fig. 6. Infiltration rate at three different locations in the research area.

Reference Crop Evapo-transpiration was estimated by the penman monteith method [14]. This value is dependent on several factors which include: altitude, air temperature, humidity, radiation and the speed of winds speed. Which are obtain from the metrological station of MAUTECH and other are obtained from the relevant web site. The Crop Evapo-transpiration was estimated to be 5.62 mm/day. This is the height in m needed to generate enough pressure to push the water through the emitters at an optimum rate while overcoming the frictional losses in the lines. It is composed of the suction lift, friction losses in the pipelines, emitter operating pressure and other minor losses. The value of the head is given by the Darcy Weisbach equation. The value of f is assumed to be 0.01 and 0.005 for old and new pipes respectively. Assuming a velocity of 1 m/s, pipe diameter of 50 mm, therefore, the frictional head required for irrigating the dates palm was computed as 40.39 m.

The discharge through the pipeline was estimated to be 2.27 l/s. Power require to pump the irrigation water was estimated to be 4.53 KW. The size of the lateral pipe was calculated as 12 mm. Sub main diameter was estimated as 12 m/s, main line diameter as 38 mm. The number of emitters required per plant is worked out (7 x 7 x 0.07)/2 = 1 emitter per plant. The spacing between the plants was computed to be 7 m interval. The design of the drip irrigation system encompasses the consideration of several factors that are vital for the growth and development of crops. The site (location) of the system also matters and the climatic conditions of that area have to be studied and put into consideration as they play a vital role in the determination of the crop irrigation specify and also help in the determination of the irrigation components specifications(size, quantity and quality). The date palm water requirements must also be considered to ensure that they are met. Other factors important in drip irrigation systems like the duration of irrigation (irrigation interval) and how often (irrigation frequency) also need to be considered to ensure that the crop water requirements are met at all times.

4.1. Evaluation

The evaluation of the design was carried out by applying the parameters obtained from the designed values. The field layout (Figure 7) was obtained from the design values of the research work. After installation of the layout in the field water was supplied from the two head tanks through the pipes to test the system. The discharges from the emitters were adequately delivering water to the date palm plantations effectively. However, some linkages were observed at some locations of the lateral pipes and the linkages were fixed appropriately. Table 3 shows the detailed cost implication for designing and installing the system layout in the research area. Figure 8 shows the pipes layout for the drip irrigation system and overhead tank in the research area.

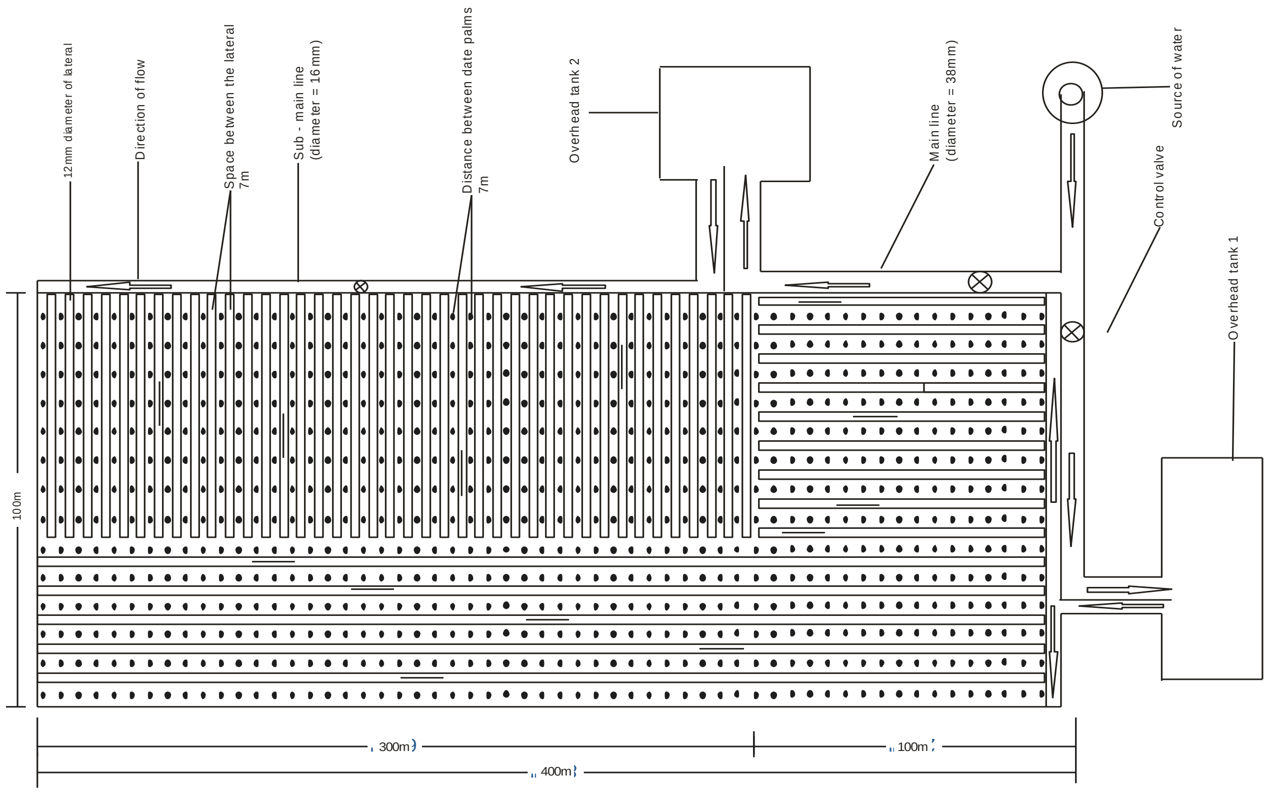

Fig. 7. Drip Irrigation System layout for date palms irrigation in MAUTECH, Yola.

Fig. 8. The pipes layout for the drip irrigation system and overhead tank in the research area.

Table 3
Cost break down for designing and installing the system layout.

Items	Quantity	Unit	Cost (USD $)
PVC pipe 38 mm (main supply pipe)	60	Meter	17.15
PVC sub main pipe 18 mm	14	Meter	3.2
PVC lateral pipe 12 mm	60	Meter	8.57
1¼ by 1 PVC bushing	60	Inch	25.72
1¼ PVC T-joint	60	Inch	42.86
¾ by 1 PVC bushing	100	Inch	17.15
6 m length of pipes 1¼ diameter	70	Inch	220
¾ by ½ PVC bushing	798	Inch	182.29
Pipe of 6 m length ¾ diameter	969	Inch	1,384.29
Control valves of ¾	60	Inch	42.86
6m length of pipes ½ diameter	100	Inch	100
PVC Gum	10	-	80
Over head	2	Meter	1,428.57
Elbow 90º uPVC 38 mm	60		3.43
Elbow 90° PVC 18 mm	14		4
End cap uPVC	57	Inch	8.15
Gate valve 38 mm	8	Inch	16
Union 12 mm	10	Inch	4.29
Union 38 mm	8	Inch	4.57
Transport of materials			285.72
Labour			857.15
Total Cost			**4,735.97**

5. Conclusion

The design and evaluation of date palm plantation was carried out on the MAUTECH, Yola, plain. However, same approach could be applied to other crops in different agricultural fields in same region. The elevation across the floodplain gives a slope of 0.02% which moderately gives water flows by gravity through the pipes to the date palms. The particle size analysis result shows that the sediments on the floodplain include sand to sandy loam, this type of sediment is suitable for the Date Palms. The infiltration rate was estimated to be 208.27 mm/hr, which is moderately enough for the dates. The discharge of the dripper was estimated as 2.265 l/s through the velocity of 1.82 m/s under the pressure head of 8.02 m. The water application uniformity was found to be above 90% which describes that the drip irrigation system was designed on proper scale and dimensions. The performance evaluation of the drip irrigation system was carried out in the field after design process and the result shows that the emitters are discharging water effectively to the date palm plantations. However, some linkage problems were observed along the lateral pipes and were fixed to avoid water wastages.

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