

Assessment of Yam Yield Performance Under Drip Irrigation Using Sack Farming Technology

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ABSTRACT

This research was carried out at the Organic farm of Federal College of Agriculture Moor Plantation Ibadan, Nigeria with the aim of investigating the prospects of yam farming under drip irrigation in that agro-climatic region. The farm site was cleared and made into ten (10) rows of six (6) heaps each, that were formed by filling soil into perforated 50kg cement bags. Three species of yam namely; “Hembankwase”, “Faketsa”, and “Sudan” (a variety of water yam) code named A, B and C respectively were planted each per row, and each treated to irrigation water application at an interval of three days. This was replicated three times with 0.5, 1.0 and 1.5 liters, as the control plot had a mixture of all the three varieties and was treated to 0.5 litre daily water application. The planted yam sets weighing averagely 0.3 kg each were mulched after planting to reduce excessive heat and evaporation, and staked to support the vines after emergence.

At harvest, record of yam yield in terms of number and weight of tubers harvested were taken. These collected data were subjected to statistical analysis of variance and results obtained indicated no significant difference in the yield of the three varieties of yams across the three levels of water application in terms of number of tubers ($F=2.118$, $p>0.05$) and weight of tubers ($F=1.082$, $p>0.05$). In spite of these outcomes, a critical examination of the mean scores of the weight and number of tubers produced by the yams showed that, all the three varieties recorded their optimum performance at the 1.0 litre level of water application; indicating that the best irrigation water application level at the chosen irrigation interval of 3 days was 1.0 litre. This clearly shows that with appropriate level of irrigation application to support rainfall even in the given climatic region, yam performance on the field would be better enhanced. Therefore, drip irrigation with alternative production techniques like the type adopted in this research should be considered as a powerful intervention to support yam production in Nigeria.

Keywords: Drip Irrigation, Yam Yield, Sack Farming, Soil and Water

Introduction

Yam (*Dioscorea rotundata* Poir) is a staple food and major source of calories for about one-third of the world's population. It is a preferred food, and a food security crop in most sub-Saharan Africa countries. In West Africa, it is often pounded into a thick paste after boiling, and eaten with soup, and can also be processed into flour, which is used in the preparation of its paste [1]. Virtually all its products are used as food for humans as the tubers of yam are good energy sources, and the energy is derived mainly from its carbohydrate content since they are low in fats even as some of the species may be considered rich in some

minerals such as calcium, phosphorus and iron [2].

Though, yam thrives well in most parts of the tropical regions of the world, in Nigeria, for limitation of water supply, its cultivation is restricted to the Southern parts of the country with a little extension to the Sudan Savannah vegetation belt, and the rain forest regions of West Africa where it is grown but in the wet season [3]. To expand and sustain yam cultivation and production in Nigeria, irrigation as an aspect of water management along with alternative production methods must be incorporated. This is because water is one of the most important inputs essential for crop production that plants need continuously during their life, and in huge quantities. It profoundly influences photosynthesis, respiration, absorption, translocation and utilization of mineral

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nutrients, and cell division besides some other processes. Abayomi, noted that insufficient moisture in the soil could lead to water stress in plants resulting in stomata closure, and in effect, reduce transpiration thereby increasing canopy temperature [4]. However, both the shortage and excess of water affect the growth and development of yam and consequently, its yield and quality. Therefore, artificial water supply through irrigation and the removal of excess water through drainage on another occasion becomes imperative if yam is to be raised successfully. Water management in yam production thus comprises irrigation or drainage or both, depending considerably on the environmental conditions, soil, and climate. It is a situation orientated entity. In this regard, effective water management strategies such as efficient irrigation systems help to conserve soil moisture, reduce soil erosion, and improve soil structure and fertility, thereby increasing yam yield [5].

Growing yam under irrigation can result in a number of benefits to the farmer as well as his community as this brings about stabilization in farm production, as it protects the farm against drought thus, increasing crop yield and quality when rainfall is insufficient [6]. Drip irrigation therefore is seen as a powerful intervention in this regard, since drip irrigation ensures efficient utilization of water by applying precise amount of water around the root zone of the crop with a high degree of uniformity and frequency. This feature makes it potentially much more efficient than other irrigation methods. In this regard, adopting drip irrigation may help in saving significant amount of water and increase the quality and quantity of produce which is the hall mark of water management in crop production. The use of this micro irrigation technology optimises water use at the crop root zone and also avoid soil nutrient's leaching since it is well known fact that drip irrigation sends an even and deep supply of water directly to the root zone of the plant without waste or run-off. Its major advantages as compared to other methods which includes; higher crop yield, water saving, increase fertilizer use efficiency, reduce energy consumption, reduce labor cost, improve disease and pest control, as well as its suitability in problem soils and improve tolerance to salinity [5]. It is good to note that environmental problems associated with the surface method of irrigation like water logging and salinity are completely absent under drip method of irrigation. This irrigation method significantly reduces weeds by watering deeply instead of on the surface, i.e weed will have less access to water needed for germination.

Also, irrigation scheduling which involves determining when to irrigate, the amount of water to apply at each irrigation event and each growth stage of plant is also a very important tool of water management in crop production [7]. This is because the decision to irrigate should be based upon an estimate of crop and soil water status more so as water is a scarce resource. This measure facilitates timely application of water to crop and can improve water use efficiency and ultimately yield.

In view of this, the study aims to investigate the prospects of yam farming under drip irrigation by determining the most appropriate level of water application that would support the growth and yield potentials of yam in the given agro climatic region.

Sack Farming Technology

As the effect of climate change coupled with the availability of land are beginning to impact crop production in a number of ways especially in urban areas, it has become imperative to adopt innovative ways of farming as against the conventional methods. This challenge has given rise to the adoption of sack farming for a number of crops. This is a method of growing crops in soil filled sacks or polyethylene bags, containers or plastics [8]. It involves filling of bags with soil, manure, and pebbles for drainage, and growing plants on the top and in the sides. The sacks allow people to grow food in places with limited access to arable land and water.

Research has shown that crops like tomatoes, onions, cabbages, pepper, mushrooms, and many other crops such as yam do well in this method. This sack method allows a freer flow of water to the roots and retains moisture more efficiently than traditional methods, meaning sack farmers can keep their plants hydrated with less water. One major advantage of this farming method is its profitability and productivity at low cost. The method can contribute to food security at family level as well as enhance their incomes. Sack bag farming is a very good option for landless households to ensure food and nutrition security. It is also a solution for people who have land with low soil fertility or too rocky to support cultivation of crops [9].

Materials and Methods

Description of the Experimental Site

This field experiment was conducted at the Organic Farm of Federal College of Agriculture, Moor Plantation Ibadan, Oyo State. Ibadan is located on latitude 7°22'36.25"N and longitude 3°56'23.23"E (Lat. Long.net). The city ranges in elevation from 150m in the valley area, to 275m above sea level on the major north-south ridge which crosses the central part of the city and has a tropical wet and dry climate with a lengthy wet season and relatively constant temperatures throughout the year [10]. Wet season runs from March through to October, though August sees somewhat of full in precipitation [11]. The vegetation pattern of Oyo state generally, is that of rain forest in the South, and guinea Savannah in north. Thick forest in the south gives way to grassland interspersed with trees in the north. The soil type is that of deep well drained sand [11].

Determination of Soil Physico-chemical and Mechanical Properties

The surface soil of the project area was subjected to laboratory analysis to determine its mechanical, physical and chemical properties. Top soil structure, soil depth, soil permeability, soil type and water holding capacity were all determined as well as its texture and organic content, organic matter, pH, nitrogen, phosphorus, potassium, sodium, magnesium and calcium. Also, exchangeable base, cation exchange capacity, exchangeable acidity and base saturation were determined.

Water Source and Irrigation Water Quality

The water source for this research was River Ona, which the research plot was situated by its bank. River Ona according to Ijadunola et. al., is suitable for irrigation purpose [12].

Design of Drip System

The following were taken into account in the design of the

gravity drip irrigation system; the yam crop water requirement, and the gross and net depth of water application.

Estimation of Crop Water Requirement of Yam

$ET_{(crop)}$, was determined using Equation 1:

$$ET_{(crop)} = k_c \times ET_0 \text{-----} 1$$

Where, ET_0 = reference evapotranspiration of the area and k_c = Crop factor.

Blaney-Criddle method was used to estimate ET_0 . This method is straight forward and requires only data on mean daily temperatures and extent of day time hours as stated in Equation 2.

The Blaney-Criddle formula according to Audu, et. al. (2015) states that:

$$ET_0 = P(0.46T_{mean} + 8) \text{-----} 2$$

Where; ET_0 = reference crop evapotranspiration (mm/day), T_{mean} = mean daily temperature ($^{\circ}\text{C}$) and p = mean daily percentage of annual daytime hours.

The mean daily temperatures in Ibadan from the month of December to May as obtained from Oladapo and Adesoji were 25.5°C , 26.2°C , 27.3°C , 28.2°C , 28.5°C , 27.7°C , respectively [13]. Also, the approximate P values for Ibadan which lies on latitude 7.22° north of the equator were determined to be 0.27 from the months of December to March and 0.28 from April

to June. With the above information, and using equation 2, the approximate daily ET_0 values for Ibadan in the months of December to May were computed as; 5.33mm, 5.41mm, 5.55mm, 5.66mm, 5.91mm, and 5.81mm respectively.

The k_c values of yams were determined according to the growth stages of the crop [14]. These crop factor values indicate the crop's water requirements relative to reference evapo-transpiration, ET_0 . The Yam growth stages with their duration and respective average crop factor values are given as; germination stage (0-10days), 0.35, vine development (10-30days), 0.55, tuber formation (30-60days), 0.75, tuber bulking (60-90days) 0.85, maturation (90-120days), 0.65, harvest (120days above), 0.45.

With these values of ET_0 and k_c , the mean daily water requirement of the yam crop grown in Ibadan for the respective months of December to May were determined to be 2.49mm, 3.90mm, 4.72mm, 3.79mm, 2.90mm and 2.62mm respectively. These daily ET_0 values translate to 74.7mm, 117mm, 141.6mm, 113.7mm, 87.0mm, and 78.4mm per the respective months, giving a total of 612.4mm for the entire growing period.

Irrigation scheduling

Irrigation scheduling involves planning and managing irrigation applications to optimize water use, reduce waste, and ensure crops receive the right amount of water at the right time. Here, the simple calculation method was used to determine the irrigation schedule, based on the calculated irrigation water need of the crop over the growing season, and the estimated gross irrigation depth in mm of the irrigation applications as shown in Table 1.

Table 1: Parameters used in determining irrigation Schedule

S/No	Parameter	Formula used	Value	Reference
1	Net depth of irrigation, d_{net}	Adopted	12.5mm/day for yam grown on sandy soil	Oladapo and Adesoji [13]
2.	Irrigation application efficiency, e_a	Adopted	90% for drip irrigation system	Singh and Singh, (2017)
3.	Gross irrigation depth	$d_{gross} = \frac{100 \times d_{net}}{e_a}$	13.89mm	Michael [14]
4.	Number of irrigation applications	$\frac{\text{Total irrigation water need for the entire growing}}{\text{daily Net depth of application}}$	≈ 49	Michael [15]
5.	Irrigation interval	No of days in the growing period / Number of irrigation applications	≈ 3 days	
6.	Volume of water applied to satisfied the estimated depth of irrigation	Gross application depth x effective wetted area.	0.26L	Michael [15]
7.	Irrigation run time	$\frac{\text{Water requirement}}{\text{system flow rate}} \times \frac{1}{\text{system efficiency}}$	≈ 4 hr.	IWMI [16]
8	Water use efficiency	$\frac{ET_{(crop)}}{\text{Total water applied}} \times 100$	29.4%	Singh and Singh, (2017)

Sizing and Description of the Drip System

With the chosen emitter of 4L/hr, and having 6 emitters on a lateral line based on the 1m spacing of the yam stands (sack), discharge rate for each lateral line = 24L/hr. Thus, the main line discharge which linked 10 laterals = 24L/hr x 10 = 240L/hr

Storage tank capacity

With a system design capacity of 240L/hr, and a run time of 4hr per single irrigation event, a water storage tank of $240 \times 4 = 960\text{L}$ $\approx 1000\text{L}$ was expected to be suitable for the irrigation system.

Site Preparation and Planting

An experimental farm site of 45m² was cleared and made into ten (10) rows of six (6) heaps each, that were formed by filling soil into perforated 50kg cement bags. A 1000 litre container was placed on raised wooden platform and connected to a network of pvc pipes that were lined each along the rows of the heaps for the purpose of supplying water. Improvised emitters (hospital serving sets) that are capable of regulating the flow of water was connected to the pvc water lines for accurate supply of the estimated amount of water to each of the formed heaps (soil filled sacks).

Three species of yam namely; “Hembankwase”, Faketsa and “Sudan” (a variety of water yam) labelled A, B and C respectively were trimmed averagely to 0.3kg and planted each per row, with each variety occupying three rows while the remaining row had a mixture of all the three varieties and was treated as a control plots. These were all mulched to reduce excessive heat and evaporation, and also staked to support the vines after emergence.

Irrigation Water Application

The planted yam varieties were all treated to a dedicated level of water application through the installed drip irrigation system at a designed interval of 3 days for 4hrs, which was replicated three times with 0.5, 1.0 and 1.5 liters, while the control plot was treated with daily water application of 0.5litres. All these adopted levels of water application were well above 0.26L; the design water application level.

Measurement Yield

At harvest, the yield of the yams was determined by recording the number and weight of fresh yam tubers from each of the three randomly selected stands per row, and the data subjected to statistical analysis of variance (ANOVA) to determine the influence of water application level on the yield of the yam plant under this growing condition.

Results And Discussion

Results

Soil Analysis: Results of some physical properties of the site soil were determined as well as its physico-chemical properties as discussed in section 3.2.1.

Yield Parameters

Tables 2 shows the average yield of the yam varieties in terms of number and weight of tubers formed per each variety at the different levels of water application while Table 3 presents the analysed result using ANOVA. Figures 1 and 2 are the graphical plot of number, and weight of the harvested tubers of the yams with respect to the level of water applied.

Table 2: Result of the Average Yam Yield Under Different Levels of Water Application

Treatment	Number of tubers	Weight of tubers (kg)
A ₁	1	1.4
A ₂	2	4.3
A ₃	2	2.8
A ₄	2	2.6

B ₁	1	1.25
B ₂	1	3.2
B ₃	2	3.0
B ₄	1	1.8
C ₁	2	3.2
C ₂	3	3.6
C ₃	1	1.3
C ₄	3	3.2

Table 3: ANOVA Result of Yam Yield Under Different Levels of Water Application

Yield	Type of yam	Mean	Std. Deviation	Std. Error	F	Sig
Number of tubers	Hembankwase	1.7500	.50000	.25000	2.118	.176
	Faketsa	1.2500	.50000	.25000		
	Sudan	2.2500	.95743	.47871		
	Total	1.7500	.75378	.21760		
Weight of tubers	Hembankwase	2.7750	1.18989	.59494	1.082	.379
	Faketsa	2.3125	.77500	.38750		
	Sudan	2.8250	1.03401	.51700		

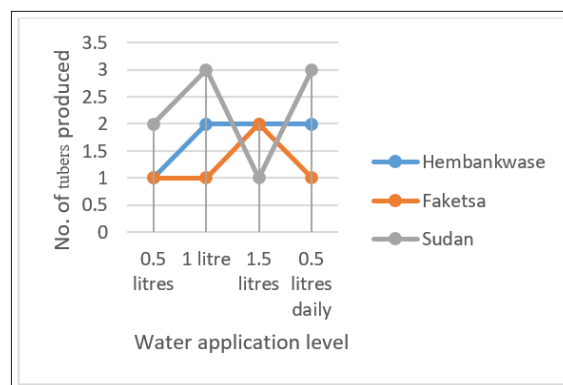


Figure 1: A Plot of number of tubers produced versus water application level

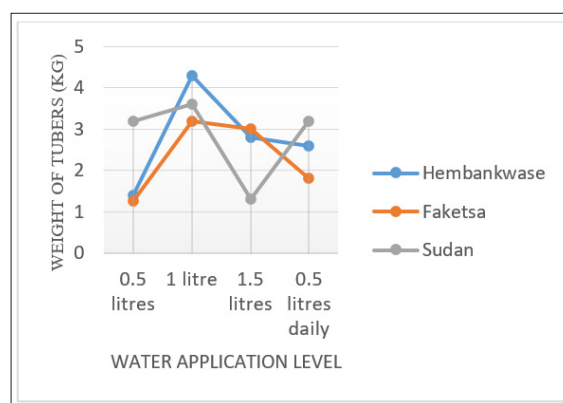


Figure 2: A Plot of Tuber Weight versus Water Application

Discussion

Site Soil Condition

Results of the mechanical analysis of the soil used for the experiment confirms the soil to be predominantly sandy with 69.9% sand composition, and 143mm/m water holding capacity. Also, the analysed soil physico-chemical properties indicated that organic content was (1.10%), organic matter (1.15%), cation exchange capacity (7.2Cmol/kg), base saturation

(85.12%), nitrogen (0.096%), phosphorus (4.70mg/l) potassium (0.26Cmol/kg), sodium (0.24%), magnesium (1.73Cmol/kg), calcium (2.93Cmol/kg) and exchangeable acidity (1.07Cmol/kg). This result indicates that, the soil is generally suitable for yam production when compared with standard ratings for physico-chemical properties of soil for effective yam growth presented by Howler [17].

Water Use Efficiency

The water use efficiency was found to be 29.4%. This low water use efficiency was believed to be affected by the soil physical characteristics, as result of the analysed site soil sample indicated that the soil was predominantly sandy with sand proportion of 69.9%. This agrees with Oladapo and Adesoji, who in their findings submitted that soils with high proportion of sand possess poor water use efficiency for crops especially yam, providing the ideal soil with high irrigation water use efficiency for yam to be loamy soils which are a mix of clay, silt and sand having such characteristic as good drainage and aeration, moderate water holding capacity, high organic matter content, and a pH range of 5.5 – 6.5 [18].

Yield Response to Water Application

Though the number and weight of tubers harvested per variety of the yams revealed variations within and across the varieties with respect to the level of water applied (Table 2), ANOVA result presented in Table 3 shows there was no significant difference among the varieties with F values for number and weight of tuber of yams being ($F = 2.118$, $p > 0.05$) and ($F = 1.082$, $p > 0.05$) respectively. In spite of the fact that there was no significant difference across the water levels at 5% level of significance, raw data presented in Table 2 showed that Sudan scored a bit higher than the other two varieties in terms of number of tubers formed. Figure 1 shows that Sudan recorded 3 tubers, the highest among the three varieties both at treatment 1 litre and 0.5 litre daily water application, and the least number of two tubers at 0.5 litre treatment, Hembankwase scored its highest number (2 tubers) at both 1 litre treatment and 0.5 litre daily application unlike Faketsa which recorded 2 tubers, its highest value only at 1.5 litre treatment. In terms of weight, all the three yam varieties yielded the most at 1 litre water treatment level as compared to their yields at the other levels of water application. Figure 2 revealed that Hembankwase scored 4.3kg, Faketsa, 3.2kg while Sudan recorded 3.6kg the highest among all the treatments. This result agrees with the findings of Oladipo, which clearly shows that even though, statistically there was no variation in the yield of the yams across the different levels of water applied, 1 litre water application level produced a better result [19].

Conclusion

This research provides valuable insights into the yield potentials of yam planted under different levels of water application. Findings of the study revealed that, the applied levels of water at the chosen irrigation interval of 3 days did not produce any significant difference in the yield parameters considered in the study. In spite of these out comes, a critical examination of the mean scores of the weight and number of tubers produced by the yams showed that, all the three varieties recorded their optimum performance at the 1.0 litre level of water application. This finding showed that with appropriate level of irrigation

application to support rainfall even in the given climatic region, yam performance on the field would be better enhanced.

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