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Original Research Paper

Effect of irrigation water depth on tomato yield, water charge and net returns at Geriyo Irrigation Project, Yola, Nigeria

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An experiment was set up to study the effect of irrigation water depth on tomato yield, water charge and net returns. Six different depths of water; 100, 125, 150, 175, 200 and 225 mm designated as treatment A,B,C,D,E and F were applied to six basins of the same size (2 m ×2 m), respectively at the Geriyo Irrigation Project during the 2011/2012 dry season farming. Tomato (*lycpersicon esculetum*) Pevabo variety was used as a trial crop. Irrigation interval of 7 days was applied throughout the season. The result shows that crop yield increased with increase in depth of water applied up to an optimum value of 125 mm per irrigation beyond which resulted in decrease in crop yield. An overall average crop yield of 11.7 t/ha was obtained for all the treatments. Highest net returns of $547.68/ha and irrigation water charge of $7.71/ha was recorded for the experiment. The highest water use efficiency was found to be 8.46X10^{-3} t/ha/mm found at the 100 mm water depth. Correlation coefficient (r^2) between the yield and the amount of water applied was found to be 0.863. Statistically using analysis of variance, the result showed that there was no significant difference among the crop yield at 5% level of significance. This means that crop yield is not influenced by the amount of water applied in the location. Irrigation depth of 125 mm is hereby recommended for tomato in the irrigation project for water saving and yield increase at Geriyo irrigation Scheme.

Key word: Basin, Geriyo, net return, water depth, water use efficiency

INTRODUCTION

In Northern Nigeria, irrigation farming particularly in the flood plain usually called ''Fadama'' have been in existence for centuries, but the proper utilization of the available water to boost crop yields have not been attained. An estimated area of 2 million hectares of Fadama land along the country's watershed has been identified as suitable for irrigation purposes in Nigeria, half of which can easily be exploited (Erincle, 1991). In addition, Mudiare and Tya (2001) observed that minimum and maximum cultivated irrigated farm sizes of 0.20 to 16 ha with a model size of 1.0 to 2.0 ha are being used by the majority of the farmers in Fadama areas. In Nigeria, Fadama is a flood plain area along the streams where farmer-managed irrigation system is being practiced. On the other hand, there are many formal Irrigation Projects under the management of the 12 River Basin Development Authorities, in most of the projects; the major constraint to production is poor on-farm water management.

Tomato (*Lycopersicon esculentum*) is one of the important horticultural plants which can be consumed as either vegetable or fruit crops. In line with increasing population and income, the demand for tomato in Nigeria increase from year to year. However, tomato production is still low with average yield of 12.3 t/ha (Anonymous, 1979). This is far below the potential yield of tomato crop which can reach 58 t/ha (Erinle, 1991). In Nigeria mostly tomato is planted in Fadama area during the dry season and it is a crop that is known to be sensitive to water stress

(Falola and Sangari, 1994). Therefore, it is suggested that one of the reason for the low yield of tomato crops in Nigeria was the inadequate of water supply during tomato growth. As far as there no other limiting factor, any crop will growth normally and produce maximum yield if there is enough water availability (Koesriharti et al., 2012). In addition,Tan (2013) observed that irregular and inadequate water supply reduced growth, yield and quality of tomatoes, while using irrigation, resulted in good crop yield. William and George (2014) stated that water requirement for irrigated tomatoes are affected by soil, plant, climate and management practices. At sowing, Tan (2013) observed that tomato crop evapotranspiration was 0.4 mm/day, while at harvesting, crop evapotranspiration was 2.4 mm/day on clay-loam soil.

However, water as one of agricultural source was found to be limited and sometime observed to be over stretched especially in Public Irrigation Projects. Alternative source need to be sought to expand crop production to sustain irrigation farming (Qamar and Tyem, 1994). Thus, water supply is limited due to increase in demand for agricultural, urban and industrial uses. Similarly, water supply is limited due to decrease in river flows. Water is priced well below its marginal value which results in its inefficient use because water charges in Nigeria are meagre and do not affect farmers' net returns. In addition, there is inconsistency in rationing water thereby making some farms to be over irrigated, while others are deficient in water supply. This constitutes poor water management with reduction in the irrigation efficiency and yield. Thus, the main objective of this study is to examine the effects of the amount of water applied on tomato yield, net returns, irrigation water charge and to specify the optimum irrigation depth to be adopted by a small-scale farmer whose aim is to get optimum crop yield that enhances maximum profit.

MATERIALS AND METHODS

Location sand description of the study area

The experiment was conducted at the Geriyo Irrigation Project of Upper Benue River Basin Development Authority, Yola during the cool dry season farming using check basin irrigation method. The site is located 2 km North of Jimeta metropolis, Yola North Local Government Area, Adamawa State, within the Savannah Ecological Zone of Nigeria. The locations lie between 12 °21' to 22°18' E latitude and 9°16′ to 19°19' N. longitude with altitude range of 150-180 m above the sea level. The area has two major seasons; rainy and dry season. The rainy season lasts from the beginning of May to the end of October with mean annual rainfall of 958.99mm, while the dry season lasts mainly from November to the end of April. The hottest months, February and March with mean monthly maximum temperature of 39.7°C, while the coldest months are December and January with mean minimum temperature of 16°C.The average minimum relative humidity during the dried months is 13%. This is mainly due to the prevalent dry and desiccating North-East Trade Wind This season is favorable for the cultivation of many crops under irrigation as there is no rainfall during the period. The wettest months are August and September when depth of rainfall reaches up to 25% of total annual rainfall. The relative humidity of air rises in these months to about 81% from July to September. Temperatures in the area vary; the hottest period is the month of April.

Field layout and experimental design

Experimental field plot of 6.48 x 10^{-2} ha size with dimension 27m x 24 m was divided into three equal parts called plot units, and each plot unit representing a replication of the experiment and the unit is situated along the direction of the predominant slope. The plots were laid across the contours of the farm in order to have as much homogeneous soil as possible within and between the units. Treatments were six different water depths for irrigation, which were; 100, 125, 150, 175, 200 and 225 mm applied to six basins of the same sizes (2 m x 2 m) designated as A, B, C, D, E and F, respectively. Randomized complete block design for a single factor experiment was used for the layout of the treatments within the three replications

Soil textural classification

Soil samples were taken at incremental depth of 150 mm down to a depth of 600 mm below the soil surface. A minimum of three replications were made during each of the soil sampling which was randomized within the three plot units. The soil textural class was determined using mechanical analysis as detailed by Loveday (1974) as presented in Table 1.
Table 1 showed that the soil textural classification of the experimental farm is predominantly clayloam in texture.

Soil moisture determination

Soil samples were taken at incremental depth of 150 mm down to a depth of 600 mm using a soil sampling auger at six locations randomized within the plot units and ensuring that each treatment was represented within each unit. The samples were taken just before and 2 days after irrigation due to the light nature of the soil. The soil moisture, were determined using gravimetric method.

Field operations

Tomato seedling (Pevabo) variety was raised on a plot of land adjacent to the experiment plot for a period of thirty

Table 1. Textural Classification of the Experimental Farm

Replications	Depth of soil sampling (cm)	Sand (%)	Silt (%)	Clay (%)	Textural Classification[a]	Bulk density (g/cm^3)
1	00-15	25	45	30	CL	1.51
	15-30	21	40	39	CL	1.58
	30-45	30	31	39	L	1.60
	45-60	39	32	29	CL	1.61
2	00-15	30	38	32	CL	1.55
	15-30	30	30	40	CL	1.60
	30-45	45	35	20	L	1.62
	45-60	43	26	31	CL	1.64
3	00-15	37	43	20	L	1.53
	15-30	28	35	37	CL	1.57
	30-45	35	30	35	CL	1.60
	45-60	30	31	39	CL	1.61

a= Based on USDA Soil Textural Classification. L = loam, CL = clayloam

days in accordance with recommendation of Anonymous, (1976) before being transplanted. In accordance with FAO (2002) recommendation, fertilizer (NPK 15-15-15) was applied as a basal application at the rate of 250 Kg/ha to the field before the formation of the basins commenced. The basins were pre-irrigated to wet the soil down to a considerable depth to enhance rapid development of the tomato root-system a day before transplanting up to 13 irrigations. Transplanting was done manually. Irrigation interval of 7 days was adopted for the crop after transplanting up to 13 Irrigations. Manual weeding was done two times. Thus, the crop was subjected to all the usual agronomic practice done by tomato farmers in the area.

Water use efficiency

Water use efficiency was determined as the ratio of the amount of economic crop yield to the amount of water required for growing the crops. In line with Majumdar (2004) it was determined to evaluate the benefit of applied water through economic crop production expressed as;

$$E_u = \frac{Y}{WR} \quad (1)$$

Where;

E_u = field water use efficiency (t/ha-mm)
Y = economic crop yield (t/ha)
WR = Water requirement of the crop (ha-mm)

RESULTS AND DISCUSSIONS

The performance of the various depth of water applied were based on tomato yield, cost of production and profit made. Average tomato yield for the various amount of water applied were determined and compared. The most economic irrigation water charge for the various amount of water applied and net returns were determined.

Tomato yield

Tomatoes harvested were estimated into marketable and non-marketable yields. Marketable yields were those crops harvested and transported to the market with minimum damage and were sold at market prevailing price. Non-marketable yields were those crops obtained from the experimental site as damaged tomatoes and/or those that could not be sold when conveyed to the market.

Table 2 shows the average tomato yield made up of the marketable and non-marketable components. The Table indicates that average tomato yield of 11.5, 14.2, 13.1, 12.2, 9.9 and 9.3 t/ha was obtained for treatments A, B, C, D, E and F, respectively. Similarly, average tomato yield of 15.3, 12.6 and 7.2 t/ha were recorded for farm plot units 1, 2 and 3, respectively. The overall average tomato yield of 11.7 t/ha was obtained for the whole plots. These averages of tomato yields obtained in the range of 7.0-15.3 t/ha for all the treatments and plot units were within the range of 6.0-17.9 t/ha obtained by Anonymous (1979). However, Table 3 shows the analysis of variance of the tomato crop yield distribution for treatments and plot units, which indicated that there was no significant difference among the crop yield at 5 % level of significance even though irrigation water depth of 125 mm gave the highest mean crop yield of 14.2 t/ha

Tomato yield- water use function

Table 4 shows the total amount of water applied and the mean crop yields for treatments. Table 4 reveals that tomato yields increased with the depth of water applied up

Table 2. Tomato Yield Distribution for Treatments and Plot Units

	Yield Per Plot Unit (t/ha)			
Treatments	1	2	3	**Mean**
A	17.8	10.9	5.6	11.5
B	18.8	16.6	7.3	14.2
C	17.4	15.3	6.5	13.1
D	15.3	11.9	9.4	12.2
E	11.9	10.6	7.2	9.9
F	10.4	10.4	7.0	9.3
Mean	15.3	12.6	7.2	11.7

Table 3. ANOVA of Tomato Yield Distribution for treatments and plot units

Sources	Df	SS	MS	$F_{Calculted\ Value}$	$F_{Table\ Value}$
Plots	2	204.67	102.33	21.17	3.59
Crop Yield	5	53.29	10.66	2.21	2.81
Error	10	48.33	4.93		
Total	17	306.29			

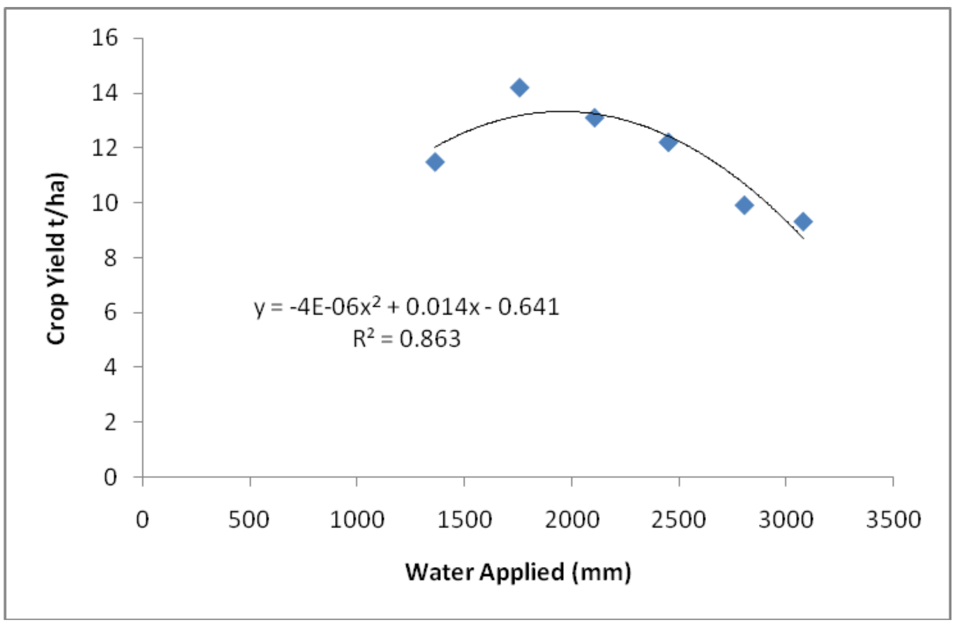

Figure 1: Relation of total amount of water applied and the mean crop yields.

to an optimum value of 14.2 t/ha and there after decreased with more water. Treatment B (125 mm) depth of water applied per irrigation and 1775 mm total amount of water applied gave the highest average tomato yield of 14.2 t/ha. This amount of water applied of 125 mm per irrigation is less than 150mm as practice by farmers in the area which gave crop yield of 14.2 t/ha compared to 9.5 t/ha obtained in the area. This was followed by treatments C, D, A and E. Treatment F with 3080 mm amount of water applied gave the lowest average tomato crop yield of 9.3 t/ha. It was found from Figure 1 that the tomato crop yield and the amount of water applied can be related as;

$$Y= 0.641 + 0.014X - 4E.06X^2 \quad (2)$$

Where;

Y=yield, t/ha

X=depth of water applied, mm, and r^2 =0.863

The water use efficiency for each of the treatment is presented in Table 4. The treatment with 100 mm depth

Table 4. Gross Water Applied and Mean Tomato Yield for Treatments

Treatments	Water Applied (mm)	Mean Tomato Yield (t/ha)	Water use efficiency (t/ha/mm)
A	1360	11.5	$8.46X10^{-3}$
B	1755	14.2	$8.09\ X10^{-3}$
C	2105	13.1	$6.22\ X10^{-3}$
D	2450	12.2	$4.98\ X10^{-3}$
E	2805	9.9	$3.53\ X10^{-3}$
F	3080	9.3	$3.2\ X10^{-3}$

Table 5. Total Cost of Production for Treatments ($/ha)

Cost Description	A	B	C	D	E	F
Fixed Cost	42.69	42.69	42.69	42.69	42.69	42.69
Variable Cost	275.39	285.57	293.89	302.14	310.35	316.95
Total	318.08	328.26	336.58	344.83	353.04	359.64

has the highest water use efficiency of $8.46X10^{-3}$ t/ha/mm which is close to $9.0\ X\ 10^{-3}$ t/ha/mm obtained in another study by Majumdar (2004). It is observed that the water use efficiency decreases with increase in water depth. The implication is that the more water is applied after a threshold of 100 mm depth, the yield decreases per unit depth of water. Consequently, when water saving is the major interest in the irrigation, then adopting 100 mm depth of water application is better; however, when the interest is the yield as well as the water saving then the 125 mm depth of water is better.

Cost of production

The cost of production is made up of the fixed cost and the variable cost. The fixed cost of production consisted of pump maintenance, depreciation values for the pump and other farm tools used annually. The variable costs consisted of labour and material costs for the treatments along with unit prices and time taken per activity per hectare.

The total cost of production was obtained by summing the fixed and variable costs for all the treatments as shown in Table 5. The Table indicates that the total cost of production was highest for treatment F, while the lowest cost of production was recorded for treatment A. These differences in cost of production among the treatments were due to the varied amounts of water applied to the basins resulting in high cost of labour required for the irrigation.

Irrigation water charge

This is the money paid to make the water available to the farmer on schedule. The cost of water was estimated using the volume of water applied for the season, total time of irrigation, the fuel(PMS) cost price of $0.60/ha and an average fuel consumption rate of 0.65 l/ha for water pump of 3.0 Hp capacity. The cost of irrigation water was estimated based on the amount of water applied to each basin. It was observed that irrigation water charge was $30.56, $39.48, $47.36, $55.13, $63,11 and $69.30/ha obtained for treatments A, B, C, D, E and F, respectively.

Net returns

The revenue generated from each treatment was determined by first obtaining the gross income from tomato sales. The total cost of production and loss in income due to land loss as an additional income that the farmer would have obtained if the land had been utilized was subtracted from the gross income, thus resulting in profit made in each treatment.

Table 6 shows the gross income, cost of production and the net returns for each treatment. Table 6 reveals that treatment B recorded highest gross income of $889.06/ha and profit of $547.68/ha, while the lowest income of $579.50/ha and net returns of $206.74/ha was obtained in treatment F. This variation in income and profit may be due to differences in depth of water applied which required more labour that resulted in increase in cost of production. It may also be due to differences in crop yield at the end of the farming season.

Assessment of irrigation water depth

Figure 2 shows the relation of the average tomato yield, net returns, irrigation water charge versus the irrigation water depth applied. Figure 2 indicated that tomato yield increased with the amount of water applied up to a maximum yield of 14.2 t/ha and there after decreased with further increase in the amount of water applied. This trend is similar to that of net returns versus water applied where maximum profit of $547.68/ ha was recorded. However, irrigation water cost was found to be increasing with the amount of water applied. The cost of pumping water at the point of maximum profit was found to be $3.46/ha.

Table 6. Gross Income, Cost of Production and Net Return for Treatments ($/ha)

Treatment	Gross Income	Cost of Production	Loss in Income due to Land loss	Profit
A	717.25	318.08	13.13	386.04
B	889.06	328.26	13.13	547.67
C	818.06	336.58	13.13	468.35
D	762.25	344.83	13.13	404.29
E	618.06	353.04	13.13	251.89
F	579.50	359.63	13.13	206.74

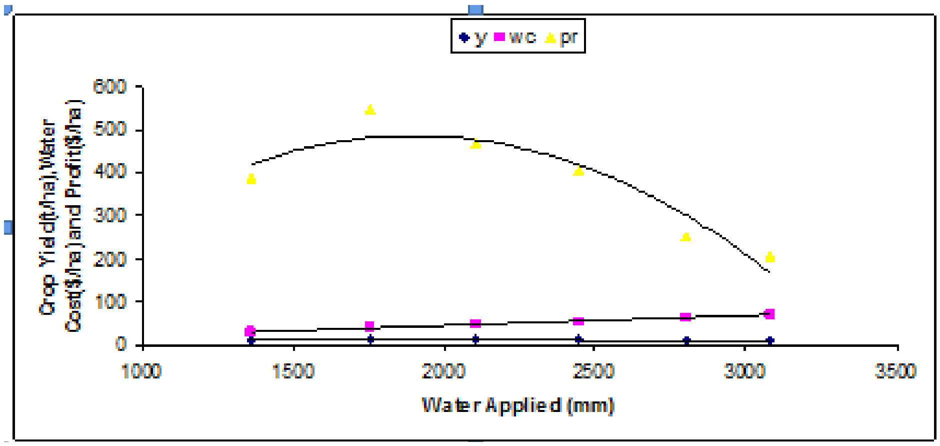

Figure 2: Relation of crop yield, net returns, irrigation water charge and depth of water applied

When pump depreciation and maintenance are included, the water charge becomes $7.71/ha. Figure 2 also shows that for optimum crop yield and maximum profit, water applied in the range of 1360-2650 mm and water charge in the range of $30.56 to $56.25/ha required. Beyond this range, farmers will not be willing to pay for the amount of water applied. The amount of water applied will be large such that it tends to reduce yield with high water charge resulting in low profit made.

The cost of hiring an irrigation pump at the experimental area was $5.00/ha (Sunday, 2012). The amount paid in hiring a pump does not include the cost of petrol. Thus, the cost of using a rented pump is $8.66/ha when fuel cost is included. Thus, it is quite obvious that most farmers who do not own pumps are likely to have reasonable profit from their tomato farms. There is need to educate the farmers and pump owners to make them appreciate the problems involved. In this way farmers can be encouraged to maintain their current levels of tomato production.

Conclusions

It is concluded that crop yield increase with increase in depth of water applied up to an optimum value beyond which it tends to reduce crop yield in the experimental area which is predominantly clayloam in texture. Water application depth of 125 mm per irrigation gave an optimum crop yield of 14.2 t/ha, net returns of $547.68/ha and an economic water charge of $7.71/ha. This water charge ensures maximum profit to be realized by the farmer as optimum depth of water application under fadama conditions.

Recommendations

The following are recommendations suggested to improved on the amount of water applied to be applied for efficient and effective growth of tomato production during irrigation period

1. Water should be well priced in order to improve on its marginal value which results in its efficient use and to avoid over irrigation.
2. There should be consistency in rationing water thereby making equal distribution to farmers.
3. This research work should be carried out using different tomato variety and irrigation method

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