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EFFECT OF VARIOUS IRRIGATION LEVELS AND FERTILIZER MATERIALS ON WATER USE AND YIELD OF ONION UNDER CHECK BASIN IRRIGATION

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ABSTARCT

The aim of the study was to evaluate the effect of various irrigation levels and fertilizer materials on water use and yield of onion crop (Allium cepa L.). The experiment was carried out at the Irrigation Research Farm which is located at latitude 11^0 11’ N longitude 7^0 38’E and 686m above the mean sea level in the Northern Guinea Savanna ecological zone of Nigeria (semi-arid zone). A randomized block design was used, with four irrigation levels and three fertilizer materials in three replications. Water was conveyed to the check basins using calibrated 7.5cm diameter Plastic pipes under observation using stopwatch. The minimum crop water use was 275.4mm corresponding to the treatment 25% irrigation level and chicken droppings (CH) while the maximum CWU was 405.2mm corresponding to 100% irrigation level and Nitrogen Phosphorus Potassium (NPK). The crop water use efficiency varied from a minimum value of 1.24kg/m^3 recorded at 25% irrigation level and NPK to a maximum value of 2.41 kg/m^3 recorded at 100% irrigation level and CD. The highest irrigation water use efficiency of 1.02kg/m^3 was recorded at 25% irrigation level and CH while the corresponding lowest value of 0.23kg/m^3 was recorded at the 75% irrigation level and NPK. This implies that irrigation water use efficiency has an indirect relationship with irrigation level. The biomass yield ranged from the minimum of 22.0 t/ha recorded at the 75% irrigation level and NPK to the maximum of 39.2t/ha obtained from 100% irrigation level and CH. After curing, the yield ranged from 13.9t/ha to 25.6t/ha obtained from 25% irrigation level and CD and 100% irrigation level and CH respectively.

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Keywords: Irrigation, NPK Fertilizer, Water, Onion, Chicken droppings

1. INTRODUCTION

1.1 Nature of the work

Water is a finite resource for which there is increasing competition among agricultural, industrial and domestic sectors. According to Kemp (1996), in Mediterranean countries, the World Bank argues that the allocation of water to agriculture, which accounts for about 90% of regional water use, no longer makes economic sense. Hence, as world population increases on a daily basis, serious stress is posed on available water, thus, affecting agricultural production as water is one of the most important natural resources that have direct influence on man's daily life. Besides the increasing demand for water in other sectors such as industry and domestic use, degradation of water quality also limits water availability for the agricultural sector. Notwithstanding that irrigation farming is still practiced at the lowest ebb in Nigeria, the increasing high cost of development of additional water sources and the growing demand for the readily available ones make it necessary to use available water more efficiently. Hence, water management which is a very important aspect of irrigation farming world over especially in water stressed regions has become a topical issue requiring innovative approaches to increase water use efficiency.

Proper irrigation planning is not only essential for water saving but also for yield enhancement and cost optimization (Nazeer and Ali, 2012). The challenge is to develop and supply water saving technology and management methods and, through capacity building enable farming communities to adopt new approaches in irrigated Agriculture. Organic manure is also a sure and economically viable means of improving crop productivity especially among the subsistence farmers. Therefore, a careful combination of good water management practice capable of increasing water productivity with organic manure will lead to improved yield and resource conservation. In irrigated agriculture, water use efficiency can be increased through improved irrigation timing techniques. Regulated irrigation is one of the numerous ways of maximizing output per unit of irrigation water applied. In deficit irrigation method, the crop is exposed to a certain level of water stress either at a particular stage or sometimes throughout the growing season (English and Raja, 1996). The expectation is that the yield reduction by inducing controlled water stress (supplying lesser irrigation water) will be insignificant compared with the benefits gained through diverting the saved water to irrigate additional cropped area (Kirda, 2002; Kirnak *et al.*, 2002; Gijon *et al.*, 2007). Owusu-Sekyere *et al.* (2010) observed that reduction in 20% water need of hot pepper has no significant effect on growth, development and fruiting of the crop. Bekele and Tilahun (2007) reported that controlled irrigation increased the water use efficiency of onion from a minimum of 6% to a maximum of 13% by stressing the crop during the first growth stage through denying the crop about 75% reference

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evapotranspiration (ETo) throughout the growing season. As a shallow rooted crop, onion requires frequent irrigation which promotes high wastage of irrigation water. Farmers often employ surface irrigation method which promotes low water use efficiency and productivity.

1.2 Statement of the Problem

Onions is one of the most popular vegetables grown in home gardens and also the first crop to market during the rainy season. It is mainly grown by small scale farmers with little resources to ensure elongation of the income regime amongst other things. Paucity of funds makes it very difficult for these farmers to access and deliver sufficient amount of water for irrigation consequently limiting their capacity to expand irrigation farming and guarantee all season crop Production. Therefore, sustained efforts ought to be made on how to minimize crop water use through application of efficient and proper water management practices and cost effective fertilization techniques to boost yield. Under conditions of limited water application, crop production is adversely affected by reduction in yield (Itier, 1996). Hence there is a need for the development and maintenance of optimal water use efficiency to achieve proper water balance for the target crop.

1.3 Aims and Objectives

The aim of the study is to evaluate the effect of various irrigation levels and fertilization materials on the yield and water use efficiencies of Onions with the target of optimizing water use and maximizing the profit margin in onion production under check basin irrigation method. The specific objectives are:

- To determine the crop water requirement of onion under various levels of irrigation and fertilizer materials.
- To determine soil moisture depletion trends under different levels of irrigation and fertilizer materials.

1.4 Previous work

As the search for methods of producing more crops with limited water supply while minimizing water used for irrigation at field levels in order to release more water for other uses beside agriculture intensifies, irrigation with mulching is seen as one of the options of achieving the aforementioned goal (Igbadun and Oiganji, 2012). Bakhsh *et al* (2007) noted that vegetable production can be enhanced in three possible ways which are by allocating more area, by developing and adopting new technologies or by utilizing the available resources more efficiently. Varying irrigation levels is aimed at utilizing the available irrigation water more

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efficiently by maximizing crop yield per water applied. Water is considered very important for plant growth and food production.

There is competition between municipal, industry users and agriculture for the finite amount of available water. Thus, estimating irrigation water requirements accurately is important for water project planning and management (Michael, 1978). The primary objective of irrigation is to apply water to maintain crop evapotranspiration (etc.) when precipitation is insufficient. Hence varying irrigation levels is aimed at improving the efficiency of crop water use to achieve greater yield per unit of water. For various levels of irrigation and its schedules to be successful, some knowledge of crop response to water stress at specific growth stages or entire season is essential. FAO suggested that crop varieties most suitable to various levels of irrigation are those with short growing season and are tolerant to drought. In practicing irrigation at various levels, consideration must be given to soil retention capacity, plant population, and date of planting and fertilizer application (Ramalan *et al*., 2010). The onion crop being shallow rooted, extracts water from the top 30cm depth of soil; thus, the upper soil area must be kept moist to enhance root growth and provide adequate water for the plant. Organic manures are also well known to be one means of conserving soil moisture and reducing evaporation from the topsoil areas well as improving the soil fertility.

2. MATERIALS AND METHODS

2.1 Experimental Design and Field Layout

A field experiment was conducted during the 2014/2015 dry season, from November, 2014 through April, 2015. The experimental crop; onion (Allium Cepa L.) was cultivated in check basins measuring 2m by 3m. The factors considered in this experiment are four levels of irrigation (100%, 75%, 50% and 25% of weekly ET_0) and three fertilizer types (Cow Dung, Chicken Droppings and NPK. They were combined in a randomized complete block design and laid out as twelve treatments in plots measuring 2m × 3m ($6m^2$) in line with FAO recommendation. Each treatment was replicated three times totaling 36 plots. Graduated gauges were placed at the water inlet of each basin to measure the depth of water flowing through the plastic pipes used to convey water to the plots. Thus the discharges through the pipe into the basins were quickly computed using equation 3.1 and the depth of water applied was monitored using a stopwatch to know the time taken using equation 3.2 to apply desired depth.

2.2 Field Operation

The entire site measuring $335m^2$ was ploughed and harrowed to a depth of 0.5m to facilitate rooting, encourage aeration, infiltration and to prepare the soil for planting. The soil was marked out for check basin irrigation with waterways running in between pairs of basins as shown in Fig

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3.1. The onion seedlings with height range of 10-12cm and three true leaves; were transplanted to the field on 13th January, 2015 after they were raised in the nursery for 6 weeks. The seedlings were planted in check basins at intra-row and inter-row spacing of 10cm and 20cm, respectively.

The fertilizer treatment was applied after the marking out of the field (plate 3.1) two days before transplanting. The moisture content of the soil was measured using the theta probe moisture metre prior to transplanting. Thereafter, the soil was irrigated to field capacity to raise the soil moisture content one day before transplanting. After transplanting, full irrigation to restore the soil to field capacity, based on effective rooting depth of 15cm, was given to all the treatment plots. The irrigation treatment was commenced after four weeks. Weeding was done by hand hoeing to avoid damage.

Plate 3.1: Marking out of the experimental plots.

2.3 Water Application to the Field

Poly Venyl Concentrate (PVC) Pipes measuring 7.5cm diameter by 50cm length were installed to convey water into each basin. The depth of water was monitored using calibrated rulers at the water inlet of each basin and the time of application was also measured with the use of a stopwatch at the desired depth. Equation 3.2 shows the time of application of water to achieve a predetermined depth through calibration:

$$Q = C_d A\sqrt{2gh} \quad (3.1)$$

Where:

Q = Discharge (m^3/sec)

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C_d = Coefficient of discharge (dimensionless)

A = Cross Sectional Area of PVC pipe (m^2)

h = Height of water above the pipe (m)

The outcome was used to cross check the depth of water applied over the period to ensure compliance with the standards of the imposed treatment.

$$t = Ad/Qn \quad (3.2)$$

A = Area of basin in m^2

n = Water application efficiency for check basin which is approximately 0.75

d = Depth of water (m)

t = time (sec)

Q = Discharge (m^3/sec)

2.4 Measurement of Soil Moisture

A calibrated Theta probe was used to measure the moisture content of the soil by inserting it to a depth range of 0-25cm and 25 - 50cm for each plot through access tubes as shown in plate 3.2 strategically installed in the various plots.

Plate 3.2: Field Showing various depths and onion crops at early growth stage

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2.5 Determination of the Yield Response Factor

Considering the impact of water on final yields, farmers have the tendency to over irrigate, an approach that contradicts the conservation practise of scarce resources. When there is water deficit at a specific growth stage of the crop, the yield response can vary depending on crop sensitivity at that development stage (FAO, 2014). A standard formulation according to (Vaux and Pruitt, 1983) relates four parameters (Y_a, Y_m, ET_a and ET_m) to a fifth: K_y the yield response factor which relates relative yield decrease to relative evapotranspiration deficit as shown in the equation below.

$$[1-Y_a/Y_m] = K_y (l- ET_a/ET_m) \qquad (3.3)$$

Where:

Y_a = actual yield in (Kg/ha)

Y_m=Maximum yield in (Kg/ha)

K_y =Yield Response Factor (dimensionless)

ET_m = Maximum evapotranspiration (mm/day)

ET_a = Actual crop evapotranspiration (mm/day)

Mannocchi and Mecarelli (1994) showed that using the Eqn 3.3, it is possible to model relationships between crop yield and water applied.

2.6 Crop Water Use and Irrigation Water Use Efficiencies

Water use efficiency is a measure of the crop water productivity given in Eqn 3.3 above

While Irrigation water use efficiency measures the irrigation water productivity and is given as:

$$IWUE = Y/IWA$$

Where:

IWUE = Irrigation water use efficiency ($Kg.m^{-3}$)

Y= Yield ($Kg.m^{-2}$)

IWA= irrigation water applied to the field (m)

(Michael, 1978)

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3. RESULTS AND DISCUSSION

3.1: Effect of Four Irrigation Levels and Three Fertilizer Materials on Crop Water Use, (CWU)

Table 1.1: Seasonal Crop Water Use (CWU), CWUE and IWUE recorded against treatment

Treatments	CWU (mm)	TBY (t/ha)	CWUE (Kg/ m^3)	IWUE (Kg/ m^3)
DI_0CD	375.73	24.44	2.41	0.31
DI_0CH	400.10	25.56	2.11	0.33
DI_0NPK	405.17	18.80	1.55	0.24
$DI_{25}CD$	347.87	20.80	1.85	0.36
$DI_{25}CH$	371.90	20.40	1.56	0.30
$DI_{25}NPK$	375.67	13.91	1.24	0.24
$DI_{50}CD$	336.10	16.10	1.66	0.42
$DI_{50}CH$	367.30	19.48	1.84	0.53
$DI_{50}NPK$	294.37	14.31	1.62	0.37
$DI_{75}CD$	330.83	13.85	1.41	0.72
$DI_{75}CH$	368.13	17.28	1.78	1.01
$DI_{75}NPK$	275.40	14.95	1.86	0.78

Table 4.1 shows that the minimum CWU recorded was 275.40mm corresponding to the treatment 25% irrigation level and NPK while the maximum CWU recorded was 405.17mm corresponding to 100% irrigation level and NPK. This result is in agreement with the report by (Allen, etal., 1998) which stated that for optimum yield, onion requires 350-550mm of water. Table 1.1 shows the seasonal crop water use and water use efficiencies vis a vis the various treatments. The CWU was recorded with the aid of tetha probe while the water use efficiencies were computed.

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Table 1.1 indicates that the higher the irrigation level, a corresponding increase in CWU is recorded and this was observed across all the fertilization materials used. However, this pattern also applied to the bulb yield and IWUE except for few instances

Table 1.2: Variation of CWU, CWUE and IWUE with Irrigation Levels for CH.

Irrigation Level	Designation	CWU (mm)	CWUE (Kg/ m^3)	IWUE (Kg/ m^3)
100%	DI_0	400.01	2.11	0.33
75%	DI_{25}	371.90	1.56	0.30
50%	DI_{50}	367.30	1.84	0.53
25%	DI_{75}	368.13	1.78	1.01

Table 1.3: Variation of CWU, CWUE and IWUE with Irrigation Levels for CD

Irrigation Level	Designation	CWU (mm)	CWUE (Kg/ m^3)	IWUE (Kg/ m^3)
100%	DI_0	375.73	2.41	0.31
75%	DI_{25}	347.87	1.85	0.36
50%	DI_{50}	336.10	1.66	0.42
25%	DI_{75}	330.83	1.41	0.72

Table 1.4: Variation of CWU, CWUE and IWUE with Irrigation Levels for NPK.

Irrigation Level	Designation	CWU (mm)	CWUE (Kg/ m^3)	IWUE (Kg/ m^3)
100%	DI_0	405.17	1.55	0.24
75%	DI_{25}	375.67	1.24	0.24
50%	DI_{50}	294.37	1.62	0.37
25%	DI_{75}	275.40	1.86	0.78

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3.2 Effect of Four Irrigation levels and Fertilizer Materials on Onion Yield

The effects of various treatments on the yield of onions were observed. The onion bulbs were weighed after harvest to obtain the yields as shown in Table 1.5

Table 1.5: Biomass yield for 2014/2015 dry season farming in Samaru.

Treatment	Biomass Yield(t/ha)
DI_0CD	35.49
DI_0CH	39.23
DI_0NPK	31.99
$DI_{25}CD$	33.51
$DI_{25}CH$	32.67
$DI_{25}NPK$	22.02
$DI_{50}CD$	26.61
$DI_{50}CH$	29.87
$DI_{50}NPK$	22.13
$DI_{75}CD$	24.21
$DI_{75}CH$	26.03
$DI_{75}NPK$	23.30

Table 1.4 shows that the CWU is statistically insignificant for the various irrigation levels except for the 25% irrigation level. This implies that the irrigation levels from 50% and 100% will result to similar CWU with the exception of 25% irrigation level. Hence, to save irrigation water, lower irrigation levels of either 50% or 75% should be used instead of irrigating at full level of 100%.

Although, the 100% irrigation level resulted to the highest mean cured bulb yield of 7.646t/ha, it is also statistically insignificant.

However, the fertilizer materials, the cured bulb yield varied insignificantly between CH and CD but varied significantly with NPK. Hence, the CH resulted to the highest cured bulb yield followed by the CD while the NPK resulted to the least cured bulb yield. Considering that ADRA (2005) reported that the use of poultry manure by farmers is far cheaper than NPK fertilizers, CH is therefore recommended for onion production.

3.3 Crop water use efficiency, (CWUE)

The crop water use efficiency varied from the lowest value of 1.24 kg/m^3 recorded at 75% irrigation level and NPK to the highest value of2.41 kg/m^3 recorded at 100% irrigation level and

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CD.The trend is such that onion crop water use efficiency varied with irrigation levels confirming the established trend of direct relationship between onion crop water use efficiency and irrigation levels.

Table 1.6: Analysis of Variance for Results of Crop Water Use Efficiencies (CWUE) and Irrigation Water Use Efficiencies (IWUE)

Treatment	CWUE (Kg/m3)	IWUE (Kg/m3)
Irrigaton Level		
DI0	2.0245a	0.2967b
DI25	1.7054a	0.2979b
DI50	1.6843a	0.4389b
DI75	1.5476a	0.8333a
LSD	0.73	0.20
Fertilizer Material		
CD	1.8300a	0.45083a
CH	1.8222a	0.54167a
NPK	1.5691a	0.40750a
LSD	0.63	0.17
I*F	NS	NS

Table 1.6 indicates that the CWUE is statistically insignificant for both the various irrigation levels and fertilizer materials. This also suggests that considering that less irrigation level can lead to similar results with full irrigation level, irrigation water can be saved by applying less than the full irrigation requirement. IWUE is observed to be statistically insignificant for the various fertilizer materials and irrigation levels except the 25% irrigation level is is statistically significant. This is in agreement with the position that IWUE increases as irrigation level decreases.

3.3.1 Irrigation water use efficiency, (IWUE)

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The highest irrigation water use efficiency of 1.01 kg/m^3 was recorded against 25% irrigation level and CH while the lowest IWUE of 0.23 kg/m^3 was recorded against the 75% irrigation level and NPK. This trend corroborates with Howell *et al*. (1990), who opined that maximum IWUE usually occur at an evapotranspiration less than the maximum. Hence, suggested that irrigating to achieve the maximum yield and evapotranspiration would not be the most efficient use of irrigation water. Irrigation water use efficiency is also statistically significant at 25% irrigation level; the irrigation water is highly utilized.

3.4 Soil moisture depletion

Fig. 4.1 shows that the highest mean of soil moisture depletion of 26.93mm was recorded in the fifth week under 25% irrigation level and cow dung designated as $DI_{75}CD$ while the lowest mean depletion of 7.2mm was recorded in the seventh week for the same treatment as observed in the field.

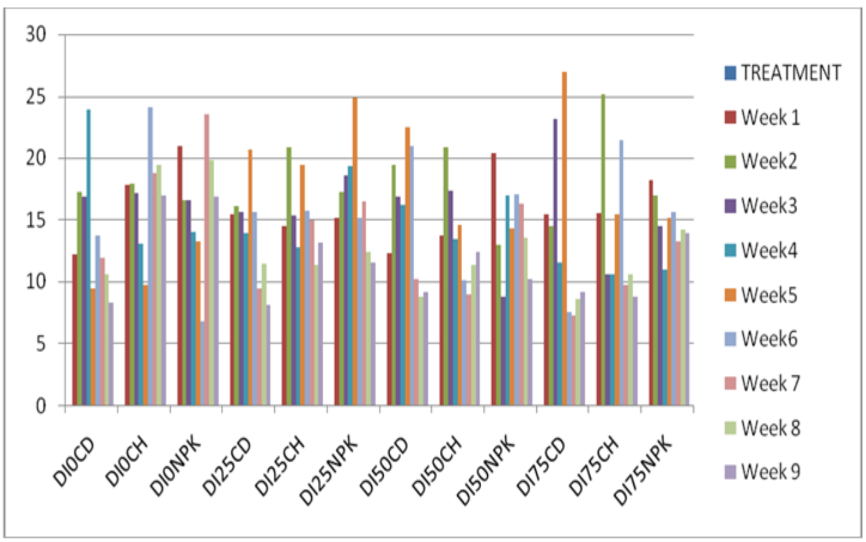

Figure 4.1: Moisture Depletion Trends

This could suggest that of all three fertilization materials, cow dung and chicken droppings retains moisture more than NPK due to the osmotic effects of the later. Other factors that could have contributed to the trend of the weekly moisture depletion are the varying weather conditions and the growth stage of the onion crop

3.5 Yield Response Factor

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The plots of the yield response to the reduction in relative evapotranspiration is represented in figs. 4.2, 4.3 and 4.4. The yield response factors for the CD , CH and NPK are 0.11, 0.34 and 0.82 respectively. Higher Ky shows that reduction in crop evapotranspiration has significant effect on the yield and vice versa. Therefore, the yield response to reduced evapotranspiration has minimum effect on yield in cow dungs and maximum effect in NPK.

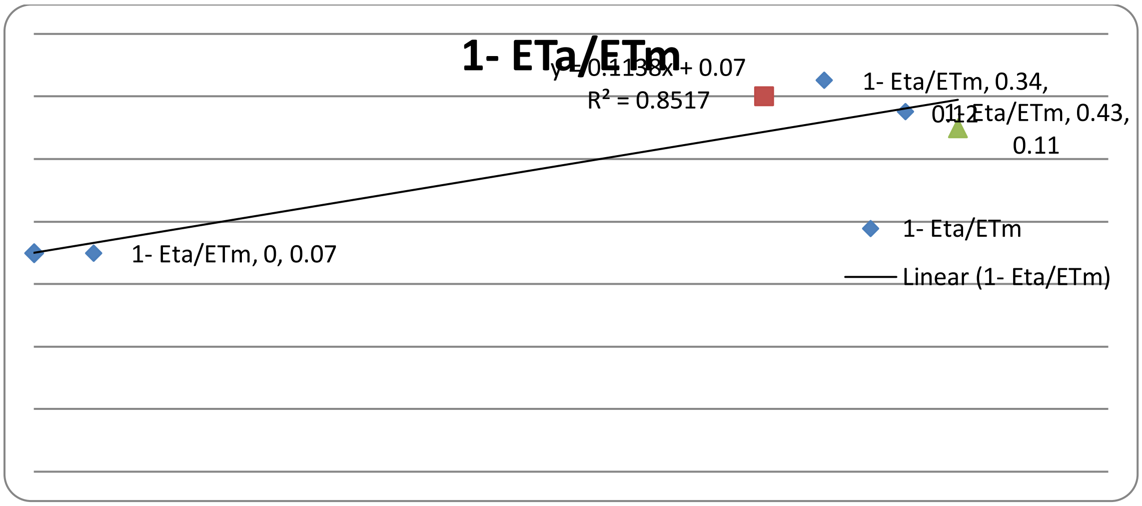

Figure 4.2: Plot of 1-(Y_a/Y_m) against 1-(ET_a/ET_m) for various irrigation and CD

Hence, Ky = 0.11 for CD

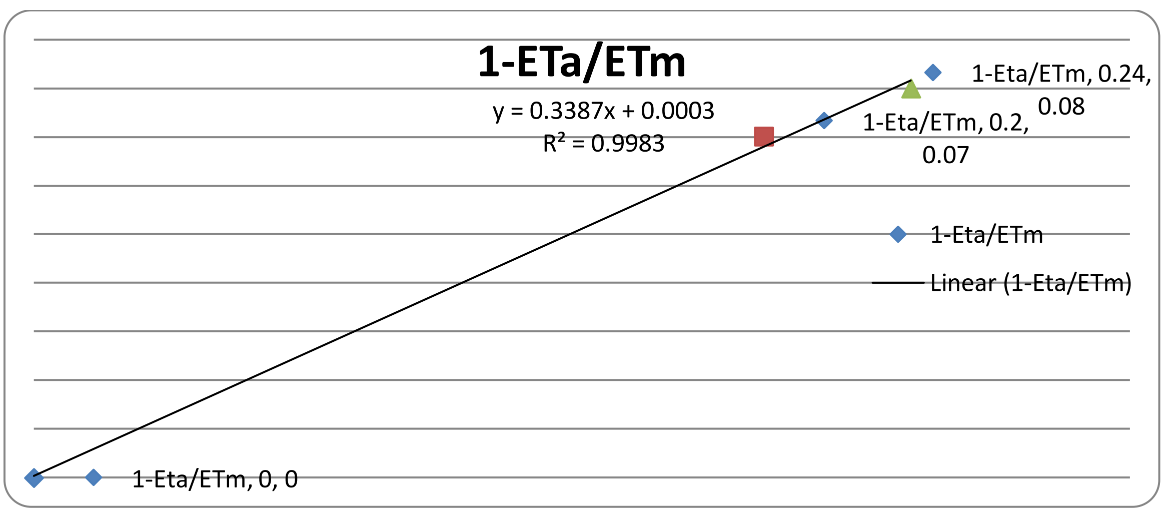

Figure 4.3: Plot of 1-(Y_a/Y_m) against 1-(ET_a/ET_m) for various irrigation and CH

Here, Ky =0.34

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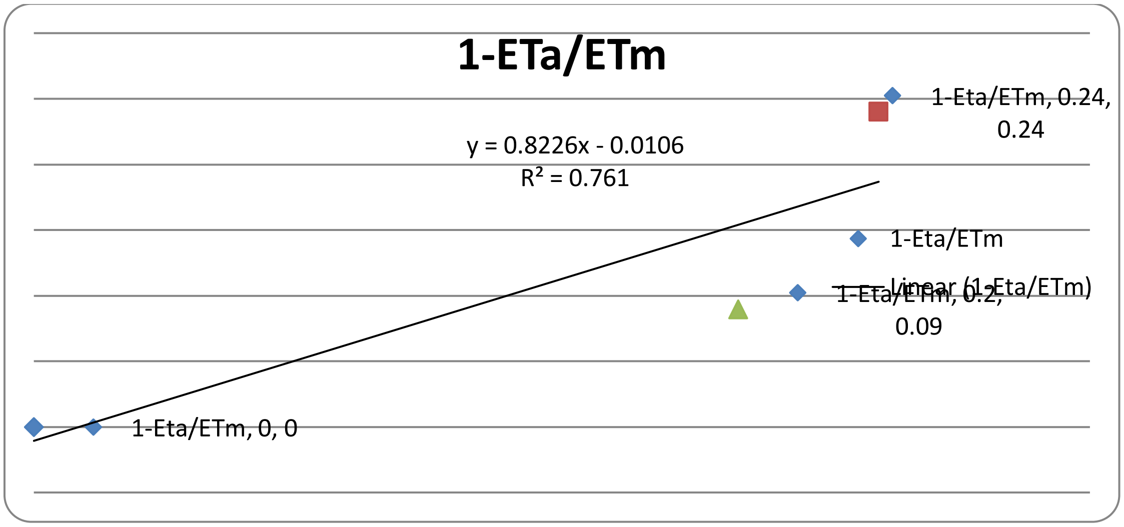

Figure 4.4: Plot of 1-(Y_a/Y_m) against 1-(ET_a/ET_m) for various irrigation and NPK

Ky = 0.82 for NPK

NB. For all the graphs above the following points were ignored as they deviated significantly from other points. For fig.4.2 (0.15, 0.00), for fig.4.3 (0.32,0.31), for fig. 4.4 (0.24,0.24). Tables in Appendix B.

4.0 SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

4.1 Summary

The effect of four irrigation levels and three fertilizer materials on water use and yield of onion under check basin irrigation (2mx3m) was studied. The study was carried out at the IAR farm in Samaru Zaria during the 2014/2015 dry season farming. In this experiment, the minimum CWU recorded was 275.40mm corresponding to the treatment DI_{75}NPK while the maximum CWU recorded was 405.17mm corresponding to DI_0NPK. This result is in agreement with the report by (Allen, etal., 1998) which stated that for optimum yield, onion requires 350-550mm of water.

Irrigation at 100% and 75% levels significantly differ from the irrigation levels at 50% and 25%. Expectedly, the least seasonal crop water use of 275.40mm was recorded for the least irrigation level of 25% and NPK while the highest seasonal crop water use of 405.17mm was recorded at 100% irrigation level.

The maximum biomass yield of 39.23t/ha was obtained at 100% irrigation level and CH while the minimum biomass yield of 22.02t/ha was recorded against 75% irrigation level and NPK fertilizer.

However, after curing, the cured bulb yield was measured and the maximum yield of 25.56t/ha was obtained from 100% irrigation level and CH whereas the minimum yield of 13.85t/ha was obtained from 25% irrigation level and NPK.

Interestingly, 50% irrigation level and CH resulted to greater yield compared to100% irrigation level and NPK fertilizer. This suggests that the use of chicken droppings and 50% of available irrigation water can lead to almost the same yield with 100% irrigation water and NPK fertilizer. The water use efficiency ranged from 1.24 kg/m^3 recorded at 25% irrigation level and NPK to 2.40 kg/m^3 recorded at 100% irrigation level and CD. The irrigation water use efficiency of 1.01kg/m^3 was recorded against 25% irrigation level and CH while the lowest 0.24 kg/m^3 was recorded against the 75% irrigation level NPK. This trend corroborates with the findings of Howell *et al*. (1990), who pointed out that maximum IWUE usually occurs at an evapotranspiration less than the maximum.

4.2 Conclusions

The following conclusions have been drawn from the findings of this research work;

- The seasonal crop water use varied directly with irrigation levels. For the various fertilizer materials considered, the maximum CWU was obtained at the 100% irrigation levels.
- The highest CWUE observed was 2.41 kg/m^3corresponding to 100% irrigation level and CD while the minimum is 1.24 kg/m^3 corresponding to 75% irrigation level and NPK.
- Irrigation water use efficiency varied inversely with the irrigation levels. The maximum IWUE (1.01 kg/m^3) was recorded at 100% irrigation level and chicken droppings whereas the minimum value of (0.24 kg/m^3) was recorded at 75% irrigation level and NPK.
- CH at 100% irrigation level resulted to the highest cured bulb yield of 25.56 t/ha when compared with other fertilizer materials across the various irrigation levels. For instance, at 100% irrigation level. CH resulted to cured bulb yield of 25.56t/ha compared to 24.44t/ha and 18.80t/ha for CD and NPK respectively. At 50% irrigation level, CH resulted to cured bulb yield of yield of 19.48 t/ha whereas CD and NPK resulted to a marketable yield of 16.10 t/ha and 14.31 t/ha respectively. This trend was observed across all irrigation levels.
- Although water is saved from irrigating below 100%, the corresponding loss in yield seems to be more significant than the cost of water saved, hence it is still more advisable to irrigate at 100%. Hence, for maximum yield of onion crop 100% irrigation level and CH is recommended.

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- The yield response factors recorded were 0.11 for CD, 0.34 for CH and 0.82 for NPK. This shows that the reduction in onion yield resulting from reduction in evapotranspiration is least when cow dung is used compared to CH and NPK.
- Trend analysis of moisture depletion indicated that cow dungs and chicken droppings retained more water than NPK due to the osmotic effects of the later.

4.3 Recommendations

From the study, the following recommendations are made:

- The growth stages of the onion crop should be considered for further studies on various irrigation levels as the crop water requirement at different growth stages differ.
- Considering that the essence of this study is water conservation/optimization, a longer irrigation interval of 14 days should be studied to further establish the effect on crop yield and compare same with the economic gains derived from water saving.
- A similar study should be carried out with other vegetable crops to ascertain the effect of various irrigation levels and fertilization materials on such crops.

4.4 Acknowledgement

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