

## ASSESSMENT OF SUPPLEMENTAL IRRIGATION AND VARIETY ON WATER EFFICIENCY OF POTATO IN KURU, JOS, NIGERIA

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### ABSTRACT

*Assessment of supplemental irrigation (SI) rate and variety on water use (WUE) of potato (*Solanum tuberosum* L) was conducted during the cropping seasons of 2017 and 2018 at the Research Farm of National Root Crops Research Institute Kuru, Jos Nigeria. The treatments consisted of four levels of water applications (W1 = control, W2 = SI of 200 m<sup>3</sup>, W3 = SI of 400 m<sup>3</sup>, W6 = SI of 600 m<sup>3</sup>) and two variety of potato (V1 = diamat; improved variety and V2 = local variety). The factors were combined to give 8 treatments combinations that were laid in a 2x4 split plot arrangement in a Randomized Complete Block Design (RCBD) each replicated three times. Water use efficiency of potato was calculated using formula. Water use efficiency data collected were subjected to analysis of variance (ANOVA). Supplemental irrigation of 400 m<sup>3</sup> gave higher water use efficiency. The interaction effect showed that supplemental irrigation rate of 400 m<sup>3</sup> x variety diamat produced better water use efficiency. Variety diamat x supplemental irrigation of 400 m<sup>3</sup> is recommended for potato growers in the study area.*

**Key Words:** Supplemental, Efficiency

### INTRODUCTION

Potato is the most fruitful and efficient tuber crop in the world in terms of tuber yield and days to maturity. It matures in about 60-90 days (2-3 months) as compared to 9 and 12 months of yam and cassava respectively (Kudi., Akpoko and Yada, 2008). It is one of the most important food crops of the world. It's probable centre of origin is in South America in Central Andean Region (Reader, 2008). Hijman's and Spooner (2003) reported that the crop was first introduced outside the Andes region four centuries ago, and have become an integral part of world's food consumption. Potato is fairly new to Sub-Saharan Africa (SSA) where it was introduced in the 19<sup>th</sup> centuries through the activities of European Missionaries (Okonkwo., Amadi and Nwosu, 2009). It was introduced in Nigeria during the 1920s by way of Germans living in the Cameroons and by other Europeans involved in Missionary and Tin mining activities on the Jos Plateau, where production was limited to small garden plots (Mosely., Vales., Memoran and Yilma, 2000). Supplemental irrigation is a temporal intervention, designed to augment natural precipitation at the time of dry spell. It is irrelevant when daily rainfall is adequate to support crop growth, but there is frequent period of shortages, during which crop would die or yield would be substantially reduced by moisture shortage. The high Plateau of Jos, Biu and the Adamawa high lands experience climatic conditions which are markedly different from the generalized dry and wet period in northern Nigeria. Temperatures are 5-10 °C lower due to high altitudes than in the surrounding areas. The high altitude and lower temperatures give these areas a microclimate of the temperate regions. This is the particular reasons that these areas are favorable to the production of potato (Kashap and Panda, 2003). In most regions of the world, rainfall distribution is erratic and poor, showing high temporal and spatial variability. Thus, during the rainy season in Nigeria, there may occur several rainless days. Even when the occurrence of "drought" is of relatively short duration, it may coincide with a critical phonological stage of a crop thereby reducing crop yield if not total crop failure could occur. The need for artificial application of water to the soil to supplement or replace rainfall, lengthen the cropping season and thereby, help to create optimum conditions for crop growth and development is very vital (NRCRI, 2015).

In Jos, Plateau area, many agronomic aspects of potato production have been researched into with a view of raising the present level of potato yield on farmers' farm; Ifenkwe (1989) compared production on flats and ridges during dry season and examined fertilizer requirement for potato/ wheat crop in the dry season. Other

researchers (Jwanya., Ishaya and Alabura,2013) have compared profitability and technical efficiency of rain fed and dry season potato production in Plateau State. Ndor (2013) surveyed potato diseases under rain fed while Dibal., Ramadan and Oyeboode (2010) examined varietal response of potato to irrigation scheduling. However, growth and yield as well as water use efficiency on potato varieties as affected by supplemental irrigation is yet to be given enough research attention.

With the establishment of potato program at Kuru, Jos by National Root Crop Research Institute Umudike in 1976, potato production steadily rose from 473, 420 metric tons in 1991 to 742, 870 metric tons in 1996. However, production has gradually declined to about 470, 000 metric tons in 2000 (PADP, 2002). The reasons attributed to the drop in production are poor and erratic rainfall among other factors.

). There are now over a thousand different types of potatoes worldwide descended from varieties that originated from the low lands of South Central Chile which displaced formally popular varieties from the Indian high lands (Burton, 1966)

Since no single variety can satisfy all farmers' needs because of varying production processing needs, the following groups of selected clones are presently recommended (Harkes, 1990).

1. Medium yielding: varieties with tolerance/resistance to late blight and bacterial wilt, RC 767- 2 areta, Roslin Guacha, B9493-4-2 Rosline Ruaka
2. High yielding with fair resistance to late blight and bacterial wilt; Arka, Nicola, Mirka, Desiree B9462-1, Barka.
3. Raining and dry season varieties; Rc767-2, Rc777-3, Ruaka and B9462-1 (varieties with short dormancy).
4. Dry season varieties; Mirka, B9462-1, Estima, Arka, Desiree and Diamat.
5. Good processing varieties and their strengths are also presented below:

The aimed of this research was to assess the effect of variety and supplemental irrigation on water use efficiency of potato .

**Table 1. Potato Variety, Yield Potential and Day to Maturity**

Improved Potato Variety	Potential Yield Days to Maturity		
	(t/ha)		
Agria	15		90-100
Caruso	25	80-90	
Connect	30		90
Diamat	15	80-90	
Ditta	15		80-90
Jelly	25		80-90
Marabel	25		70-80
Nicola	10		90
Rumba	25		90
Lady Christyl	25		80-90

Source: NRCRI (2005)

## MATERIALS AND METHODS

### Site Description and Characteristics

The field experiment was conducted at the Research Farm of the Potato Program, National Root Crops Research Institute, Kuru (09<sup>o</sup>44' N,08<sup>o</sup>47'E, elevation 1,236.3 m a.m.s.l.) Jos, Plateau State. The soil of the study site belongs to the soil order Alfisols (SSS, 1975) of the basement complex volcanic rocks origin and has a sandy loam texture at the surface. It is slightly acidic to neutral. Mean rainfall is about 1500 mm received in 130-150 days from May to September (Danbaba and Fogah, 2013). It has a maximum temperature of 27 °C and a minimum temperature of 10 °C. The dominant Vegetation at the site includes guinea grass (*Panicum maximun*), gamba grass (*Andropogon gayanus*) and elephant grass (*Penisetum pueperum*) (Usman, 2018).

The climate is characterized by two distinct wet and dry seasons. The wet season starts from late April and end in October while the dry season starts from November to mid-April. It is located within the northern guinea savanna agro-ecological zone of Nigeria (Daggash, 2018). The map of Plateau State and map of the study area are presented in figure 1 and 2 respectively.

**Experimental Treatments and Design**

The treatments consist of two varieties of potato:  $V_1$  ( Daimat; improved variety ), and  $V_2$  (Local variety) and four levels of water application:  $W_1$  ( control; No Supplemental irrigation ),  $W_2$  ( supplemental irrigation of 200 m<sup>3</sup>- $W_3$  ( Supplemental irrigation 400 m<sup>3</sup>) and  $W_4$  ( supplemental irrigation of 600 m<sup>3</sup>). The factors were combined to give a total of 8 treatment combinations as follows;

$T_1 = V_1W_1$	$T_5 = V_2W_1$
$T_2 = V_1W_2$	$T_6 = V_2W_2$
$T_3 = V_1W_3$	$T_7 = V_2W_3$
$T_4 = V_1W_4$	$T_8 = V_2W_4$

The treatments were laid out in a 2x4 split – split plot arrangement in a randomized complete block design (R C B D) and replicated three (3) times making a total of 24 plots. Each sub plots area had a dimension of 2 m x 3 m (6 m<sup>2</sup>) separated by 1 m between block and replicated respectively. The size of the experimental area was 517 m<sup>2</sup>

**Field Study**

Two profile pits were dug one at the upper and the other at the lower slope position of the land. Each pit measures 2 m x 1 m x 2 m. The profile pits were dug showing the soil horizon facing the sun rays for easy identification of the horizons. Six generic horizons were identified from each pit. One soil sample was collected from each identified horizon given a total of 12 samples collected from the two pits. The profile pits were described according to USDA soil taxonomy (FAO, 2008) procedure for soil profile using description sheet for the description of the soil (Munsell, 1975). The samples were kept in polythene bags and taken to the Agricultural Service and Training Centres (ASTC) Kassa, Barkin Ladi, Plateau state for analysis.

**Agronomic Practices**

**Land clearing and sowing**

The vegetation was manually cleared. Ploughing, harrowing and ridging were done mechanically. Seeds were sourced from NRCRI Vom. Sowing was done at a spacing of 30 cm x 100 cm (33,333 plants per ha). Planting was done in 2<sup>nd</sup> week of April.

**Application of supplemental irrigation**

Application of supplementary irrigation was achieved through monitoring of soil moisture content. Level furrows were created between rows to ensure uniform distribution of water in irrigated plots. Furrows were closed to prevent runoff and a flow meter was used to measure the amount of water applied to each plot. Furrows not used for irrigation were dammed and at least one dammed furrow was created between two irrigated ones.

More number of potato roots are located at 30 cm soil depth up until flowering and increase to 60 cm depth during tuberization (Tan, 1990). Therefore, total available water was determined by multiplying the appropriate water values by 50 %.

The soil water content by weight was measured at field capacity (under 0.3 bar) and wilting point (under 15 bar) (Klute and Dirksen, 1986). Available water capacity was calculated using equation 1 and 2.

$$\text{Total available water capacity (TAWC)} \\ \text{TAWC} = (\text{FC} - \text{WPT}) \times \text{B.D} \times 100 \times \text{DRZ} \text{ (mm}^{-1}\text{)} \dots\dots\dots 1$$

Where

FC= field capacity

WPT= wilting point

B. D= Bulk density

D R Z=Depth of root zone (main root zone at the time of peak demand for water (60 cm for potato at tuber bulking)

$$\text{DNWR} = \text{TAWC} \times \text{MAD} \dots\dots\dots 2$$

DNWR= Design net water requirement

MAD = management allowable water depletion (lowest soil water content that is allowed before next irrigation so that undesirable crop stress does not occur – taken as 50 % of available soil moisture content for soil.

Hence

DNWR = (FC-PWPT) x B.D. x 100 x DRZ x MAD (%).....3

Tensiometers were installed in the field to monitor the available moisture range. Depth of placement of tensiometer was 46 - 51 cm to reflect the effective rooting depth of potato (Tan, 1990). Supplementary irrigation levels of 0, 200, 400 and 600 mm were applied to the respective plots when the available moisture content were below their expected range

**Fertilizer application and weed control**

NPK fertilizer was applied at 90 kgN – ha<sup>-1</sup>, 60 kg P<sub>2</sub>O<sub>5</sub> ha<sup>-1</sup>, 120 kg K<sub>2</sub>O ha<sup>-1</sup>at 5 WAP. Weed control was done manually using small hoe at regular intervals to keep the field free of weed.

**Data Collection**

**Climatic data**

Meteorological data including daily rainfall, sunshine hours, maximum and minimum temperature, air humidity and wind speed were obtained from the Meteorological Station of National Root Crops Research Institute (NRCRI) Vom. Evapotranspiration (ET) was obtained from class A pan of NRCRI after first irrigation application. Seasonal weather data such as air temperature (min. and max), relative humidity, wind speed, sunshine hour, average solar radiation, atmospheric pressure, site elevation above sea level, Julian day and latitude were taken and used to calculate the reference evapotranspiration (ET<sub>o</sub>) (Allen., Periera., Res and Simith, 1968).

**Water use efficiency (WUE)**

Water use efficiency was calculated as follows:

$$WUE = \frac{Yield (Kg)}{E_{ta}(m^3)} \dots\dots\dots 4$$

Where

WUE =water use efficiency

E<sub>ta</sub> = actual evapotranspiration

**Reference evapotranspiration computation**

Reference evapotranspiration ET<sub>o</sub>was computed using climatic data. The equation below was used to compute the value of the ET<sub>o</sub>. The value of the ET<sub>o</sub> obtained was then used to compute the actual evapotranspiration by multiplying ET<sub>o</sub> and the Coefficient of the crop.

$$ET_o = \frac{0.408\Delta(Rn-G) + \gamma \frac{900}{T+273} U_2 (es-ea)}{\Delta + \gamma(1+0.34 U_2)} \dots\dots\dots 5$$

Where;

ET<sub>o</sub>=reference evapotranspiration rate (mmd<sup>-1</sup>).

Δ= slope of the saturated vapour pressure curve(  $\frac{\delta e^a}{\delta T}$ )

Where e<sup>a</sup> =saturated vapour pressure (KPa) and T mean= daily mean temperature (o<sub>c</sub>)

G= sensible heat flux into the soil (MJm<sup>-2</sup>d<sup>-1</sup>).

γ = psychometric constant (Pak<sup>-1</sup>).

Rn = Net radiation flux (MJm<sup>-2</sup>d<sup>-1</sup>).

T= mean air temperature (o<sub>c</sub>)

U<sub>2</sub> =Wind speed (ms<sup>-1</sup>)

es =Saturated vapour pressure (Kpa)

ea= vapour transport of flux (mmd<sup>-1</sup>).

**Statistical Analysis**

Data generated were subjected to analysis of variance (ANOVA) using GenStat. Means that were statistically significant were separated using Least Significant Difference (LSD) according to Steel and Torries (1980).

## RESULTS

### Effects of variety and supplementary irrigation rate on water use efficiency of potato in 2017 and 2018

The main effects of variety and supplementary irrigation rate on water use efficiency of potato are presented in Table 2.

Variety had no significant effect on WUE in both 2017 and 2018.

Supplementary irrigation (SI) had significant ( $P < 0.05$ ) effects on WUE of potato in both 2017 and 2018. WUE were better under the supplementary irrigation rate of 400 m<sup>3</sup> followed by supplementary irrigation rate of 600 m<sup>3</sup>. The least WUE was obtained under the No SI condition. The effects of supplementary irrigation rate on water use efficiency in 2017 are in the following order: 400 m<sup>3</sup> SI > 600 m<sup>3</sup> SI > 200 m<sup>3</sup> SI > No SI. The trend was the same in 2018.

Interaction effects of variety x supplementary irrigation rate on water use efficiency is presented in Tables 3. Table 3 shows that the interaction effects of variety x SI rate on water use efficiency of potato was significant only under SI x variety Daimat but there was no effect of the interaction under local variety x No SI rate in 2017 and 2018. In 2017, variety Daimat x SI rate of 400 m<sup>3</sup> gave higher water use efficiency of 5.38 kg m<sup>-3</sup> while the least (0.79 kgm<sup>-3</sup>) water use efficiency was obtained under the interaction effect of variety Daimat x No SI. Similar results were obtained in 2018 planting season.

## DISCUSSION

The main effect of variety and supplemental irrigation on water use efficiency of potato showed that Supplemental irrigation had significant effect on WUE of potato but there was no significant effect of variety on water use efficiency of potato in both 2017 and 2018 planting seasons. Water was used more efficiently under SI of 400 m<sup>3</sup> compared to other levels of water applications in both seasons. The lower water use efficiency of potato under No SI could be as a result of moisture stress due to insufficient water. Dayok (2020) reported that under increasing moisture stress, photosynthesis and relative transpiration rate decreases faster in potatoes compared to other crops. This is so because potato appeared to close its stomata at relatively low moisture deficits. Ojala., Stark and Kleinkopf (1990) further stressed that if the water stress is prolonged, plants will be stunted and yield and water used efficiency greatly depressed.

The combined effect of SI and variety on WUE of potato showed that there was significant effect of the interaction of diamat x SI but there was no significant effect of the local variety x SI on water use efficiency of potato in both seasons. Variety diamat x SI of 400 m<sup>3</sup> gave better water use efficiency of potato compared to interaction of variety and the levels of SI. The result implies that though sufficient moisture is needed for potato growth, development and productivity, it is not any amount of water that is required. Dayok (2020) reported WUE of potato increases with levels of water application up to a point where any addition of more water will be waste and may even cause harm to the potato. This calls for adequate monitoring and regulation of moisture through supplemental irrigation throughout the period of the growth and development of potato.

From the study conducted, it can be concluded that:

- i. though, there was no statistical significant difference between the local variety and the improved (Daimat) variety, the improved variety had significant higher water use efficiency.
- ii. Supplemental irrigation of 400 m<sup>3</sup> gave higher water use efficiency of potato.
- iii. Interaction of Diamat variety x supplementary (400 m<sup>3</sup>) irrigation gave higher water use efficiency.

It is hereby recommended that grower should plant improved variety (diamt) and supplement the natural precipitation with supplemental irrigation of 400 m<sup>3</sup> where dry spell occurs in the study area.

**Table 2: Main Effects of Planting Date, Variety, and Supplementary Irrigation Rate on Water Use Efficiency of Potato**

	Water Use Efficiency (Kgm <sup>-3</sup> )	
	2017	2018
Variety		
Diamat	3.15	3.10
Local variety	2.27	2.55
P-value	0.25	0.31
LOS	Ns	Ns

Supplementary Irrigation		
Control	0.52	0.49
200	2.43	2.47
400	4.66	4.83
600	3.25	3.51
P-value	0.033	0.031
LOS	**	**

Note: \*= significant at 0.01, \*\*=significant at 0.05, ns=not significant, Los = level of significant

**Table 3: Interaction Effects of Variety x Supplementary Irrigation Rate on Water Use Efficiency of Potato**

Irrigation	2017		2018	
	Diamat	Local Variety	Diamat	Local Variety
Control	0.79	0.23	0.76	0.24
200	2.74	2.12	2.64	2.29
400	5.38	3.93	5.31	4.36
600	3.71	2.80	3.69	3.33
P-value	0.03	0.08	0.04	0.08
LOS	***	Ns	***	Ns

Note: \*\*\*=significant at (p<0.05), ns=not significant, W1-W4= Supplementary Irrigation at Different Level (0, 200, 400, and 600), V1= improved variety, V1= local variety, LOS = Level of Significance.

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