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Assessment of supplemental irrigation rate and planting date on water use efficiency of Potato in Kuru, Jos, Nigeria

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Abstract

The effect of supplementary irrigation (SI) rate and planting date on water use efficiency of potato (*Solanum tuberosum L.*) was conducted during the 2017 and 2018 cropping seasons at the Research Farm of the National Root Crops Research Institute (NRCRI) Kuru, Jos in Plateau State, Nigeria. The treatments consisted of two planting dates (2nd week of April, 2nd week of May) and four levels of water application (W_1 = Control, W_2 = SI of 200 m^3 W_3= SI of 400 m^3, W_4 = SI of 600 m^3). The factors were combined to give 8 treatment combinations that were laid out in a 2×4 split plot arrangement in a Randomized Complete Block Design (RCBD) and replicated three times. Water use efficiency of potato was computed using formulae. Crop and water use efficiency data collected were subjected to Analysis of Variance (ANOVA. Planting of potato in April uses water more efficiently and also gave higher potato yield. Interaction effect of planting in April x 400 m^3 SI gave higher water use efficiency of potato. It is recommended that potatoes should be planted in the second week of April and rainfall augmented with 400 m^3SI rates, especially at the period of dry-spell.

Keywords: Potato; Supplemental irrigation; Water use efficiency; planting date; dry spell

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1.0 Introduction

Potato is the most abundant 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 *et al.,* 2008).

Supplemental irrigation is a temporal intervention, designed to augment natural precipitation at the time of the dry spell. Field observations and erratic rainfall pattern over the last few years coupled with uneven distribution in Nigeria indicate that early-season drought has become severe limiting factors in agricultural production in northern Nigeria either by delaying planting or causing severe moisture stress in young seedling

Potato growers are in a great dilemma because early planting may correspond with early-season drought (dry spell) and potato is very sensitive to moisture stress. On the other hand delay planting may lead to sensitive developmental stages of the crop to extend into a period of high relative humidity in the season which allows potato blight and other diseases to thrive well and cause severe damage and yield reduction to the crop.

The window opened to the farmer may be supplemental irrigation where he could decide to plant earlier and supplement the natural precipitation in the event of a dry spell. Also, the crop may escape the incidence of blight since maturity may be reached before the relative humidity becomes conducive for its activity.

During the dry season, potato production in Nigeria is targeted to coincide with the coldest months (November - February) each year to maximize tuberization and tuber bulking. To achieve this, potato is planted in the last week of October or the first week of November. During the rainy season, the prediction time of planting depends on the onset of rains (Amadi *et al.,* 2009). The authors also reported that in Jos, Plateau, potato is planted when rain becomes stable usually between the last week of April and the last week of May each year. Hijmans and Spooner (2005) added that planting during the rainy season could be done at least 1 -2 weeks after steady rain might have commenced, which is around April or May. They added that in the dry season, the crop might be planted between November and January where it will be ready for harvest in about three (3) months after planting depending on the variety

This study aims to assess the influence of supplemental irrigation and planting date on the water use efficiency of potatoes.

2.0 Materials and methods

2.1 Site Description and Characteristics

The field experiment was conducted at the Research Farm of the Potato Program, National Root Crops Research Institute, Kuru (09°44'N,08°47'E, elevation 1,236.3 m) Jos, Plateau State. 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 maximum*), gamba grass (*Andropogon gayanus*), and elephant grass (*Pennisetum puerperium*) (Usman, 2018).

The climate is characterized by two distinct wet and dry seasons. The wet season starts from late April and ends 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).

2.2 ExperimentalTreatments and Design

The treatments consist of two (2) planting dates: D_1 (2nd Week of April) and D_2(2ndWeek of May)and four levels of water application: W_1(control; No Supplemental irrigation), W_2 (supplemental irrigation of 200 m^3, W_3(Supplemental irrigation 400 m^3) and W_4 (supplemental irrigation of 600 m^3). The factors where combined to give a total of 8 treatment combinations as follows;

$T_1 = W_1D_1$	$T_5 = W_3D_1$
$T_2 = W_1D_2$	$T_6 = W_3D_2$
$T_3 = W_2D_1$	$T_7 = W_4D_1$
$T_4 = W_2D_2$	$T_8= W_4D_2$

The treatments were laid out in a a2x4split-plot arrangement in a randomized complete block design (R C B D) and replicated three (3) times, making a total of 24 plots.

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2.3 Agronomic Practices

2.3.1 *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 the 2nd week of April and the 2nd week of May.

2.3.2 Application of supplemental irrigation

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.

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.

Total available water capacity (TAWC)

$$TAWC= (FC- WPT) \times B.D \times 100 \times DRZ\ (mm^{-1}) \ldots\ldots\ldots\ldots 1$$

Where

FC= field capacity

WPT= wilting point

B.D= Bulk density

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

$$DNWR = TAWC \times MAD \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 2$$

DNWR= Design net water requirement

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

$$DNWR = (FC-PWPT) \times B.D. \times 100 \times DRZ \times MAD\ (\%) \ldots\ldots\ldots\ldots 3$$

Hence

Tensiometers were installed in the field to monitor the available moisture range. Supplemental irrigation levels of 0, 200, 400, and 600 m^3 were applied to the respective plots when the available moisture content was below their expected range

2.3.3 Fertilizer application and weed control

NPK fertilizer was applied at 90 kg N ha^{-1}, 60 kg P_2O_5 ha^{-1}, 120 kg K_2O ha^{-1}at 5 WAP. Weed control was done manually using a small hoe at regular intervals to keep the field free of weed.

3.4 *Data Collection*

3.4.1 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 the 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_O) (Allen *et al.,* 2007).

The crop coefficient was calculated as the ratio between ET_a and ET_O (Doorenbos and Pruitt, 1977).

Where ETa = actual evapotranspiration

ETo = reference evapotranspiration).

3.4.2 Statistical Analysis

Data generated were subjected to analysis of variance (ANOVA) using GenStat. Statistically significant means were separated using the Least Significant Difference (LSD) according to Steel and Torrie (1980).

4.0 RESULTS

4.1 Climatic Data for the Study Area

Some meteorological data for Kuru during the period of study are presented in Table 1. The monthly rainfall recorded during the period of study ranged from 13. 5 to 308. 7 mm for March and August respectively in 2017. the total annual rainfall in 2017 stood at 1588 mm while the mean annual rainfall was 132 mm. The maximum temperature (30° C) was recorded in March, and the least temperature (12°C) was recorded in December. Relative humidity varies from 31% in January to 84% in August. The sunshine was highest (277.3 hrs.) in February to 68 hrs. Least, in September.

In 2018, the highest amount of rainfall (310.8mm) was observed in August while the least (10.05 mm) was in February (Table, 1). The total rainfall for 2018 was 1525.25 mm while the mean rainfall for the period of study in 2018 was 127.10 mm. Temperature varies from 22°C (lowest) to 26°C (highest). Relative humidity varied from 18% in January to 80% in July 2018. The highest amount of sunshine (369.3

Table 1: Climatic Data for Kuru in Jos

Month	**Rainfall** (mm)	**Temperature (°C)** min.	max.	**Relative humidity** (%)	**Sunshine** (hrs.)
January	0	13	27	31	252.8
February	0	16	30	25	277.3
March	13.5	18	31	34	240.8
April	96.2	20	28	59	189.5
May	143.8	19	28	71	186.4
June	202.3	18	25	80	150.2
July	214.8	18	23	81	123.8
August	308.7	17	22	84	770
September	256.3	17	25	78	68.3
	276	17	28	51	200.6
October					
November	76.4	14	28	32	276.7
December	0	12	28	34	269.2
			2018		
January	0	11	26	18	276.6
February	10.05	15	25	20	265.4
March	36	19	26	22	223.9
April	28	18	26	56	257.1
May	218.5	19	25	64	212.2
June	156.4	17	22	73	165.3
July	283.3	18	24	80	148.2
August	310.8	18.0	26.0	75.0	147.3
September	279.0	17.0	27.0	77.0	137.9
October	196.0	17.0	29.0	62.0	184.4
November	7.2	13.0	30.0	23.0	369.3
December	0.0	12.0	27.0	17.0	278.4

Source: NRCRI Kuru Meteorological Station (2017/ 2018) hrs.) was recorded in November while the least amount of sunshine (148.2 hrs.) was recorded in the mount of July.

4.2 Main effects of planting date and supplemental irrigation rate on water use efficiency of potato

The main effects of planting date and supplemental irrigation (SI) rate on water use efficiency of potato are presented in Table 2.

The results showed that planting date had a significant ($p < 0.05$) effect on water use efficiency of potato in the 2017 and 2018 planting seasons. In 2017, planting potato in April gave better water use efficiency (WUE) of 5.15 kgm^{-3} compared to planting potato in May which gave WUE of 0.27 kgm^{-3}. Similar results were obtained in 2018 where potato planted in April produced 5.31 kgm^{-3} compared to 0. 35 kgm^{-3} water use efficiency was produced when the potato was planted in May.

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

Table 2: Main Effects of Planting Date and Supplemental Irrigation Rate on Water Use Efficiency of Potato

	Water Use Efficiency (Kgm^{-3})	
	2017	2018
Planting Date		
April	5.15	5.31
May	0.27	0.35
P-value	0.000	0.000
LOS	*	*
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

Combined effects of planting date and supplemental irrigation rate on water use efficiency of potato

Results in Table 3 showed that the interactive effects of planting date x SI rate on water use efficiency of potato were significant ($p < 0.05$) only at planting in April x SI rate but there were no significant combined effects of plating in May x SI rate both in 2017 and 2018 planting seasons. Planting in April x SI at 400 m^3 gave the higher water use efficiency of 8.97 kgm^{-3} followed by planting date April x SI at 600 m^3 with 6.27 kgm^{-3} while the least water use efficiency was obtained under the combined effects of planting in April x No SI in 2017. The results show a similar trend in the 2018 planting season.

5.0 **DISCUSSION**

5.1 _Effects of Planting Date and Supplemental Irrigation Rate on Water Use Efficiency of Potato

Planting date had a significant effect on the WUE of potato. Potato planted in April uses water more efficiently compared to planting in May. The WUE of potato planted in April was 4.96 kgm^{-3} more than when planting was delayed to May. Ojala *et al.*(1990) reported that water stress during tuber initiation and early bulking appears to reduce potato yield by increasing tuber malfunction.

Supplemental irrigation showed a positive relationship with the yield of potatoes, under increasing soil moisture stress, photosynthesis, and relative transpiration rate decrease faster in potatoes compared to other crops. This is so because the crop appears to close its stomata at relatively low soil moisture deficits. Ojala *et al.* (1990) further stressed that if the water stress is prolonged, plants will be stunted and yield significantly reduced.

It has been said that SI aims to increase the total farm yield and WUE by maximizing the area that benefits from the water available (Caliandro and Boari, 1992). Shuhao *et al.* (2013) has also reported an increase in evapotranspiration (ET) and tuber yield with SI on potato, and consequently,

WUE was improved.
It is concluded that planting potatoes in April gave better water use efficiency compared to planting in May. Similarly, supplemental irrigation of 400m^{3}gave better water use efficiency to other supplemental irrigation rates used in this study. Early planting (second week of April) is recommended. Supplemental irrigation of 400m^{3}is recommended in the study area.

Table 3: Interaction Effect of Planting Date x Supplemental Irrigation on Water Use Efficiency of potato

	2017		2018	
Irrigation	**April**	**May**	**April**	**May**
Control	0.84	0.19	0.76	0.24
200	4.52	0.34	4.49	0.39
400	8.97	0.35	9.27	0.44
600	6.27	0.24	6.71	0.30
P-value	0.001	0.08	0.001	0.05
LOS	**	Ns	**	Ns

Note: **=significant at (p<0.001), ns=not significant), D1= Planting Date at 2nd week of April, D2= Planting Date at 2nd Week of May, W1-W4= Supplemental Irrigation at Different Level (0, 200, 400, and 600), LOS = Level of Significance

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