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EFFECT OF WATER STRESS ON GROWTH AND YIELD OF POTATO (*Solanum* Spp.) VARIETIES IN JOS, PLATEAU STATE, NIGERIA

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Abstract

This study was conducted in Jos North Local Government Area of Plateau State, Nigeria to investigate the effect of water deficit on the growth and yield of two varieties of Potato. In this study, three (3) regulated water application depths at 50, 75 and 100% with respect to daily evapotranspiration values were applied to Nicola yellow and Marabel Irish potato (*Solanum* Spp.) varieties. The experiment involves six treatment laid in a Randomized Complete Block Design (RCDB). Data were collected from week three (3) to week eight (8) and analyzed at $\alpha < 0.05$. The results showed that number of leaves show no significant difference ($p>0.05$) for both -varieties during the course of the study. However, plant height and collar girth only showed significant statistical ($p<0.05$) difference due to variety at week four (4) and week one (1) respectively. Nicola yellow yield of 14.19 t/ha was significantly higher ($p<0.05$) than that of Marabel at 9.61t /ha. As water depth increases from 50% to 75% and 75% to 100%, there was a corresponding significant ($p<0.05$) yield increase by 21.66% and 15.78% respectively. The results indicated that Nicola yellow shows more resistant to water stress when compared to Marabel. Nicola yellow cultivation combined with water depth level of 75% can successfully be adopted to obtain optimum yield in Irish potato cultivation under limited water condition in the study area.

Keywords: Water Stress, Nicola, Marabel, Potato, yield

Introduction

The exponential growth in population has led to food shortage; also water scarcity has led to competition for alternative uses of fresh water, this has necessitated a rapid expansion of irrigated agriculture throughout the world (Awulachew *et al.,* 2005). These aforementioned circumstances also prevail in Nigeria and a host of other African Countries with ever increasing population and heighten risk of drought (Wuyep 2013). Nigeria has a continuous population growth of 4.82% per annum, with a food demand growth of 6.5% annually (UN, 2017; therefore efforts has to be put in place to tackle food insecurity, among many options

is the use of irrigation (Liverpool-Tasie *et al.*,2016; NBS 2016).

Irrigation is an agricultural practice designed to compliment and/or supplement the deficiency of climate resulting in less water being available for agriculture (Shock, 2002;Oguntunde, 2004). Deficit irrigation is a strategy which allows a crop to sustain some degree of water in order to reduce irrigation costs and potentially increase revenue (Heng *et al.,* 2009). Oguntunde (2004), stated that deficit irrigation can lead, in principle, to increased profits where water are high or where water supplies are limited.

Deficit irrigation has proved successful with a number of crops in various parts of the world. Deficit irrigation in Potatoes, may however be difficult to manage because reductions in yield and quality can result from even brief periods of water stress following tuber set (Bashir and

Duru, 2000). Potatoes varieties differ in tolerance to water stress (Mofoke, 2002). The adaptation of new cultivars by growers and processors makes it desirable to re-examine deficit irrigation. (Zhang *et al.,* 2004).

Irish potato is a seasonal crop grown in temperate zones all over the world but primarily in the northern hemisphere (FAOSTAT, 2012). It is the world's fourth largest crop after wheat, rice and maize. Irish potato has the potential to relieve the pressure of food insecurity on the rural poor farmers due to its short maturity period of about 60 to 90 days which makes cultivation possible thrice a year (Okunade and Ibrahim, 2011). Thirty percent of world's potato production is from developing Countries. In Nigeria, potato is produced in several northern states such as in

Borno, Kaduna, Kano and Sokoto during the colds and dry periods. However 85% of potato produced comes from Jos, Plateau (Mohammed *et al.,* 2015).

Nigeria is located in the tropics where two-third of her total land area is arid and semi-arid with mean annual rainfall of 250-1300 mm (Wuyep, 2013). Okai *et al*. (2002) reported that crop production in Northern Guinea Savanna of Nigeria is being adversely affected by insufficient water supply. Water stress has been identified as one of the constraints to potato production in the tropics (Mofoke, 2000). Raji (2001) also, reported that in arid and semi-arid lands, water is the most limiting factor for plant growth, and rain fed agriculture has low and unpredicted yields.

Although formal potato research in Nigeria dates from 1940, there is still inadequate information on the stress resistant capacity of potato in the study area. Farmers do not have enough information on efficient water management techniques that would avert stress on potato and ensure efficient water use (Mofoke, 2000; Wuyep, 2013).

The right cultivar to use in tandem with climate and soil (especially areas prone to drought) in order to ensure maximum yield is also a major hindrance in irrigated potato farm (Zhang, 2016). Mofoke (2000) and Fatai (2001) worked on potato irrigation, but did not recommend any irrigation scheduling for the crop in the study area or state in specific terms the variety or varieties which are more resistant to water stress common in the study area, hence the reason for this research.

Jos Plateau has a high altitude and thus a cool climate, which promotes growth of potatoes in the area (Wuyep *et al,* 2013). Better yield of potatoes are obtained in regions where the climate is tempered by altitude (1800-2300m) or, alternatively at a low altitudes; provided the crop is grow during the coolest season (the dry season). Potato prefers a light, moist and well drained soil. It also can tolerate slightly acid soil (pH of 5.5-6.0) (Dimlong, 2012).

The information obtained will help to reduce the extensive water loss through evapotranspiration (ET) and develop efficient water management techniques such as irrigation scheduling that will ultimately reduce water stress on potatoes and ensure efficient water use (Wuyep 2013).

Location of the study area

This experiment was conducted on a research farm behind the Federal College of Forestry, Jos Plateau State, Nigeria. The college is located on latitudes 9º 45'N and longitude 8º 54'E on an altitude of about 180 metres above sea level. The area lies within the Southern Guinea Savannah ecological zone. The mean rainfall for the area is about 1250mm and a mean temperature of 35.5ºC (FAOSTAT, 2015).

Soil Physical and Chemical Properties

Soil samples were taken from the field at a depth of 30cm from the soil surface. Samples collected were taken to the Soil Science Lab of the Federal College of Forestry for analysis to determine the particle size distribution, textural class, bulk density, field capacity, electrical conductivity and pH.

Land preparation and field layout

The site was manually tilled and prepared, the plot size was 2x2m and separated by 1m buffer between blocks, the experiment consists of factorial combination of irrigation schedules at 100, 75 and 50% depth of daily water requirement and two varieties of Irish potatoes, Marabel and Nicola Yellow, laid in a randomized complete block design (RCBD) resulting into six (6) treatments replicated thrice. The treatment descriptions are presented in Table 1.

Table 1: Treatments Description

Treatments	Description
T1= ($V_1$100)	Variety one and 100%
T2= ($V_1$75)	Variety one and 75%
T3= ($V_1$50)	Variety one and 50%
T4= ($V_2$100)	Variety two and 100%
T5 =($V_2$75)	Variety two and 75%
T6 =($V_2$50)	Variety two and 50%

V1 = Nicola Yellow, **V2=** Marabel

Agronomic Practices

The Irish Potato cultivars were planted on the 10th of February, 2020. A single seed was planted at a spacing of 20 x 20cm and at a depth of 10cm. Germination took place fourteen days after planting with 75-80% germination rate. Each experimental plot consists of 25 plants giving a total of 450 stands in the experimental layout. Five (5) plants per plot were randomly selected and tagged making a total of 90 plants to represent the entire population. Weeding was done manually at eight (8) weeks after sowing. NPK 20-10-10 fertilizer was applied at a rate of 350kg/ha NPK on the plot on the 7th of March, 2020 – four (4) weeks after sowing. Furthermore, during the four weeks, equal depths of water were applied to all the treatments, after which treatment were imposed on all the plots.

Data Collection

Growth Parameters were collected at week three to weeks eight after sowing (WAS).The plants were harvested manually using hoe on the 4th of May, 2020. Each plot yield was bagged and weighed using a weighing balance.

Statistical Tool and Data Analysis

The data obtained from measured plant parameters were subjected to analysis of variance (ANOVA) for Complete Randomized Block Design (RCBD) and analyzed using SAS 2000 version. The differences among the treatments were determined using least significant difference (LSD) at $P < 0.05$ probability level.

Results and Discussion

Table 2 shows that the soil is sandy loam, the soil bulk density of the experimental area ranges from 1.28-1.63 g/cm^3. It is generally desirable to have soil with low bulk density (< 1.5 g/cm^3) for optimum movement of air and water through soil as reported by Sher *et al.,* (2016) because Soils with bulk density higher than 1.6 g/cm^3 tend to restrict root growth (Ojo, 2013).The mean soil pH was 6.12, which shows that the soil is slightly acidic and suitable for potatoes production (Dimlong, 2012; Sher *et al.,* 2016).

Table 2: Soil Physical Properties of the study area

Bulk Density (g/cm^3)	pH	EC (ohms/cm)	Clay (%)	Silt (%)	Sandy loam (%)	Field Capacity (ml/L)
1.28	5.91	0.002	8.5	7.50	84.3	40.0
1.28	6.00	0.001	6.5	17.5	76.0	44.0
1.63	6.46	0.002	8.2	15.8	76.0	42.0

Effect of variety and water stress on leaf morphometric parameters at week 3

Table 3 shows the effect of variety and water stress on leaf morphometric parameter at week 3, number of branches and collar girth between the two varieties differs significantly ($p<0.05$), Water stress at 50% had higher number of leaves, number of branches, though water depth at 100 had higher plant height and collar girth. The interaction between water depth and varieties were not significant ($p>0.05$), it is assumed that same quantity of water was applied; hence there may not be any significance.

Table 3: Effect of variety and water stress on leaf morphometric parameters at week 3

Parameters	**Variety**		**P value**	**Water stress**				
	1	2		50	75	100	**P value**	**VXWD**
Plant height (cm)	8.00	8.20	**0.12**	8.15	7.51	8.65	**1.24**	**0.26**
No of branches	3.30a	2.8b	**0.05***	3.33	2.83	3.00	**4.81**	**1.35**
No of leaves	21.50	17.10	**0.08**	22.40	16.93	18.60	**0.19**	**0.18**
Collar girth (mm)	0.40a	0.30b	**0.004***	0.35	0.35	0.37	**0.62**	**0.57**

VXWD = interaction between water stress and variety, *1 = Nicola Yellow 2= Marabel*

Effect of variety and water depth on leaf morphometric parameters at week 4

Table 4 shows that Plant height differs significantly ($p<0.05$) between the Marable and Nicola

Table 4: Effect of variety and water stress on leaf morphometric parameters at week 4

Parameters	**Variety**		**P value**	**Water depth**				
	1	2		50	75	100	**P value**	**VXWD**
Plant height (cm)	10.7b	11.00a	**0.04***	10.41	11.32	10.69	**0.65**	**1.68**

No of branches	4.19	3.47	**0.08**	3.98	3.63	3.87	**0.75**	**0.84**
No of leaves	32.5	27.5	**0.11**	30.40	28.07	31.57	**0.62**	**0.55**
Collar girth (mm)	0.49	0.41	**0.15**	0.46	0.44	0.44	**0.90**	**0.74**

VXWD = interaction between water stress and variety, 1 = Nicola Yellow 2= Marabel

yellow at week 4, though number of branches, number of leaves and collar girth were statistically similar ($p>0.05$). Marabel had higher plant height than Nicola Yellow. Water depth was statistically similar ($p>0.05$) for plant height, number of branches, number of leaves and collar girth. Water depth at 50% had the least plant height, though water depth at 75 had higher plant height. The interaction between water depth and varieties were not significant ($p>0.05$) for all the parameters at week 4, at this stage the effect of the water stress may make any significance effect

Effect of variety and water stress on leaf morphometric parameters at week 5,6 and 7

Number of branches differs significantly ($p<0.05$) between the two varieties at week 5,6 and 7 plant height, number of leaves and collar girth were at par at ($p<0.05$), the interaction between water stress and varieties were not significant at week 5,6 and 7.

Table 5: Effect of variety and water stress on leaf morphometric parameters at week 5

Parameters	**Variety**		**P value**	**Water depth**				
	1	**2**		**50**	**75**	**100**	**P value**	**VXWD**
Plant height (cm)	12.0	12.30	**0.70**	11.8	12.7	12.0	**0.65**	**0.34**
No of branches	4.60a	3.90b	**0.05***	4.27	4.30	4.2	**0.98**	**0.80**
No of leaves	46.5	45.8	**0.83**	47.1	45.3	46.1	**0.90**	**0.44**
Collar girth (mm)	3.00	2.80	**0.11**	2.80	3.00	3.10	**0.24**	**0.20**

VXWD = interaction between water stress and variety, 1 = Nicola Yellow 2= Marabel

Table 6 : Effect of variety and water stress on leaf morphometric parameters at week

Parameters	**Variety**		**P value**	**Water depth**				
	1	**2**		**50**	**75**	**100**	**P value**	**VXWD**
Plant height (cm)	14.10	14.80	**0.78**	14.21	14.77	14.29	**0.40**	**0.41**
No of branches	6.00a	5.71b	**0.03**	6.33	5.77	5.40	**0.34**	**0.16**
No of leaves	53.24	55.24	**0.74**	56.07	53.70	52.97	**0.57**	**0.51**
Collar girth (mm)	4.02	4.04	**0.80**	3.97	4.12	4.00	**0.47**	**0.42**

VXWD = interaction between water stress and variety, 1 = Nicola Yellow 2= Marabel

Table 7: Effect of variety and water stress on leaf morphometric parameters at week 7

Parameters	**Variety**		**P value**	**Water depth**				
	1	**2**		**50**	**75**	**100**	**P value**	**VXWD**
Plant height	17.59	17.78	**0.63**	17.61	17.64	17.81	**0.90**	**0.61**

(cm)								
No of branches	8.84a	8.58b	**0.05***	8.27	8.73	9.13	**0.35**	**0.73**
No of leaves	62.73	66.98	**0.10**	64.43	65.13	65.00	**0.97**	**0.77**
Collar girth (mm)	5.25	5.35	**0.62**	5.23	5.34	5.33	**0.89**	**0.62**

VXWD = interaction between water stress and variety, 1 = Nicola Yellow 2= Marabel

Effect of variety and water stress on leaf morphometric parameters at week 8

The vegetative growth parameters evaluated in this research were not significantly different with respect to varieties considered and the water stress imposed at 50, 75 and 100% at week 8. However, numerical increased was observed for all the vegetative growth parameters as time progressed from week 3 to 8 but at different rates, this is similar to what Deshi *et al.* (2016) reported in their research on the pattern of growth of five varieties of potato (*Solanum tuberosum* L.) during three season in Jos Plateau, Nigeria where the number of leaves increased with time in all the varieties used, varying within varieties and with year of study, also plant height in their study increased with time till cycle ends and it varied with variety and year of study

Table 8: Effect of variety and water stress on leaf morphometric parameters at week 8.

Parameters	**Variety**		**P value**	**Water depth**				
	1	**2**		**50**	**75**	**100**	**P value**	**VXWD**
Plant height (cm)	17.22	17.77	**0.24**	17.06	17.63	17.80	**0.40**	**0.56**
No of branches	8.84	8.49	**0.27**	8.27	8.67	9.07	**0.15**	**0.68**
No of leaves	51.98	54.42	**0.16**	52.63	53.50	53.47	**0.89**	**0.91**
Collar girth (mm)	5.25	5.34	**0.65**	5.23	5.34	5.32	**0.87**	**0.61**

VXWD = interaction between water stress and variety, 1 = Nicola Yellow 2= Marabel

Egbe *et al.* (2012) reported in their research on the performance of improved potato varieties in Makurdi, Nigeria that all these vegetative growth characters showed an upward trend of growth, the number of branches and collar girth increased slowly from week 3 to a maximum in week 8 for both varieties. Plant height for Marabel differed statistically ($p<0.05$) at week 4 compared to Nicola yellow while collar girth differed statistically ($p<0.05$) only at week 3. Number of leaves show no significant difference ($p>0.05$) between the two varieties from week 3 to week 8. However, Nicola Yellow consistently had the highest number of branches for week 3 to week 8 being statistically significant ($p< 0.05$) in weeks 3, 5, 6 and 7. This agrees with Wailare and Madu (2018) who reported in their research on yield variability of Irish potato as affected by cultivars and sowing date in the Sudan Savanna zone of Nigeria that, Nicola Yellow produces more branch numbers than Marabel. Plant height and number of leaves shows a sharp increase from week 3 to week 7 for both varieties, at week 8 both this parameter shows a slight decrease for both varieties. Plant height and number of leaves parameters for Nicola yellow and Marabel are statistically at par (with the exception at week 4 for plant height). The varietal difference purely accounted for the germination differences agreeing with Dibal (2005) who worked on the varietal response of irish potatoes to irrigation scheduling in the Northern Guinea-Savannah Zone of Nigeria.

Water depth levels at 50, 75 and 100% did not show significant difference ($p>0.05$) for all vegetative parameters for all weeks recorded. It agrees with Hassan *et al.* (2002) report that initial vegetative stages of potato are not sensitive to water stress.

The interaction between water depth and varieties was not significant ($p>0.05$) for all the parameters (plant height, number of branches, number of leaves and collar girth) studied from week 3 to week 8, this is similar to Dibal (2005) who also noted that irrigation scheduling treatments had no effect on vegetative growth parameters and flowering for all four varieties of Irish potatoes used in his study , this also agrees with Hassan *et al.* (2002) report, that initial vegetative stages of potato are not sensitive to water stress.

Effect of variety and water stress on yield

Table 9 shows the effect of variety and water depth on yield of varieties of potato considered in this study, the effect of water stress and variety independently had significant ($p<0.05$) effect on yield of Nicola yellow and Marabel. Nicola Yellow had higher significant ($p<0.05$) yield of 1419.44 kg/ha compared to that of Marabel at 961.11 kg/ha. This result agrees with the research of Wailare and Madu (2018) that reported a higher number of tubers produced per plant were highly significantly ($p\leq 0.01$) affected by variety. Nicola yellow and Nicola GL produced higher number of tubers per plant (kg), followed by Ditta, Marabel and Bertita, which respectively produced almost similar number of tubers per plant. The results is similar as that of Deshi *et al.* (2016) who reported that total number of tubers was significantly ($p< 0.05$) influenced by variety in 2010 and 2012.

Table 9: Effect of variety and water stress on yield

Parameter	1	2	P value	50	75	100	P val	WD XV
Yield	14.19a	9.61b	0.23	12.66c	13.61b	16.16a	0.006	0.68

VXWD = interaction between water stress and variety, 1 = Nicola Yellow 2= Marabel

Water stress had significant effect ($p<0.05$) on the yield, this implies that the lower the water stress with respect to daily water requirement, the better the yield. Water stress had significant ($p<0.05$) effect on yield as shown in Table 9, as water reduces from 50% to 75% it resulted to a significant ($p<0.05$) percentage yield increase of 21.66% and when water stress reduced from 75% to 100% it resulted in a corresponding significant ($p<0.05$) yield percentage of 15.78%. This result is in agreement with those of Borza *et al.* (2010) who found out that deficit irrigation had significant effect on the yield of potato.

However, there was no significant interaction ($p=0.68$) between variety and water stress on the yield, which implies that the synergy between variety and water stress did not amount to increase in the yield. This seems to agree with what Serhat and Abdurrahim (2010) reported, they researched on the water-yield relationships in deficit irrigated potato and reported that the Interaction between water depth and variety show no significant effect on the yields, which is also similar to what Dibal (2005) reported that the interaction between varieties and irrigation schedules show no significant ($p>0.05$) effect on yield.

Conclusion

Nicola yellow had a total yield of 14.19 t /ha which was significantly higher than the 9.61 t/ha total yield recorded for Mirabel. Nicola yellow is more resistant to water stress when compared with Marabel in the Jos, Nigeria.

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