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POTENTIAL YIELD OF IRISH POTATOES UNDER SURFACE IRRIGATION IN SEMI ARID ZONE OF BENUE VALLEY AT MAKURDI, NIGERIA

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ABSTRACT

Irish potato is a whether sensitive crop, depends on a regular water supply, to secure high quality yields. Abiotic stress factors, such as drought, heat and salinity, have severe, adverse effects on growth and yield. The production of Irish potato in any part of Nigeria is an integral part of the rural economy, as it is cultivated as a rain-fed and irrigated crop. Timing of both the rain fed and irrigated cultivation is often misplaced, which adversely affect growth and yield in some hot climate areas in some States in Nigeria.The research was experimented with cultivation of Irish potatoes under Makurdi climate in Benue valley - an area believe to be hot, not suitable for cultivating Irish potatoes. The soil of the area was studied, to be sandy clay loam, with a pH of 6.67, which is suitable for the production of Irish Potato. Three 3 varieties of Irish potatoes (Merabel,Nicola and Bertista) were used for the study.25 heads each of the seedlings was planted. Merabel produced the lowest tubers of 86, Nicola 129 tubers and the highest by Bertista with 181tubers. Bertista proved resistant to high temperatures, therefore the most suitable to be cultivated under Benue valley climate at Makurdi.

Keywords: whether sensitive crop, Abiotic stress factors, such as drought, heat and salinity, have severe, adverse effects.

1. INTRODUCTION

Irish potato (*Solanum tuberosum*) is said to have originated from the highland of Boloivia in South America (Martin and Leonard, 1949; Ifenkwe and Nwokocha, 1987). The spread of the crop outside its centre of origin was mainly by deliberate introduction. Irish potato is ranked first in energy production per hectare per day, significantly above cassava and cereals. It is a lover of cool climate and therefore requires a cool growing season with a moderate and well distributed rainfall of about 800 mm during growing seasons with no prolonged dry weather. It could be grown under rain-fed condition or irrigated, but waterlogged areas are unsuitable. Temperatures higher than 27˚C are unfavorable for the production of economic size tubers. Observations have shown that temperature ranges of 21˚C – 26˚C is required for sprouting of the tubers (Ahmed, 1980). Irish potato was introduced into Nigeria early in the 20th Century by European miners in Jos Plateau state.

Potatoes are important staple food worldwide and climate change adversely affect potato production primarily in warm, dry climates(WPC,2021). About 95% of Irish potato produced in Nigeria comes from Jos Plateau State, which has near temperate climatic conditions that favour Irish potato production (NRCRI, 2005). According to Okonkwo *et al.*(1995), Irish potato can be grown on the Obudu Highlands, Mambilla Plateau and Biu in Cross Rivers, Taraba and Borno State respectively. Research also revealed that during the cold harmattan periods of November to February, Irish Potato can grow under irrigation in most Northern States of Nigeria (NRCRI,

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2005). A modeling study carried out at the International Potato Center indicates that most potato producing countries experience considerable declines in potato yield when temperature change was the major driver (Hijmans, 2003).

1.1 Irish Potato Crop and Climatic Factors

About 70% of the available agricultural land is suitable for potato production which is located at an altitude of 1500 to 3000 m.a.s.l with an annual rainfall between 600 and 1200 mm (Gebremedhin et al. 2008; Zamil *et al.*, 2010).

The rate of moisture use by the crop depends very much on the weather condition. On a hot summer day with a shade temperature higher than 40°C and a strong dry northerly wind, moisture losses from a crop in full leaf cover can be as high as 12 mm in 24 hours. At the other extreme, overcast weather with little wind and very high humidity can result in transpiration losses lower than 1mm (kopoku-Ameyaw, 2001).

1.1.1 Varieties of Irish Potatoes

The most common types of Irish potatoes are red or white. Most red varieties can be stored longer than do white varieties; but most white varieties have better cooking qualities than red varieties. Therefore, after harvesting ,the whites are used first and the reds are stored for later use (ASTC, 2019).In Nigeria, there are about 5 varieties of seed potatoes that are high yielding and highly resistant to diseases (ASTC, 2019). These include:

Nicola: This variety come in two type, yellow and green leafs hence the green leaves is the old type but recently improved Nicola variety is the yellow leaf and is one of the high yield variety today, it take up to 75-90days to matured depending on climate condition and soil suitability. Mostly consume best by frying as chips and food processing industries. Produces best both rain fed and irrigation.

Bertista: Dark green leaf in physical appearance, red tuber flesh, produced both rain fed and irrigation, and matured within 60-75 days.

Diamant: Green leaf, doted design tuber flesh and produced best during irrigation, it is a climatic and soil temperature sensitive variety and matured in 75-90 days.

Kondor: Dark green in physical leaf appearance, high yield during rain fed and irrigation during cool hamatan, and matured 90-120days

Mirabel: This is one the must high yield variety today, Green leaf in physical appearance, very sensitive to climatic condition, soil type and temperature, tubers storage facilities (room temperature) which may result in tubers roten. It takes up to 90days to mature. (ASTC, 2019).

1.2 Cultivation of Irish Potato in Nigeria

In Nigeria, Plateau state has the highest altitude and therefore, cool climate which is favourable for the development of the Irish Potato crop in its natural state. The crop is efficient in converting land, labour, water and capital into a highly yielding production. It has a shorter growing cycle of about 60 to 90 days than most other tuber crops in the tropics. Irish potato is an important staple food as well as raw materials for industries. In order to meet the demand for industrial and human consumption, the yield per hectare needs to be improved. Such imminent improvement could be achieved through efficient management and monitoring of agro-climatic parameters. Several studies have been conducted towards improving the yield of Irish potato on the following

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areas: effect of stem thinning on yield and vegetative characteristics (Damkor, 1983); growth/ development and yield in varieties of Irish potatoes(Ajala,1981); flowering behaviour of some varieties(Szlachetha,1982); water stress and related analysis on different varieties of Irish potatoes, Wolfe *et al,*1983; Susnochi and Shimshi,1985).

The crop breeders have developed varieties of Irish potato, which are capable of responding to improved cultural practices, (Okonkwo 1992). In other to sustain these improvements, an appraisal of climatic parameter affecting Irish potato has become necessary. This increase could be attributed to advances in agricultural technology such as the introduction and provision of extension services, new adventures in irrigation of Irish potato as well as way of diversifying its sources of livelihood (Wuyep, 2012).

However, despite the advanced techniques used in crop husbandry, the yield of Irish Potato under Nigerian space is still very limited. Climatic conditions of different states in Nigerian appears to be the major factor influencing the spatio-temporal variations in the yield of Irish potatoes, hence, the need for continues research on various locations, soil conditions, temperature, irrigation methods, water availability and further means of manipulation of the climate conditions to suite the production of Irish potato under any State climate in Nigerian.

2.MATERIALS AND METHODS

2.1 Study Area

Makurdi (the study area) lies between latitudes 7^0 45'and 7^0 52'N of the equator and longitude 8^0 35' and 8^0 41'E of Greenwich meridian. During rainfall, a lot of runoff is recorded that end up in the Rivers. The area lies in the Northern Guinea Savannah agro-ecological zone and with an average annual rainfall of between 1077-1140mm (NMI, 2017). The area is highly agriculturally productive as it produces a variety of crops like cassava, soybean, guinea corn, yams, sesame, rice and groundnuts for the country(referred to as 'Food Basket of Nigeria'.

2.1.1 Climate of the Area

The study site was Federal University of Agriculture Makurdi; it lies within the humid zone with little seasonal temperature variation throughout the year, referred to as a local steppe climate. Two major seasons do exist, the rainy season between April and October and the dry season between November and March (Anthea, 2015). The temperature in Makurdi averages 27.58°C. The average annual rainfall is 690 mm. The least amount of rainfall occurs in March. The average in this month is 10 mm. The greatest amount of precipitation occurs in August and September, with an average of 260 mm. The temperatures are highest on average in March, at about 37.0°C. The lowest average temperatures in the year occur in January, with 18.4 °C (NMI, 2019).

2.1.2 Experimental Site

The experiment was conducted at the experimental fish pond site, University fish farm Department of Fisheries and Aquaculture, University of Agricultural Makurdi, Benue state.

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2.1.3Soil properties of the study site

Since Irish potato perform best in loose soil, properties of the study area was analyzed according to standards (Schoeneberger et al*. 2012, USDA, 2014**);** the following properties were determined:*

- *Physical properties of soil; include soil texture, bulk density, water-holding capacity, organic matter content, soil structure, soil colour, and soil consistence**.***
- *Chemical properties of soil; include cation exchange capacity and soil pH.*

2.2 Materials used for the Study

The materials used to carry out the study are as shown in Table 1 below.

2.2.1 Irrigation Water Source

The source of water used for the experiment were taken from the water reservoir of the University water buster pump unit opposite the fish farm through a pipe attached at upper point of the reservoir which convey excess water (to avoid over flooding) and send into the University fish pond through an underground pipe. During this study, the water flowing into the fish pond was channel to the study plot throughout the periods of irrigation schedule.

2.3 Design Considerations.

In designing for this experiment, three blocks (A,B and C) with the same equal size was considered, that can accommodate 25 heads of three different variaties of Irish potato in each block.

Table 1: Materials Used for Land Preparation, Measurement, Soil Test.

S/N	*Materials*	*Uses*
1	***Meter rule***	***Measures plant spacing, growth of crop and length of basin layout.***
2	***Measuring tape***	***Measures size of blocks and height of bund***
3	***Big and small hoe***	***For clearing, digging and designing the basin layout***
4	***Germinated Irish potato seeds (three different varieties)***	***For the planting***
5	***Soil Moisture Content Test Instruments***	***Obtain mass of soil samples***
	Weigh Scale	
	Oven	***Dry soil sample***
	Cans	***Collect soil sample.***
6	***Bulk Density Test Instrument; Set of sieves, sieve shaker, weigh balance, brush, mortal/piston***	***Determine the soil's bulk density.***
7	Chemical fertilizer, (NPK 20-10-10)	Additional plant nutrient for growth and yield

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8	Organic manure (cow dung)	of crop Effective crop yield and qualitative product
9	***Three different varieties of Irish potatoes (Mirabel 25 tuber seeds, Nicola yellow, 25 tuber seeds and Bertister, red flesh 25 tuber seeds).***	***The crop for the experiment.***

2.3.1 Land preparation and planting

After choosing the suitable site for the study, the following land preparations followed;
Clearing the land: *Tall grasses, shrubs and stones were completely removed from the field.*
Cultivation: *the soil was dug 15-20cm depth using big and small hoe (Plate 1).*

2.3.2 Design of experimental plots

After cultivation, the plot was designed into 3 blocks of strip basin of equal sizes (A,B,C) in square shape of 140 by 140cm, and a water channel of 450cm length, 30cm width from water source. The shape of the basin was squared in four equal sizes, bounded by bunds, the bunds formed the wall of the blocks and water channel, and planting spacing was measured 30cm apart
(Plate 2).The layout was design such that, water into each block was by gravitational flow. Thus, the following were the design specifications perculiar for basin irrigation (Brouwer et al, *2001)**:***
Width size of blocks = 140 by 140cm (L×W); Water channel; length = 450 by 30cm (L×W), Bund = 15cm height.
Planting: *Three varieties of Irish potatoes(ASTC,2019), were selected for this study,(Merable, Nicola and Bertista) (plate 3) below. They were planted accordingly on the blocks (A,B,C) as shown in plate(7). Potato crops normally need 25 to 40 cm spacing apart depending on the variaties, for access to ventilation and enough spacing for tuber initiation. For this study, 25 seeds each of the selected varieties were planted according to the following criteria:*

Plate (a): Land clearing *Plate (b): Designing of the three blocks*
Plate 1: Land Clearing and Making of Experimental Plots

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Plate (a): Making holes to 15cm depth *Plate (b): planting heads at 20cm spacing*

Plate 2: Making of holes and planting process

Plate c: Bertista *Plate a: Merabel* *Plate b: Nicola*

Plate 4: *Variety of Seeds Planted*

crop and moisture content of the soil. From Evaporation test carried out on the experimental field 0.65cm/day (Ogbe *et al*, 2019).

2.3.3 Irrigation water schedule

The irrigation was schedule for 2 times a week, with 3 days interval, once a day from week 1 to 5 (plate 5), 3 times a week with 2 days interval, once a day from week 6 to 10 (plate 6), and 2 times a week at week 11 and harvested at week 12(plate 7).

Various studies have shown that one of the promising irrigation strategies might be deficit irrigation (Ali and Talukder, 2008), whereby less water than required is applied during the growing period causing crop stress and yield depression. High yield can be obtained by supplying the required amount of irrigation water during sensitive crop growth stages, and restricting water stress to tolerant growth stages (Geerts and Raes, 2009). Therefore the irrigation water schedule was determined by the evapotranspiration of the crop and moisture content of the experimental field soil.

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Plate 5: *irrigation from week 1 to week 5*

Plate 6: *Irrigation from week 5 to week 11*

Plate (a): Plants at week 12

Plate 7: *Plants from week 11 to week 12- Ready for Harvest*

Plate (a): Product of block A (Mirabel) *Plate (b): block B (Nicola)* *Plate (c): block C (Bertista)*

Plate 8: *Product Yield From the Study Field*

Crop water consumptive use

The consumptive use of water at growth stage of crop and reference transpiration (ETo) (Malum *et al,* 2022), and determine using the following relations:

ETo = K pan × E pan 1

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Where:

ETo : reference crop evapo-transpiration; K pan: pan coefficient.

a. Net Irrigation Requirement (NIR): This is the amount of irrigation water required to bring the soil moisture level in the effective root zone to field capacity. The net depth of irrigation can be determined from readily available moisture (RAW)(Edoga and Edoga,2006, Malum *et al*, 2022):

RAW = (MAD) AW 2

Where: RAW = Readily available water (mm), MAD = Maximum allowable deficiency, and AW = Available water.

$$RAW = \frac{(MAD)X(Drz)x(FC-PWP)X(P)}{100} \quad 3$$

Where Drz = effective rooting depth of Irish potato,

FC = Average Field Capacity (%); Pwp = Permanent wilting point (%).

b. Gross Irrigation Requirement GIR: The gross irrigation requirement is the total amount of water applied throughout irrigation.

$$GIR = \frac{RAW}{FE} \quad 4$$

Where;

GIR =Gross irrigation requirement; RAW (=NIR) = Net irrigation requirement and

FE =Field efficiency of the system

c. Irrigation interval/frequency. This is the number of days between irrigations during periods without rainfall.The design irrigation frequency = Net depth of irrigation/Transpiration rate of potato crop.

$$T = Et \times \frac{Ps}{85} \quad 5$$

Where, T = average transpiration rate of the potato (mm/day), Ps = area shaded by the crop as a percentage of the total area (%), ET = conventionally accepted consumptive use rate of the crop (mm/day).

d. Irrigation period (Ip): Irrigation period is the number of days that can be allowed for applying irrigation to a given designed area during the peak of consumptive use period of the crop irrigated(Edoga and Edoga, 2006).

$$Ip = \frac{(Mb-Ml)X\ FC\ X\ bd)}{(100\ X\ Cu)} \quad 7$$

Where: Ip = irrigation period (days), Cu = consumptive use (mm/day); Mb = moisture content at the start of irrigation (%), and Ml = moisture content in the root zone at the lower limit of moisture depletion (%) FC and bd is bulk density (Edoga and Edoga, 2006).

Rate of water flow into the plots is the Actual water allowed within irrigation time , given as :

Q = volume/time = q/t 8

Where: Q = quantity of water; q = water flow; t = time taken for water flow

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2.3.3 Crop growth parameters

Makurdi climate is warm (NiMet, 2019a), compared with Jos (NiMet, 2019b), where the weather is favourable all year round for Irish potatoes cultivation. It is therefore believed that Irish potato may not be favourable under Makurdi weather; hence, crop growth parameters were monitored from sprouting stage to maturity stage.

Soil Characteristics and Moisture Content: The soil of the study area was subjected to soil analysis on each plot(A,B,C) and moisture content test to determine the amount of moisture that could be retained during irrigation recess if the crop could withstand the irrigation interval of every two or three days. Soil test was taken using soil moisture testing kits.

Plant Height: Plants heights(cm),leave length(cm) and leave width(cm) selected at random from each block (A,B,C)and their height were measured weekly using meter rule from each plot and recorded to give the weekly plant height from sprouting stage to harvest stage.

Leaf Surface Area: Leaves were also selected from some of the plant stand in each block was recorded to give the weekly leaf surface area from the sprouting stage to maturity. The length and width of the leaves were measured using meter rule, and the surface area was calculated using the relation (Awal, *et al*., 2004);

Leaf Surface Area (LSA) (cm^2) = $\frac{3(L \times w)}{4}$ or LSA = L x W x 0.75 9

Where:

L = Length of leaves (cm); W = Width of leaves (cm); 0.75 is the coefficient

Crop life span: The crop has a life span from ten to twelve weeks depending on the variety and environmental conditions. Its start tuber initiation at week six, , seventh and eighth, hence the biophysical agronomic performance was monitored.

2.3.4 Weeding and Addition of Fertilizer

At week 5, fertilizer(NPK: 20:10:10) was added to boost growth and tuber initiation. The amount of fertilizer added and specification are as shown in Table 2. Weeding became necessary at this level because some weeds emerged around the plants in all the plots.

Table 2: Application of Crop Nutrient after Planting

Blocks	Chemical fertilizer (kg)	Organic manure (kg)	Remarks
A	1.00	25.00	Chemical fertilizer
B	1.20	25.00	boost nutrients.
C	1.60	25.00	
Total	**3.80**	**75.00**	Organic manure boost tuber initiation

3. RESULTS AND DISCUSSION

3.1 Results

Results of the soil properties of grain size/sieve analysis, soil moisture content were determined and result is as shown in (Table 3). The planted seed took minimum of one week and maximum of three weeks to sprout out of the soil (Table 4). Agronomic parameters studied were plant leaves width, length, area and height, on a weekly basis from sprouting to maturity stages Table (5 - 7). Yield of Irish potatoes and percentage per variety is shown in Table 8.

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Area of Basin

L × B = 140 × 140 cm (1.4 × 1.4)m^2; Basin Area = 1.96m^2

ETo = 0.65mm/day = 0.65 x 1.96 × 10^{-3}m/day = 1.18mm/day

Irrigation was carried out in 9 minutes, therefore 60 seconds =1minute,Then, 9min = 540 seconds.

3.2 Discussion

3.2.1 Determination of water consumptive use of the Irish potatoes

Consumptive use or evapotranspiration (ET) is the sum of two terms; transpiration, which is the water entering plant from the roots and used to build plant tissue and then passed through the stomata of leaves of the plant into the atmosphere. Evaporation; is the amount of water evaporating from adjacent soils, water surfaces or from the surfaces of leaves of plant.Water deposited by dew, rainfall, or drip irrigation and subsequently evaporates without entering the plant system constitutes part of consumptive use,(Obioma *et al.* 2015).

An evapo-transpiration test was conducted from the study field to determine the evapo-transpiration rate (mm/day) for a period of one week. The calculated average was obtained as follows:

Table 3: Laboratory Analysis Results of Soils Before Experiment

									Units (Cmol/kg)							
blocks	**pH**	**% Sand**	**% Clay**	**% Silt**	**O.C %**	**O.M %**	**N %**	**P Mg/l**	K	Na	Mg	Ca	EB	EA	CEC	**% BS**
A	5.83	69.64	20.80	10.04	1.16	2.00	0.10	4.90	0.27	0.25	1.90	3.1	6.52	1.12	7.64	85.34
B	5.40	69.80	19.16	11.04	1.12	1.93	0.099	4.60	0.24	0.22	1.70	2.9	6.06	1.10	7.16	84.50
C	6.00	70.37	17.64	12.00	0.60	1.03	0.090	4.60	0.26	0.24	1.60	2.8	5.90	1.00	6.90	85.51

Table 4: Weeks Taken for Planted seeds to Sprout per Head per Block

No. of weeks	**Sprouting of the crop per week per block**		
	Block A (Mirabel)	**Block B (Nicola)**	**Block C (Bertista)**
1	2 heads	4 heads	6 heads
2	8 heads	8 heads	16 heads
3	5 heads	13 heads	3 heads
Total head sprouted	**15**	**25**	**25**

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Table 5: Leaf Surface Area and plant Height to Maturity (Block A - Mirabel)

Weeks	Leaves Expansion (cm)			Plant Height(cm)
	Length	Width	Area	
1	2.3	1.0	1.75	4
2	4	1.5	4.65	8
3	6	1.5	7.08	11
4	7	2.0	10.50	15
5	5	2.0	13.80	18
6	12	2.0	18.00	22
7	13	2.0	19.80	25
8	13.2	4.0	39.60	35
9	13.3	4.0	49.90	46
10	13.4	5.0	50.25.	50
11	13.0	4.5	48.85	53
12	12.5	4.0	37.50	50

Table 6: Leaf Surface Area and plant Height to Maturity (Block B, Nicola)

Weeks	Leaves expansion (cm)			Plant Height (cm)
	Length	Width	Area	
1	3.0	1.0	2.25	3
2	5.0	1.5	5.75	5
3	6.2	1.5	6.95	8
4	8.3	2.0	12.45	11
5	10.0	2.0	15.00	14
6	11.2	2.0	16.80	19
7	12.0	2.5	22.50	25
8	12.3	2.5	23.06	28
9	13.0	3.5	34.12	30
10	13.1	3.5	34.50	43
11	12.5	3.5	32.85	45
12	12.0	30.0	27.0	43

Table 7: Leaf surface area and plant height to maturity (Block C, Bertista)

Weeks	Leaves expansion (cm)			Plant height (cm)
	Length	Width	Area	
1	2.0	1.0	1.50	4
2	3.1	1.0	2.32	7
3	5.1	1.5	5.73	10
4	6.0	1.5	6.75	15
5	8.2	2.0	12.32	20
6	10.3	2.0	15.45	28
7	11.2	2.5	16.80	40
8	13.0	3.0	24.37	50

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9	14.0	3.0	29.70	55
10	13.5	2.5	24.35	53

Table 8: Yield of Irish Potatoes and Percentage per Variety

Plant head	**Numbers of tubers per pods per block**		
	Block A	**Block B**	**Block C**
1	8	●	6
2	3	●	7
3	1	9	8
4	3	4	10
5	●	14	3
6	6	●	8
7	8	11	5
8	0	●	5
9	●	7	13
10	*	2	5
11	●	4	9
12	*	6	7
13	*	5	8
14	12	9	10
15	●	10	5
16	*	●	9
17	4	11	5
18	●	6	12
19	*	●	4
20	4	10	8
21	●	7	4
22	●	8	10
23	10	6	5
24	●	●	10
25	●	●	5
Total tubers	**86**	**129**	181

● Produced tubers but got rotten *Plant head produce no single tuber

K pan varies between 0.27 (humid low) and 0.75 (high humidity), Average K pan = 0.65mm/day. The average wetting circumference of 60cm is large enough for production of leafy and vegetables.

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ETO of 0.65 mm/day was multiplied by crop factor value (KC) of 0.70 (Malum *et al,* 2022) for each stage of the crop development. Consumptive use were determined using the following criteria:

a. Net Irrigation Requirement (NIR): The net depth of irrigation was determined from readily available moisture (RAW). From equation (2),
MAD for leafy vegetables = 0.5, with an effective rooting depth of Irish potato at 45 cm (Drz);
P = area wetted as a percent of the total area = 40%. From equation (2),
RAW = $\frac{0.5 \, x \, 45 \, x \, (11.7-3.7) x \, 40}{100}$ = 389.6 mm

b. Gross Irrigation Requirement GIR: From equation (3),

389.6 mm x $\frac{100}{80}$ = 487 mm (for basin irrigation system, application efficiency = 60%)

c. Irrigation interval/frequency(From equation 4)**:**
Taking Ps = 40 % and ET (potato) = 3.5 mm/ day (ET Test),
T = 3.5x 40/85 = 16.47 (mm/day)
Therefore**, Irrigation interval (It)** = $\frac{2.6mm}{1.6mm}$ x day = 1.625 ≃ 2 days, which is the maximum irrigation interval that would not stress the potato crop excessively.

d. Irrigation period (Ip):(From equation 5 & 6),

Mb-Ml = 0.75FC - 0.625FC = 0.125FC
For FC = 11.7%, dz = 600 mm, Cu =5.30 mm/day, bd = 1.32g/cm^3
Ip = $\frac{(0.125 \, x \, 11.7 \, x \, 600 \, x \, 1.32)}{(100 \, x \, 3.50)}$ = 3 days

e. Amount of water applied at each stage of crop development
Vol of water used = ETo (m/day) × Kc × Area = 0.96 × $10^{-3} m^3/day$ × 1000 = 0.96 (L/day)

flow rate = $\frac{Volume}{time}$ = $\frac{0.96 \times 10^{-3}}{540}$ = 1.78 L/sec

Week (1-4)
Water vol. = 0.96 × 10^{-3} m/day × 0.35 ×1.96 = 0.637m^3/day ×1000 = 658.6 (litre/day)

Crop development Flow-rate = $\frac{volume}{time}$ = $\frac{658.6}{540} = 1.22 L/s$

Week (5-7)
Water vol. = 0.96 × 10^{-3}m/day × 0.45 × 1.96 = 0.84672m^3/day × 1000 = 846.72(litre/day)

Flow-rate = $\frac{volume}{time}$ = $\frac{846.72}{540} = 1.57 L/s$

Week (8-10)

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Water vol.= 0.65 × 10^{-3}m/day × 1.29 × 1.96 = 1.64346m^3/day × 1000 = 1643.45(litre/day)

Flow-rate =$\frac{volume}{time}$ = $\frac{1643.45}{540}$ = 3.043 L/s

Week (11)

Water vol. = 0.65 × 10^{-3}m/day × 0.63 × 1.96 =0.80262m^3/day × 1000 = 802.62 (litre/day)

Flow-rate = $\frac{volume}{time}$ = $\frac{802.62}{540} = 1.49L/s$

3.2.2 Crop performance and evaluation

The performance of the crop was considerably successful, despite the difference in temperature and precipitation in Makurdi Benue State and that of Jos Plateau State(home of Irish potatoes) (NiMet, 2019a,b).The evaluated agronomic parameters of sprouting, leaves expansion, plant height and tubers produced differs according to varieties under study:

Sprouting and plant growth: High temperature and relative humidity in Makurdi had some adverse effect on Irish potato seeds at the sprouting stage, thereby slowing the sprouting by taking about three weeks to attained total sprouting of heads, and caused decay on some few seeds. Out of the initial 25 seeds planted, a total of 15 heads sprouted in block A (Mirabel), but block B (Nicola) and block C (Bertista), all the 25 seeds sprouted successfully.

Addition of plant nutrients to the soil: A total of 75kg of organic manure (cow dung) were applied in each of the plots before planting. At week 5, chemical fertilizer (NPK 20:10:10) was applied. Chemical fertilizer makes the plants grow faster as a result, regular irrigation of 2 times a week from week 6-9 to maintain healthy growth, while organic manure was applied earlier because it dissolves slowly. Organic manure boost tuber initiation and yield, especially in Irish potatoes (NRCRI, 2015; ASTC, 2091)(Table 2).

Leaves expansion and plants height: Development and growing number of leaves showed a continues increase from first week of planting to week 10 of the plant, although some of the leaves begin to shrink at week 9-12. Leaves surface had a persistent growth in length and width from week 1 to week 9 of each blocks and shrinking from week 9-12(Plate 6 and 7).

Height of plants had a progressive growth in all the plots and continued to increase up to week 10, despite the delay in sprouting. The height grow rapidly in first week, from 4cm height to 50cm at week 10 in plot A, 3cm to 45 cm in plot B, and 4cm to 55 cm in plot C (Tables 5-7)(Figure 1).

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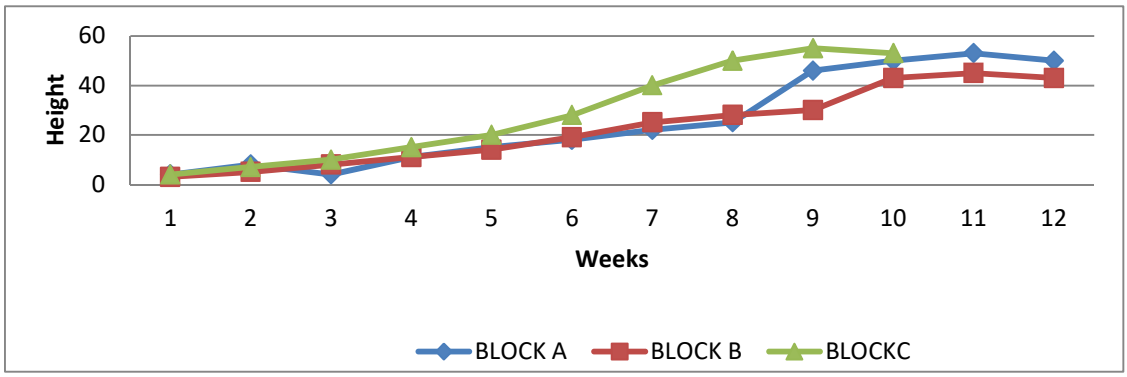

Figure 1: Different Growth Stages in each of the Three Blocks

Maturity and harvest: Maturity of the crops showed on the leaves of the plants from week 9 -10. At this stage, soil around the stem base of the plant begins to crack, showing stage of tuber maturity, the leaves gradually turn from green to yellow, to brownish and gradually drying off, signifying readiness for harvest (Plate 7). The plants were harvested at the end of week 12, using small hoe by carefully digging the tubers.

Crops yield: The plants yield differs according to variety in each of the plots (plate8). After the crop attained maturity towards harvest, evapotranspiration reduces, water consumption also reduces, hence irrigation scheduled to once in a week. Within this period,environmental temperature which is higher in Makurdi is transmitted as excess heat and led to increase in soil temperature. The high soil temperature within the shortest period affected some of the matured tubers in the soil to rot. This mostly affected the Merabel and Nicola species in block A and B. In block A (Merabel), 25 heads were planted and a total of 23 sprouted out, produced but at harvest, all tubers produced by 9 head were discovered rotten. In block B (Nicola) 25 heads

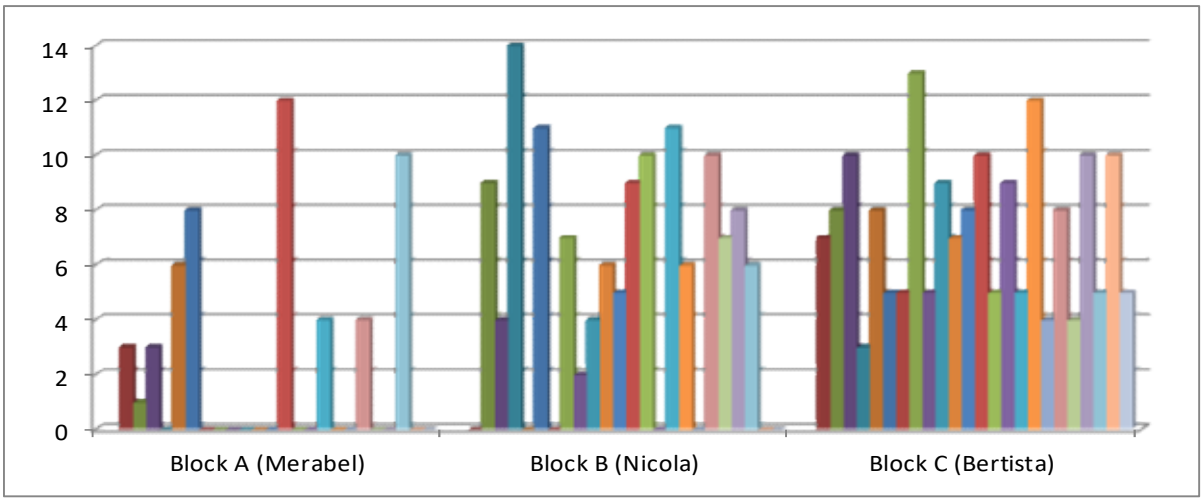

Figure 2: Crops Yield per Head in Each Block (A,B,C)

were planted all sprouted, grow and 8 tubers heads were discovered rotten during harvest, and in block C (Bertista), 25 heads planted and all sprouted, grow, produced, at harvest, none of the

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tubers rot. Thus, crops in block C (Betista) showed high resistivity to both environmental conditions and soil temperature, block B (Nicola) showed lower resistance and then block A(Merabel) showed higher sensitivity to the environmental weather condition and soil temperature(Table 8).Therefore, among the 3 varieties (Merabel, Nicola and Bertista) planted, Merabel produced the lowest tubers totaling 86 in block A, followed by Nicola with 129 tubers in block B, and the highest by Bertista with 181tubers in block C(Table 8)(Figure 2).

4. CONCLUSION

The soil of the study area was sandy clay loam with a pH of 6.67, which is suitable for the production of Irish Potato. Once there is adequate available water, basin irrigation is the most suitable for Irish potato because of high rate of heat and evapotranspiration during dry season. This prompt the need for high supply of water couple with the fact that potatoes need high water consumption during tuber initiation stages, which will lead to optimum increase in yield.

Among the 3 varieties of Irish potatoes planted, Bertista variety produces the highest numbers of tubers, hence proved the most suitable to be cultivated under Benue valley climate at Makurdi.

5. RECOMMENDATIONS

It is recommended that

Since there is abundant water sources around Benue valley and from the river Benue, irrigation of Irish potatoes can be introduced because the research has shown the practice will be viable in Makurdi and environs.

Irish potatoes are soil and weather sensitive crops, more research should be done on soil type, soil moisture, soil pH and suitable irrigation method for each condition at different part of Benue valley.

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