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Adaptation of Irish potato to Kebbi state Agro-ecological zone of Nigeria

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Abstract

Potato (Solanum tuberosum L.), sometimes known as Irish potato, was developed in the Andes Cordillera's high plains, where it is widely cultivated for food. In the mid-16th century, the Spanish conquerors of Peru discovered the crop and introduced it to Spain and western Europe. Potato tubers comprise 70–82 percent water, 17–29 percent dry matter, 11–23 percent carbohydrate, 0.8–3 percent protein, 0.1 percent fat, and 1.1 percent minerals, according to their composition. Important vitamins like thiamine, riboflavin, niacin, and vitamin C are produced in greater quantities per hectare in potatoes than in other main crops like rice, maize, and wheat. A field experiment was conducted to investigate the adaptation of Irish Potato to Kebbi State Agro-ecological zone of Nigeria during 2019/2020 and 2020/2021. Three irrigation intervals (3, 6, and 9 days), four NPK (20: 10: 10) fertilizer rates (0, 300, 600, and 900kg ha-1), and three potato cultivars are included in the treatments (Nicola, Bertita, and Diamant). A split-plot design with three replications was used to lay out the treatments. The main plots were assigned a factorial combination of irrigation interval and NPK rates, whereas the subplots were given varieties. Potato variety Diamant proved to be the most robust in terms of plant height and number of branches; and Nicola in terms of number of leaves per plant. Variety Nicola had an edge over the two other varieties in terms of fresh tuber yield probably as a result of its higher tuber number per stand. The result implies that the use of either of 600 or 900kg NPK ha^{-1} and the Variety Nicola could be considered adopted for higher fresh potato yield since recorded superior performance in the study area.

Keywords: High altitude regions; Agro-ecological zone; Variety; *Solanum tuberosum*

1 Introduction

Potato (*Solanum tuberosum L.*), sometimes known as Irish potato, was developed in the Andes Cordillera's high plains, where it is widely cultivated for food. In the mid-16th century, the Spanish conquerors of Peru discovered the crop and introduced it to Spain and Western Europe (Fergeria et al., 1991; Rolot, 2001). Potato was not transported from Europe to Africa until the end of the 19th century by missionaries and colonial administrations (Rolot, 2001).

Potato was brought to Nigeria by European tin miners on the Jos Plateau around 1920. (Rhodes et al., 2002). Until the Second World War, when the British colonial administration pushed potato growing, production was limited to tiny

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garden plots until the Second World War, when the British colonial authority supported potato farming to feed the West African troops (Rhodes et al., 2002; Ugonna et al. 2013)

Malawi, Kenya, Ethiopia, Rwanda, Cameroon, and Nigeria are the main potato-producing countries in tropical Africa, and the crop is produced at high altitudes where the temperature and photoperiod are favorable for growth (Okonkwo et al., 1995; Rolot, 2001). Potato cultivation, which is rapidly developing throughout Africa, is encouraged by its high yield potential mixed with reasonable yields even under difficult growing conditions (Rolot, 2001). Potato yields range between 40 and 60 t ha-1 under normal growth conditions (Rolot, 2001). Potatoes are the most productive tuber crop in Nigeria in terms of yield and productivity. In terms of yield and days to maturity, the potato is Nigeria's most efficient tuber crop (Okonkwo et al., 1995). It takes 80 to 90 days to develop, but yam and cassava take 9 and 12 months, respectively. In 2009, 1.14 million tonnes of potatoes were grown on 145,680 hectares of land in Nigeria. 7.8 t ha-1 was the average production for farmers (Ugonna et al. 2013; Anonymous, 2012a).

The Jos Plateau, which accounts for 85 percent of Nigeria's potato production, is the most important area. Potato can also be grown in the dry and rainy seasons on the Biu and Mambila plateaus (Alhassan et al., 2004). Potato can only be grown in the northern states of Kebbi, Kano, Kaduna, Borno, Sokoto, and Adamawa during the harmattan season (November to February), when temperatures are cool enough (Okonkwo et al., 1995).

Potatoes are one of the most important food crops on the planet. The protein-to-carbohydrate ratio is higher than in most cereals and even higher than in other tuber and root crops (Okonkwo et al., 1995). Potato tubers comprise 70–82 percent water, 17–29 percent dry matter, 11–23 percent carbohydrate, 0.8–3 percent protein, 0.1 percent fat, and 1.1 percent minerals, according to their composition. Important vitamins like thiamine, riboflavin, niacin, and vitamin C are produced in greater quantities per hectare in potatoes than in other main crops like rice, maize, and wheat (Rolot, 2001; Harris, 1992; Okonkwo et al., 1995). Except for cystine and methionine, Okonkwo et al. (1995) claim that a daily intake of 1 kilogram of potato tuber offers all of the necessary amino acids required by the body. Aside from the more traditional applications of potatoes as food, industrial processing has grown in popularity in developed countries, greatly expanding the crop's potential uses. Potatoes are used to make deep-fried potato chips and mashed potatoes in the food industry. In the brewing business, confectionery, and the distillation of alcohol, by-products such as potato starch, glucose, and dextrose are used. By-products such potato starch, starch proper, and dextrin are used in the non-food industry to make cardboard, glues, textiles, and paints, as well as ironing sprays in the laundry industry (Harris, 1992; Rolot, 2001).

1.1 Problem statement

In the lowlands of Northern Nigeria, such as Kebbi, Sokoto, and Zamfara, potato is a prized crop that is frequently seen to be a staple for the wealthy. However, due to the relatively low night temperatures that prevail in these regions throughout the year, which result in high potato prices in north-western states like Kebbi, especially during Ramadan fasting and other festivities, its production is restricted to high altitude areas like Jos, Mambila, and Biu plateaus.

1.2 Evidence for the study's justification

Inadequate water supply (rainfall or irrigation) and unfavorably high temperatures are the two most prominent factors that limit potato production in any part of Nigeria (Okonkwo et al., 2009). While the high altitude plateaus of Jos, Mambila, and Biu plateaus have relatively low temperatures that are conducive to potato production in both rainy and dry seasons, the harmattan (a hot, dry, and dusty wind blowing over West Africa between the end of November and the middle of March) in the lowland northern states of Kebbi and Sokoto provides low temperatures that support potato production, provided irrigation facilities are available (Okonkwo et al., 2009).

Almost 90% of the potatoes consumed in the country come from the Jos plateau and Zaria districts, according to reports. However, preliminary investigations conducted by the respective Agricultural Development Projects (ADPS) of the states of Kebbi and Sokoto (KARDA/SARDA) have showed a significant potential for potato production in these axes of the Sudan Savannah. In addition, the cost of the commodity in these states is so expensive that the crop is sometimes regarded as a food for the wealthy, owing to the current limited production area. Other possible regions of production must be explored.

Potatoes are a high-input crop, especially in terms of irrigation, as they are the only supply of water in lowland areas. In Nigeria's savanna areas, low soil fertility has been identified as a major and widespread crop production problem. For a crop like potato, which has a shallow root system but requires early tuber bulking, fertilizer application is required to maintain a sufficient level of soil fertility (Carl, 2003; Mandeep and Kiranjot, 2013). In addition, the crop's response was discovered to differ amongst kinds (Okonkwo et al., 1995; Babaji et al., 2009). Given the rising costs of fertilizer and irrigation, as well as the growing concern about their possible environmental impact, efficiency and sensible use of these resources have become critical features of agricultural systems that merit more investigation. Because each environment's soil has its own inherent fertility (Wild, 2008) and water holding capacity (King et al., 2006), the amounts of nutrients and water required to grow a specific crop are determined by these local soil features. A scientific study that examines the yield performance of existing varieties as well as their fertilizer and moisture requirements is required in order to establish an effective and efficient potato introduction program in the study area.

1.3 The study's purpose and objectives

The study's major goal is to figure out how adaptable Irish potatoes are in terms of output in the area under consideration. The following are the precise goals:

- Evaluate the performance of three potato types in the research region.
- To see how irrigation intervals and nitrogen fertilizer affect potato development and yield.
- To determine the nutritional value of potatoes based on variety, irrigation interval, and NPK.
- To see how different treatments affect the quality of potatoes after they've been harvested.
- To figure out how profitable it is to grow potatoes in the research area.

2 Review of the bibliography

2.1 Variety of Potatoes

The size of the foliage, the timing of tuber initiation, the length of time the foliage remains alive and photosynthesizes following tuber initiation, the maturity regime, and the reaction to external variables are all factors that influence yield (Okonkwo et al., 1995). Because no single variety has all of the production and processing attributes, yield of a certain potato variety is genetically controlled, but can be influenced by various external factors such as fertilizer, irrigation, pests, and diseases (Kenneth and Brain, 2000).

When it comes to nitrogen levels, different potato cultivars have distinct reactions. In comparison to the conventional Russet Norkotoh, Kenneth and Brain (2000) discovered that Texas and Colorado strains of Russet Norkotoh have lower nitrogen requirements. In India, Sharma and Sharma (2012) tested two potato varieties, 'Kufri Sindhuri' and 'Kufri Chandramukhi,' yielding 35.6t/ha and 12.6t/ha, respectively. Shock et al. (2003) studied the tuber weight and starch content of eight late cultivars in Australia. The best early potato cultivar was Ostara (50.82 t tuber ha-1 and 6.57 t starch ha-1); the best mid-early cultivars were 'Timate' (57.67 t ha-1 tuber yield) and Asterix (8.83 t starch ha-1 tuber yield); and the best late cultivars were St.989/84 (53.87 t starch ha-1 tuber yield).

In Switzerland, Wininger et al. (2011) tested eight potato cultivars that mature from early to late. Among the greatest yielding cultivars were 'Fantasia' and 'Panda,' while 'Shepody' produced the most big tubers. In a study of eight early potato cultivars, Zrust (2009) found a substantial and positive relationship between total yield weight/tuber and number of tubers per plant. In Jos, Nigeria, Okonkwo et al. (1995) experimented with three potato types at six different planting dates. B6934-11 generated 16.7 t ha-1 of tuber output, followed by Greta (14.2 t ha-1) and B7906-1 (13.7 t ha-1).

2.2 Potato Moisture Needs

Water is required for photosynthesis, respiration, and other physiological functions, as well as the transfer of minerals and photosynthetic products, turgidity of plant cells, transpiration, and leaf temperature regulation, according to Fernando and Huchinson (2006). Drought reduces transpiration and photosynthesis, increases soil and plant temperature, and contributes to physiological problems such internal brown spot, especially later in the season when foliage is dead and soil is exposed to sunshine (Simonne et al., 2002).

Too much water, on the other hand, prevents oxygen from reaching the potato plant's underground portions, resulting in poor root development and tuber rotting (Simonne et al., 2002). Excessive proliferation of lenticels, which permits parasites to enter, can diminish emergence, according to the study. Potato tuber quality is harmed by excessive variations in soil moisture.

Potato crop water consumption corresponds to crop evaporation (EPT), which Pereira and Shock (2006) estimated as the amount of water to be replenished during the growing season in order to ensure potential tuber yield at a given site in a review on the development of irrigation best management practices for potato. The daily variability of EPT is influenced by elements such as local atmospheric conditions, surface soil wetness, growth stage, and crop cover (Waddell et al., 2000; Shock et al., 2002). Seasonal water requirements for a potato crop with a phenological cycle ranging from 120 to 150 days, depending on climate, varied from 500 to 700 mm for high yields at a given site (Pereira and Shock, 2006).

2.3 Potato Irrigation Response

The benefits of water management are linked to the availability of sufficient soil moisture for potato growth during the cropping season's key period (Starr et al., 2008). However, due to the potato's susceptibility to water stress and the fact that irrigation requirements vary depending on location, soil type, cultural techniques, and cost, careful water application is essential to maximize tuber output under a water deficit regime (Dalton et al., 2004; Olanya et al., 2010). In a sandy loam soil in Bangladesh, Islam et al. (2009) studied the response of the potato variety Diamant to three irrigation intervals (7, 12 and 17 days) and three amounts of depleted soil moisture (50 percent, 100 percent, and 150 percent). They found that irrigation intervals of 12 days and watering at 100 percent soil moisture depletion provided the highest fresh tuber yield of 24.64 t ha-1, while irrigation intervals of 7 days and watering at 150 percent soil moisture depletion produced the lowest fresh tuber yield of 21.68 t ha-1. When the irrigation interval was kept at 7 days with 150 percent depleted soil moisture, the scab infected tubers were greatest (4.30 t ha-1) in the same experiment.

El-Sadi et al. (2010) irrigated potatoes using three different water regimes: 1738, 2607, and 3476 m3 fedan-1 season-1, corresponding to 50, 75, and 100% of the seasonal irrigation water requirement, respectively. They discovered that increasing the amount of applied water from 1738 to 2607 m3 fedan-1 season-1 raised shoot dry weight and LAI by 30.85 and 18.50 percent, respectively. They also found a similar pattern in potato quality metrics, with the highest significant percent tuber dry matter (17.10 percent), specific density (1.065 g cm-3) and total carbohydrate content (43.33 percent) attained under a 3479 m3 fedan-1 season-1 water regime. In China, Kang et al. (2004) found that potato yield was a function of irrigation frequency, with daily irrigation yielding 28.2 t ha-1 and 8 days yielding 20 t ha-1. As irrigation frequency dropped from 1 to 8 days, water use efficiency dropped from 131.6 to 104.1kg ha-1 mm-1. When the applied water was reduced from 100 to 50 percent accumulated evapotranspiration in eastern Oregon, Shock and Feibert (2002) reported a significant loss in overall potato tuber production, grade, and profit.

In China, Wang et al. (2006) investigated the effects of six different drip irrigation frequencies on potato growth, yield, and water efficiency. They discovered that frequent irrigation improved potato tuber development, water use efficiency, and assimilate partitioning rate, especially at 11 weeks after planting, when tubers become the primary storage locations for carbohydrate and inorganic nutrients.

At Botucata, Sao Paulo, Brazil, Shock et al. (2002) investigated the impact of three irrigation treatments on tuber output and grade, finding that potatoes irrigated to fully replace evapotranspiration had higher yields, better quality, and fewer physiological abnormalities. Tuber physiological abnormalities such as brown core, hollow heart, translucent end, secondary growth, growth fissures, bruise susceptibility, and heat necrosis have all been linked to water stress and/or a wide range of soil moisture content (Shock et al., 2002; Eldredge et al., 2003). For larger and heavier garlic bulbs at Zaria, Miko (2000) advocated a 5-day irrigation interval. Under semi-arid circumstances in Sokoto, Nigeria, Ahmed et al. (2007) recommended a three-day irrigation interval for improved garlic performance, while Muhammad et al. (2011) suggested a six-day irrigation interval for high onion growth and output.

2.4 Potatoes Nutrients requirement

For proper growth and development, the potato crop requires a wide spectrum of plant nutrients, however tuber output is often dependent on the availability of N, P, and K in intensively managed soils where trace element insufficiency is not a concern (Carl, 2003). According to the International Potash Institute's bulletin, potassium (K) is the most readily absorbed nutrient by potatoes, followed by nitrogen (N) and small amounts of calcium (Ca), phosphorus (P), magnesium (Mg), and sulphur (S) (IPI, 1993). Babaji et al. (2007) found a strong and positive relationship between tuber yield and shoot N, P, and K content. According to their findings, under Northern Guinea savannah conditions, shoot N and P contributed more to tuber yield directly or indirectly, both singly and in combination. They also found that N fertilizer prolonged the growing period, measured in days from planting to leaf senescence, and that N fertilizer delayed maturity, especially in years when the crop was subjected to protracted dry spells.

Okonkwo et al. (1995) found that in the Jos plateau of Nigeria, potato required up to 40 kg P2O5 ha-1, after which there was no significant yield gain. K, on the other hand, had no effect during the early phases of growth but significantly increased leaf area later in the season, delaying leaf senescence (Shock et al., 2002; Baniuniene and Zakaite, 2008). High nitrogen application rates also boosted leaf growth rather than tuber growth, delaying bulking by 7-10 days (Baniuniene and Zakaite, 2008).

2.5 Potato Response to NPK Mineral Fertilizer

Babaji et al. (2008) advised 120 kg N, 60 kg P2O5, and 60 kg K2O ha-1 for good tuber yield and quality in their trial in Zaria, Nigeria. In Sokoto, Nigeria, Alhassan et al. (2004) advised 80 kg N, 40 kg P2O5, and 40 kg K2O ha-1 for enhanced potato tuber output. In Perloja, Latvia, Baniuniene and Zekaite (2008) examined different NPK fertilizer combinations (0:0:0; 90:90:0; 0:90:120; 90:0:0; and 90:90:120) on potato and found that NPK (90:90:120) had a 32-93 percent yield advantage over the other combinations. . In Pakistan, Naz et al. (2011) looked at the impact of NPK fertilizer levels on the proximate composition of potato varieties. Tuber crude protein content increased from 0.9 percent with 0:0:0 NPK ha-1 to 1.4 percent with 140:140:210 NPK ha-1, and fiber content increased from 1.99 to 2.89 percent with 120:120:180 NPK ha-1, while percent fats decreased from 1.2 percent with 0:0:0 NPK ha-1 to 0.4 percent with 160:160:160 NPK ha-1.

Adhikari and Sharma (2004) studied the effects of NPK mineral fertilizer on potato types Kufri-Sunduri and Desiree tuber yield, quality, and leaf nutrient content in Chitwa, Nepal. According to their findings, the maximum potato tuber yields of 35.27 and 34.83 t ha-1 were produced in Kufri-Sunduri using 150:100:100 and 100:100:100 of N:P2O5:K2O kg ha-1, respectively, whereas 20.30 and 19.60 t ha-1 were obtained in Desiree using the same rates.

3 Methodology

3.1 Experimental Site

The studies was place at the Waziri Umaru Federal Polytechnic's Teaching and Research Farm in Gayi (Lat. 120 11' N; Long. 40 16' E; 250 meters above sea level) in Nigeria's Sudan savanna zone during the 2019/20 and 2020/21 dry seasons. During the dry seasons, the relative humidity was between 20 and 30%. During the dry season, temperatures ranged from 14 to 30 degrees Celsius, while the rainy season saw temperatures range from 27 to 41 degrees Celsius (Anonymous, 2012).

3.2 Soil Sampling and Analysis

Eight (8) random spots within the experimental site were chosen for soil sampling. At each site, soil auger samples were taken from depths of 0 – 30 cm. The samples were bulked, air-dried, sieved, and physical and chemical parameters were determined. The textural classes were identified using the soil textural triangle and particle size analysis was done using the hydrometer method (Bouyoucous, 1951). The Micro Kjeldhal approach was used to estimate total nitrogen, and the Bray-1 method was used to calculate available phosphorus (Bray and Kurtz, 1945). The acetic acid approach was also used to determine swappable bases. A flame photometer was used to measure potassium and sodium, while atomic absorption spectrophotometry was used to measure calcium and magnesium. The amount of exchangeable bases (Ca, Mg, K, Na) given in Cmole kg-1 was used to determine Cation Exchange Capacity (CEC).

3.3 Treatments and Experimental Design

Three irrigation intervals (3, 6, and 9 days), four NPK (20: 10: 10) fertilizer rates (0, 300, 600, and 900kg ha-1), and three potato cultivars are included in the treatments (Nicola, Bertita, and Diamant). A split-plot design with three replications was used to lay out the treatments. The main plots were assigned a factororial combination of irrigation interval and NPK rates, whereas the subplots were given varieties.

3.4 Varieties

3.4.1 Bertita

Bertita is a Mexican cultivar. It has reddish skin and white flesh and is circular in shape. It's in the middle of the maturity scale (80-95 days). Tubers have a high dry matter content (21%) and poor storability due to their short dormant period. It's also a year-round crop with a 30 t ha-1 output potential. It's resistant to bacterial wilt and fungal blight, although it's sensitive to common scab.

3.4.2 Diamant

Diamant is a Dutch variety. It's a year-round crop with a 30-tonne-per-hectare output potential. It is classified as being of medium to late maturity (95-110 days). Fungal blight, bacterial wilt, and scab are all diseases that can affect it. The dry matter composition of tubers is between 19 and 20%. The tubers are oval in shape and have a pale yellow skin with white meat.

3.4.3 Nicola

Nicola is a Dutch varietal. It's a year-round crop with a 30-tonne-per-hectare output potential. It is in the middle of its life cycle (80-90 days). The tubers have smooth pale yellow skin and meat and are long, round, and shallow eyed. The tubers contain a 17 percent dry matter content, a long dormancy period, and can be stored for up to 5 months without losing too much weight. Fungal blight and bacterial wilt are both sensitive to the plant, however it is resistant to common scab.

3.5 Cultural Practice

3.5.1 Land preparation and plot size

Ploughing and harrowing took place on the soil. Sub plots of 3.0 x 4.5m (13.5 m2) were drawn out, with a 1 m gap between them. Six ridges, 75 cm apart, make up each subplot. During irrigation, water channels were well-built to ensure that each furrow received an adequate supply of water. Two center rows (3.0 x 1.5 m = 4.5 m2) make up the net plot area.

3.5.2 Pre-planting, planting treatments, and sourcing of planting materials

The Potato Research Program of the National Root Crops Research Institute (NRCRI), Vom substation, Jos, Plateau State, provided the seed tubers for the three potato varieties. Six weeks prior to planting, the seed tubers were pre-sprouted. A fungicide (Mancuzeb powder, 2.0 g kg-1) was applied to the seed tubers the day before planting. For the 2019/20 and 2020/21 trials, respectively, planting took place on November 9, 2019 and November 2, 2020. Per hill, 30 g whole or cut tubers with a 30-cm intra-row spacing were planted.

3.5.3 Irrigation

Groundwater served as the water source. Water canals were built, and a water pump was employed to transport water from a tube-well to the field. The treatments were set for irrigation at intervals of 3 and 6. Regardless of the irrigation method, the entire field received irrigation treatments every three days. 4 weeks after planting (WAP), after the crop was fully established, the irrigation treatment was implemented.

3.5.4 Fertilizer application

NPK 20: 10: 10 compound fertilizer was applied at various treatment rates of 0, 300, 600, and 900 kg NPK ha-1. The first and second doses were applied at planting and 4 WAP, respectively, and the rates were applied according to the treatments in two equal split doses. 5 cm deep and covered, the fertilizer was put at a distance of roughly 10 cm from the plant stand.

3.5.5 Crop protection

At WAPs 4 and 7, weeds were manually managed with a hand hoe. Lambdacyhalothrin, or "karate," was sprayed against insect pests at a rate of 4 ml L-1 of water.

3.5.6 Harvesting

On February 16, 2020, for the trials in 2019–2020, and February 11, 2021, for the trials in 2020–2021, the crop was harvested in the morning. No matter how the irrigation was handled, a light irrigation was applied to all plots the day before harvesting to make it easier to lift the tubers.

3.6 Data Collection

Five randomly chosen plants were used to assess plant height, branch count, and leaf count.

3.6.1 Plant height (cm)

The tagged plants' heights were measured at 7, 9, and 11 WAP. This was done by using a measuring tape to chart the height of the plant's tallest growing point from the ground. Determined and noted was the mean.

3.6.2 Per-stand number of branches

Five tagged plants per plot at 6 and 10 WAP were counted to determine the number of stems per stand. The mean was established and noted.

3.6.3 Per-stand number of leaves

The number of leaves on the tagged plants was counted, and for each plot at 7, 9, and 11WAP, the mean number of leaves per stand was recorded.

3.6.4 Dry shoot mass per plant (g)

At 7, 9, and 11WAP, a destructive sample of three randomly chosen plants per plot were collected from outside the net plot area. In paper bags, the sample was dried in an oven at 70°C to a consistent weight.

3.6.5 Per-stand number of tubers

The number of tubers harvested from the net plots was counted, and the mean value per stand was noted.

3.6.6 Per-stand tuber weight (kg)

The mean weight per stand was calculated for the tubers gathered from the net plots.

3.6.7 Average tuber diameter (cm)

Ten randomly chosen tubers per plot had their diameters measured with a Vanier caliper, and the mean diameter of each tuber was noted.

3.6.8 Average tuber weight (g)

Metler balance was used to weigh 10 randomly chosen tubers from each plot, and the mean weight of each tuber was recorded.

3.6.9 Tuber yield

Weighing the freshly harvested tubers from the net plot allowed us to determine the yield (4.5 m2). The amount was converted to tons per hectare.

3.7 Data Analysis

According to Steel and Torrie's description, the general linear model (GLM) of the Statistical Analysis System package (SAS, 2003) was used to analyze the collected data (1987). Using the Duncan's Multiple Range Test, the treatment means were separated (Duncan, 1955). To investigate the link between the parameters measured, regression and correlation coefficient studies were performed. To calculate the contributions of growth and yield parameters to tuber yield, path coefficient analysis was utilized (Dewey and Lu, 1959). A partial economic analysis was done to determine whether growing the crop in the study area as stated by Gindi et al. was profitable or not (2013).

4 Results and discussion

4.1 Growth Response

Plant heights, Number of Leaves and Number of Branches of three potato varieties (Bertita, Nicola and Diamant) as influenced by NPK fertilizer rates (0, 300, 600 and 900kg ha^{-1}) and Tillage (Ridged and Flat) at 9 weeks after planting (WAP) for the 20019-20 and 2020-21 dry seasons are presented in Tables 2.

4.2 Effect of NPK

Plant height of potato was significantly affected by the application of NPK fertilizer in all the two trials. Application of 600 - 900 kg NPK ha^{-1} produced significantly taller potato plants than the untreated control (Table 1), and each was superior to untreated control. Plant height by 900kg NPK ha^{-1} was more than by 600kg NPK ha^{-1} followed by 300kg NPK ha^{-1}which in turn was superior to the control. However, Application of 300kg NPK ha^{-1} and above produced similar and higher numbers of leaves than the untreated control in all the trials but the number of leaves produced by 900kg NPK ha^{-1} was significantly higher. Number of branches increased with NPK rate above 300 kg NPK ha^{-1}. Application of 900 and 600kg NPK ha^{-1}gave similar branch numbers, each of which was superior to 300kg NPK ha^{-1}but untreated control recorded the lowest number. This shift in response to fertilizer rates from 600kgNPK ha^{-1} to 900kgNPK ha^{-1} as the crop ages, could be attributed to the high inherent soil fertility of the experimental site and also to the nature of the fertilizer application (split application). The half dose applied as basal, together with the inherent soil nutrient was able to nourish the crop for early growth. More so, the second fertilizer dose maintained the growth trend after which the nutrient level at the crop root zone declined, probably due to leaching (being sandy loam soil) and physiological demand such as for vegetative growth, tuberization, synthesis and translocation of starch. That could be the reason why higher fertilizer rates of 600-900 kg NPK ha^{-1} were needed for maximum growth at a later period of the crop's life cycle.Danquah*et al.* (2014) suggested application of half of N at planting to ensure a uniform establishment, and then using frequent light application of N for the rest of the season in order to maintain vegetative growth and rapid bulking of tuber.

4.3 Effect of Variety

Variety Diamant produced the tallest plants followed by Bertita and the least was variety Nicola in all the trials (2019/20 and 2020/21). In 2019/20 trial, leaves number did not respond to variety but in 2020/21 trial, Nicola produced more leaves than Bertita and Diamant which were statistically similar. In 2019/20 and 2020/21 trials, variety Diamant and Bertita produced significantly higher number of branches, and the least was by Nicola. The greater performance of variety Diamant in terms of plant height than Bertita, and Nicola even though the latter variety had more number of leaves than the former, could be attributed to larger individual leaf area produced by variety Bertita which counteracted the high leaf number by variety Nicola: all of which could be linked to the genetic variations among the three varieties. Such genetically controlled variations among potato varieties in terms of growth and development were reported by Olanya *et al.* (2010).

4.4 Effect of Tillage

The results concerning growth parameters as affected by tillage method presented in Table 2. The effect of tillage method was found significant on any measured growth parameters in all the trials (2019/20 and 2020/21). Higher values were recorded with potatoes planted in ridged while the least values were recorded with the potatoes planted in flat. This indicates that ridging provided adequately favorable conditions for Irish potato growth and both loosened the soil, optimized infiltration and facilitated root expansion. This is in line with the report of Parwada *et al*. (2011) who said that, ridges provide favourable conditions around the planting zones that are essential for the normal growth of potato.

4.5 Yield Response

Tuber Number, Mean Tuber Weight, Tuber Diameter and Tuber Yield (0, 300, 600 and 900kg ha^{-1}) and Tillage (Ridged and Flat) in Gayi for the 20019-20 and 2020-21 dry seasons are presented in Tables 3.

4.6 Effect of NPK

There was a consistent significant increase in Tuber Number, Mean Tuber Weight, Tuber Diameter and Tuber Yield as the fertilizer rate was increased from 300-600kg NPK ha^{-1} beyond which there was no further response in 20019/20 and 2020/21 (Table 3). The use of 900kg NPK ha^{-1} gave similar values on any measured yield parameters in all the trials (2019/20 and 2020/21) as 600kg rate, and was superior to lower rate of 0 and 300 kg ha^{-1}.The response of yield characters (Tuber Number, Mean Tuber Weight, Tuber Diameter and Tuber Yield) fertilizer rates from 600kgNPK ha^{-1} to 900kgNPK ha^{-1}could be attributed to the collective role of the fertilizer nutrients (N, P and K) in enhancing the metabolic processes which bring about the production and translocation of dry matter. Nitrogen was largely known to enhance vegetativeness but production, deposition and translocation of dry matter are believed to be collective functions of N, P and K. Since N content of fertilizer in these trials doubles the quantity of both P and K, application of 600 kg NPK ha^{-1} may supply adequate N for maximum Tuber Numbers, but inadequate for maximum dry matter production. Therefore, application of the highest fertilizer rate of 900kg NPK ha^{-1} supplies reasonably adequate quantities of P and K for optimum dry matter production. Also according to Alhassan *et al*. (2004) and Babaji *et al*. (2009) reported high weight per tuber, high tuber number per hill and high tuber yield with NPK rate of 80:40:40 and120:60:60, respectively. According to IPI (1993), N and K application reduced tuber dry matter content, with the effect being less in K than N, but P was reported to slightly increase tuber dry matter content. Protein content usually expressed as a percentage of dry matter was enhanced by increase in N and K but reduced by increasing P application (Ezzat *et al*., 2011).

4.7 Effect of Variety

Throughout the two seasons (20019/20 and 2020/21), the greater Mean tuber diameter of variety Bertita over Diamant and Nicola was due to the variation in the tuber shape. The tubers of Bertita are morphologically rounded, while those of Diamant and Nicola are long and oval in shape. The tendency is that the diameter of the rounded Bertita would be greater while the length (if considered) of the long, oval Bertita would be greater. However, among the two latter varieties, Diamant could be said to outsize Nicola. This could be linked to the larger assimilatory leaf area which enhanced the production of more assimilates for increased tuber size. No significant difference was observed on Mean Tuber Weight among the three varieties, the similarity in these characters could be attributed to their larger SDW and CGR which enhanced their rate of tuber bulking, hence high dry matter content which consequently translated to heavier tubers. Variety Nicola, despite its inferiority in terms of yield characters such as Tuber number and tuber diameter, was able to compete favorably in terms of fresh tuber yield with the other varieties through its high tuber number per stand, hence the lack of significant tuber yield difference among the three varieties. Okonkwo *et al*. (2009) described Diamant and Nicola as varieties that are high yielding and of similar yield potential. Other researchers observed different tuber yield with different varieties under similar environmental conditions (Adhikari and Sharma, 2004). Babaji *et al*. (2009) reported significant variation in growth and yield attributes among varieties tested, which they attributed to the influence of genotype. The significantly high tuber carbohydrate content in varieties Nicola and Diamant over Bertita, and crude protein in Bertita over Nicola further indicated the genetic variation among the three varieties tested in this study (Babaji *et al*., 2009).

4.8 Effect of Tillage

Significantly higher Tuber Number, Mean Tuber Weight, Tuber Diameter and Tuber Yield were observed in this study for ridging than flat land (Table 3). Similar observation was reported by Ennin *et al*. (2009), these researchers reported 38% increases in sweet potato yield on ridges over mounds. Similarly, Brobbey (2015) concluded that planting potato on ridges is better than mounds, as ridge planting resulted in greater growth and yield of the crop.

Table 2 Plant height, Leave Numbers and Number of Branches of Potato Varieties as Influenced by Tillage and NPK rates at 9WAP in Gayi, Kebbi State, Sudan Savanna, Nigeria during 2019-21 dry seasons

Treatment	Plant Height		Leave Numbers		Number of Branches	
	2019/2020	2020/2021	2019/2020	2020/2021	2019/2020	2020/2021
Fertilizer rates (kg ha^{-1})						
0	23.45^{b}	27.93^{c}	73.31^{b}	81.53^{b}	4.62^{c}	5.55^{c}
300	31.44^{b}	34.92^{b}	90.06^{b}	109.28^{b}	7.31^{b}	7.24^{b}
600	35.99^{b}	39.67^{ab}	99.64^{ab}	114.86^{ab}	8.97^{ab}	9.90^{a}
900	38.23^{a}	42.71^{a}	115.37^{a}	121.59^{a}	9.69^{a}	10.62^{a}
SE±	0.424	0.399	8.791	10.347	1.663	2.387
Variety						
Bertita	27.71^{b}	31.25^{b}	85.29	91.51^{b}	9.81^{ab}	10.50^{a}
Nicola	23.36^{c}	20.90^{c}	83.50	101.33^{a}	7.70^{c}	8.79^{b}
Diamant	31.16^{a}	34.70^{a}	88.25	90.08^{b}	10.58^{a}	11.07^{a}
SE±	0.368	0.321	9.077	8.297	1.440	2.891
Tillage						
Ridged	32.41^{a}	34.38^{a}	104.41^{a}	110.63^{a}	10.08^{a}	10.70^{a}
Flat	25.74^{b}	27.71^{b}	92.28^{b}	95.50^{b}	7.72^{b}	8.34^{b}
SE±	0.300	0.288	9.044	8.937	1.176	2.354
Interaction						
FERT x VAR	NS	NS	NS	NS	NS	NS
FERT x TLG	NS	NS	NS	NS	NS	NS
VAR x TLG	NS	NS	NS	NS	NS	NS

Means followed by the same letter (s) in a treatment group are not significantly different at 5% level of significance using DMRT, NS: not significant at 5% level of significance, *: significant at 5% level of significance

The higher yield of potato on ridging over mounding might be due to the higher plant population density on ridges that helped to suppress weeds and reduced competition for available nutrients between the crop and weeds. Evapotranspiration and weed infestation on mounding is high because of the greater soil surface area exposure; hence control of weeds is difficult. This might have contributed to the lower root yields on mound than on ridges (Ennin *et al*., 2009)

Table 3 Tuber Number, Mean Tuber Weight, Tuber Diameter and Tuber Yield of Potato Varieties as Influenced by Tillage and NPK rates in Gayi, Kebbi State, Sudan Savanna, Nigeria during 2019-21 dry seasons

Treatment	Tuber Number		Mean Tuber Weight		Tuber Diameter		Tuber Yield	
	2019/2020	2020/2021	2019/2020	2020/2021	2019/2020	2020/2021	2019/2020	2020/2021
Fertilizer rates (kg ha^{-1})								
0	4.99^{c}	5.96^{c}	38.08^{d}	40.40^{c}	1.96^{c}	2.00^{c}	6.61^{c}	5.59^{c}
300	7.04^{b}	8.01^{b}	89.39^{b}	81.71^{b}	2.49^{b}	2.97^{b}	12.92^{b}	13.51^{b}
600	11.88^{a}	12.43^{a}	106.64^{ab}	98.73^{ab}	3.35^{a}	3.83^{a}	17.85^{a}	18.44^{a}
900	12.65^{a}	13.20^{a}	124.73^{a}	106.16^{a}	3.44^{a}	3.92^{a}	18.39^{a}	19.98^{a}
SE±	1.337	2.987	2.955	3.873	0.975	1.089	4.164	3.784
Variety								
Bertita	10.99^{b}	10.02^{ab}	86.99	88.86	3.73^{a}	4.31^{a}	16.44	15.03
Nicola	14.28^{a}	13.31^{a}	87.56	89.43	2.64^{c}	2.55^{c}	17.38	18.97
Diamant	10.65^{b}	9.98^{b}	89.10	90.97	3.02^{b}	3.01^{b}	16.80	16.39
SE±	0.991	1.089	3.780	3.996	0.465	0.842	3.669	3.981
Tillage								
Ridged	14.78^{a}	13.09^{a}	115.51^{a}	117.38^{a}	3.37^{a}	4.39^{a}	16.47^{a}	17.06^{a}
Flat	6.50^{b}	8.81^{b}	53.58^{b}	55.45^{b}	2.26^{b}	3.28^{b}	10.61^{b}	11.20^{a}
SE±	0.568	0.639	2.453	3.086	0.053	0.887	4.116	3.994
Interaction								
FERT x VAR	NS	NS	NS	NS	NS	NS	*	*
FERT x TLG	NS	NS	NS	NS	NS	NS	NS	NS
VAR x TLG	NS	NS	NS	NS	NS	NS	NS	NS

Means followed by the same letter (s) in a treatment group are not significantly different at 5% level of significance using DMRT, NS: not significant at 5% level of significance, *: significant at 5% level of significance

4.9 Interactions

The significant response of fresh yield to the interaction of NPK fertilizer rate and the tested varieties (Table 4) have clearly indicated the interdependence and complimentary role of fertilizer and varieties of potato in influencing the manifestation of the potentials of potato genotypes in terms yield as reported by Kooman *et al*. (1996). These results were in conformity with Babaji *et al*. (2009) who reported significant improvement in yield of potato varieties as a result of increasing rates of applied NPK fertilizer (600 – 900 kg NPK ha^{-1}).

Table 4 Interaction of variety and fertilizer on potato yield (t ha-1) at Gayi location (Birnin Kebbi) during 2019/2020 and 2020/2021 dry seasons

2019/20			
Fertilizer rates (kg ha^{-1})	**Variety**		
	Bertita	**Nicola**	**Diamant**
0	5.67f	4.95g	5.09f
300	15.32d	17.98bc	12.53e
600	17.45c	19.04a	17.34c
900	17.94cc	19.99a	18.91b
SE±	5.121		
2020/21			
0	5.61f	5.33f	5.03f
300	15.99de	16.39d	15.33e
600	17.86c	18.45b	17.94bc
900	18.56b	19.22a	18.03b
SE±	3.192		

Means followed by the same later (s) are not significantly different at 5% level using DMRT

Appendix I

Table Physical and Chemical Properties of Soil of the Experimental sites at Gayi during 2019/2021 dry session

	Aliero	**Jega**
	0–30 cm depth	
Particles size Analysis		
Sand (%)	84.00	72.50
Silt (%)	10.00	15.70
Clay (%)	6.00	11.80
p^{H} (1:2:5)	7.46	6.25
Organic carbon (%)	0.16	0.28
Total Nitrogen	0.03	0.04
Available Phosphorus (Mgkg^{-1})	0.08	0.34
Exchangeable bases (Cmolkg^{-1})		
Ca	0.35	0.65
Mg	0.45	0.40
K	0.97	1.18
Na	0.45	0.52
Cation exchange capacity (molkg^{-1})	2.20	2.75

5 Conclusion

Potato variety Diamant proved to be the most robust in terms of plant height and number of branches; and Nicola in terms of number of leaves per plant. Variety Nicola had an edge over the two other varieties in terms of fresh tuber yield probably as a result of its higher tuber number per stand. From the result of this study, the use of either of 600 or 900kg NPK ha^{-1}proved best for high tuber yield and economic returns. Also in the study area, variety Nicola could be adopted due to its potential for yield.

Recommendation

From the findings of this study, the following recommendations could be made:

- The use of either of 600 or 900kg NPK ha^{-1} could be adopted for higher fresh potato yield in the study area.
- Variety Nicola could also be considered since it recorded superior performance among the varieties tested in terms of yield in the study area

Compliance with ethical standards

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Disclosure of conflict of interest

H. Yusuf, A. Muhammad, H. Y. Sanda and S. Ajikobi designed and conducted the experiment; together with M. U. Tanimu, A. Aisha, and I. I. Shade who wrote and edited the manuscript while H. Yusuf, A. L. Hafsat and S. K, Manir collected and analyzed the data.

References

[1] Adhikari, R. C. and M. D. Sharma (2004). Use of Chemical fertilizers on Potato in Sandy Loam soil under Humid Sub-Tropical conditions of Chitwa. *Nepal Agricultural Research Journal*.5:23-26.

[2] Adhikari, R. C. and M. D. Sharma (2004). Use of Chemical fertilizers on Potato in Sandy Loam soil under Humid Sub-Tropical conditions of Chitwa. *Nepal Agricultural Research Journal*.5:23-26.

[3] Ahmed, H.G., M.D. Magaji, A. I. Yakubu, L. Aliyu and A. Singh (2007). Response of Garlic (*Allium satuvum*) to Irrigation Interval and Clove size in semi-arid Nigeria. *Journal of Plant Sciences*. 2(2):202-208.

[4] Alhasan, J., A. I. Yakubu and M. D. Magaji (2004). Irish potato yield in the Sokoto – Rima River Valley. *Nigerian Journal of Horticultural Science*. 9:49 – 54.

[5] Alhasan, J., A. I. Yakubu and M. D. Magaji (2004). Irish potato yield in the Sokoto – Rima River Valley. *Nigerian Journal of Horticultural Science.* 9:49 – 54.

[6] Anonymous (2012). Crop Area and Yield Survey. A report (2010) of the National Food Reserve Agency (NFRA). Federal ministry of Agriculture and Water Resources. Abuja, Nigeria. 88pp.

[7] Babaji, B. A., E. B. Amans, U. F. Chiezey, A. M. Falaki, B. Tanimu and A. A. Mukhtar (2009). Unmarketable Tuber yield and other Agronomic Parameters of four Varieties of Irish Potato (*Solanum tuberosum* L.) as Influenced by NPK Fertilizer rates and Types of seed tuber at Samaru, Nigeria. *Asian Journal of Crop Science*. 1(1):26-33

[8] Babaji, B. A., E. B. Amans, U. F. Chiezey, A. M. Falaki, B. Tanimu and A. A. Mukhtar (2009). Unmarketable Tuber yield and other Agronomic Parameters of four Varieties of Irish Potato (*Solanum tuberosum* L.) as Influenced by NPK Fertilizer rates and Types of seed tuber at Samaru, Nigeria. *Asian Journal of Crop Science*. 1(1):26-33

[9] Baniuniene, A. and V. Zekaita (2008). The Effects of Mineral and Organic Fertilizers on Potato Tuber Yield and Quality. *Latvian Journal of Agronomy*. 11:202-206

[10] Bouyoucus, G. H. (1951). A Recalibration Hydrometer Method for Making Mechanical Analysis of Soils. *Agronomy Journal*. 43:434.

[11] Bray, R. H. and L. T. Kurtz (1945). Determination of Total Organic and Available Forms of P in Soils. *Soil Science.* 59:39-45.

[12] Brobbey A (2015) Growth, yield and quality factors of sweet potato (*Ipomoea batatas* Lam) as affected by seedbed type and fertilizer application. *M. Phil thesis submitted to Kwame Nkrumah University of Science and Technology, Kumasi.*

[13] Brown, R. H (1984). Growth of Green Plants. In: Tesar (ed). *Physiological Basis of Crop Growth and Development*. ASA. Madison, W. I. Pp 153-173.

[14] Carl, J. R. (2003). Potato fertilization on irrigation soils. University of Minnesota Extension Services. 6 pp.

[15] Dalton, T. J., G. A. Porter. and N. G. Winslow (2004). Risk Management Strategies in Humid Production Region: a Comparison of Supplemental Irrigation and Crop Insurance. *Agricultural and Resource Economics review*. 33(2):220-232.

[16] Danquah EO, Issaka RN, Acheampong PP, Numafo M and Ennin SA (2014). Mechanization, fertilization and staking options for environmentally sound yam production. African Journal of Agricultural Research, 9:2222-2230.

[17] Dirk, A. T. and H. Myrna (1984). *Soil and Plant Analysis*. Study guide for Agricultural Laboratory Directors and Technologist working in Tropical regions. IITA, Ibadan, Nigeria, p 155-170.

[18] Duncan, D. B. (1955). Multiple Ranges and Multiple F-Test. *Biometrics*. 11:1-42.

[19] El- Saidi, M. T., O. M. Kassab. and S. A. Okasha, A. R. E. Abdelghany (2010). Effect of Drip Irrigation Systems, Water Regimes and Irrigation Frequency on Growth and Quality of Potato under Organic Agriculture in sandy soils. *Australian Journal of Basic and Applied Science*. 4(9): 4131-4141.

[20] Eldredge, E. P., C. C. Shock. and L. D. Saunders (2003). Early and Late Harvest Potato Cultivar Response to Drip Irrigation. In: Yada, R.V. (ed) Potatoes – Healthy Food for Humanity. *Acta Horticultural*. 619:233-239.

[21] Ennin SA, Otoo E, Tetteh FM (2009) Ridging, a Mechanized Alternative to Mounding for Yam and Cassava Production. *West African Journal of Applied Ecology* 15: available on http://www.ajol.info/index.php/wajae/article/viewFile/49424/3 5757 access on 29th April, 2016.

[22] Ezzat, A. S., A. A. El-Awady and H. M. A. Ahmed (2011). Improving Nitrogen Utilization Efficiency by Potato (*Solanum tuberosum* L.) B. effect of Irrigation intervals, Nitrogen rate and Veterra Hydrogel on Growth, Yield , Nutrient uptake and Storability. *Nature and Science. 9 (7): 34-42.*

[23] Fergeria, N. K., V. C. Boligar and C. A. Jones (1991). *Growth and Mineral Nutrition of Field Crops.* Marcel Dekker, inc. New York. 672 pp.

[24] Gindi, A. A., Y. Kaka and A. Muhammad (2013). Contribution of motorized pump to food production in Birnin Kebbi local government of Kebbi State, Nigeria. *International Journal of Agricultural Science and Veterinary Medicine*. 1(4):1-7.

[25] Harris, P. (1992). *The Potato Crop, the Scientific Basis for Improvement.* Chapman and Hall Ltd. Landon. 909pp.

[26] I P I (1993). International Potash Institute Bulletin: Fertilizers for yield and Quality. No. 8. Potato Switzerland. 84 pp.

[27] I P I (1993). International Potash Institute Bulletin: Fertilizers for yield and Quality. No. 8. Potato Switzerland. 84 pp.

[28] Islam, M. S., M. M. Hossain, M. D. Shariful Islam and M. A. Hossain (2009). Effect of Irrigation on the yield and Scab Infection of Potato. *Bangladesh Journal of Agricultural Research*. 34(4):683-692.

[29] Jackson, K., I. Kazuto and J. Yutaka (2015). Effects of Planting Dates on the Growth and Yield of Two Potato Cultivars Grown from Microtubers and Conventional Seed Tubers. *Journal of Plant Production Science.* 8(1): 76-78.

[30] Kang, Y., F. H. Liu. and B. Yuan (2004). China: Potato Evapotranspiration and Yield under Different Drip Irrigation Regimes. *Irrigation Science*. 23:133-143.

[31] Kenneth, A. R. and A. C. Brain (2000) Variety response to fertilizer rate. Clamath Experimental Station. *Annual report*. www. octahort.org. 5pp.

[32] King, B. A., J. C. Stark and R. W. Wall (2006). Comparison of Site –Specific and Conventional Uniform Irrigation Management for Potatoes. *American Society of Agricultural and Biological Engineers.* 22 (5): 677 – 688.

[33] Mandeep, S. and S. Kiranjot (2013). Adoption of Improved Potato Cultivation Practices. *International Journal of Agricultural Science and Veterinary Medicine*. 1(2):24-34

[34] Miko, S., M. K. Ahmed, E. B. Amans, A. M. Falaki and N. Ilyas (2000). Effects of level nitrogen, phosphorus and irrigation interval on the performance and quality of garlic (A*llium sativum* L.) *Journal of Agriculture and Environment*. 1(2):23-30.

[35] Muhammad, A., B. A. Gambo and N. D. Ibrahim (2011). Reponse of onion (*Allium cepa* L.) to irrigation interval and plant density in Zuru, Northern Guinea Savanna of Nigeria. *Nigerian Journal of Basic and Applied Science*. Usmanu Danfodiyo University, Sokoto, Nigeria 19(2):241-247.

[36] Muhammad, A., E. B. Amans, B. A. Babaji, N. C. Kachinda and B. A. Gambo (2015). Growth of Potato (*Solanum tuberosum* L.) as Influenced by Irrigation Interval and NPK Rates in the Sudan Savannah of Nigeria. *Global Journal of Cassava and Potatoes Research. 1*(1): 2-8

[37] Muhammad, A., Gindi, A. A. Gona, A. and Kaka, Y. (2016). Partial Economic analysis of Irish Potato Production under the Kebbi State Agroecological Conditions. *International Journal of Life Science and Scientific Research*. 2(2):183-190

[38] Naz, F., A. Ali, Z. Iqbal, N. Akhtar, S. Asghar and B. Ahmad (2011). Effect of Different Levels of NPK Fertilizers on the Proximate Composition of Potato Crop at Abbottabad. *Sarhad Journal of Agriculture*. 27(3):353-356.

[39] Okonkwo J. C., C. Amadi and C. O. Nwosuki (2009). Potato production, storage, processing and utilization in Nigeria. National Root Crops Research Institute, Umudike, Nigeria. Bulletin No. 1.

[40] Okonkwo J. C., C. Amadi and C. O. Nwosuki (2009). Potato production, storage, processing pand utilization in Nigeria. National Root Crops Research Institute, Umudike, Nigeria. Bulletin No. 1.

[41] Okonkwo, J. C., L. S. O. Ene. and O. O. Okoli (1995). *Potato Production in Nigeria.* NVRI Press. Vom. Nigeria. 109pp.

[42] Olanya, O. M, G. A. Porter, D. H. Lambert, R. P. Lakin. and G. C. Starr (2010). The Effects of Supplemental Irrigation and Soil Management on Potato Tuber Diseases. *Plant Pathology Journal*. 9(2):65-72.

[43] Parwada C, Gadzirayi CT, Sithole AB (2011) Effect of ridge height and planting orientation on *Ipomea batatas* (sweet potato) production. *Journal of Agricultural Biotechnology and Sustainable Development* 3: 72-76

[44] Pereira, A. B., and C. C. Shock (2006). Development of irrigation best management practices for potato from a research perspective in the United States. Sakia.org e- Publish. 1:1-20. Available online at http://www.sakia.org/

[45] Radford, P. J. (1967). Growth Analysis Formulae: Their Uses and abuse. *Crop Science.* 3:171-175.

[46] Rhodes, R. E., R. J. Hijmans and L. Huaccho (2002). World Potato Atlas: Potato in Nigeria. http//www.cipotato.org/potato. htm. 7 pp.

[47] Rolot, J. L. (2001). Potato. In: Romain H. R. (ed). *Crop Production in Tropical Africa*. DGIC Belgium pp. 188 – 204

[48] SAS (2003). Statistical Analysis System. SAS Release 9.1 for windows, SAS Institute Inc. Cary, NC, USA.

[49] Shock, C. C. and E. B. G. Feibert (2002). Deficit Irrigation of Potato. In: P. Mountonnet (ed.). Deficit Irrigation Practices, Food and Agricultural Organization of the United Nation, Rome*. Water Report*. 22:47-55.

[50] Shock, C.C., E. B. G. Feibert. and L. D. Saunders (2003). Umatilla Russet and Russet Legend potato Yield and Quality Response to Irrigation. *Horticultural Science*.38:1117-1121.

[51] Simonne, E., N. Ouakrim and A. Caylor (2002). Evaluation of an Irrigation Scheduling Model for Drip-irrigated Potato in Southern United States. *Horticultural Science*. 37:104-107.

[52] Starr, G. C., D. Rowland, T. S. Griffin and O. M. Olanya (2008). Soil water in Relation to Irrigation, Water uptake and Potato Yield in a Humid Climate. *Agriculture and Water Management*: 5:292-300.

[53] Steel, R. G. D. and J. H. Torrie (1987). Principles and Procedures of Statistics. A Biometrical Approach. McGraw-Hill, New York, pp. 186-187.

[54] Ugonna, C. U, M. O. Jolaoso, A. P. Onwualu (2013). A technical appraisal of potato value chain in Nigeria. *International. Research Journal of Agricultural Science and Soil Science*. 3(8):291-301.

[55] Waddell, J. T., S. C. Gupta, J.F. Moncrief, C. J Rosen and D. D. Steele (2000). Irrigation and Nitrogen Management Impact on Nitrate Leaching under Potato. *Journal of Environmental Quality*. 29:251- 261.

[56] Wang F., Y. Kang and S. Liu (2006). Effects of Drip Irrigation Frequency on soil Wetting Pattern and Potato Growth in Northern China Plain. *Agricultural Water Management*. 79:248-264.

[57] Wild, A. (2008). *Russel's soil condition and plant growth.* 11th edition. John Wiley and sons. Inc. New York. 989 pp.

[58] Wininger, A., W. Maag, J. Rek and W. Reust (2011). Potato cultivars for the food industry. Main trials with mid-early to mid-late cultivars for technical processing 1987-9 (Series 61). *Landwirskhaft Schweiz,* 4 (8) 403-406 (Field Crops Abstract 46 (5) 384).

[59] Yusuf, R. L., J.C. Siemens and D. G. Bullock (1999). Growth Analysis of Soyabean under No-tillage and Conventional tillage Systems. *Agronomy Journal.* 91: 928 – 933.

[60] Zrust, S. (2009). Reasons for differences in early potato cultivars performance. *Rostlinna Vyroba,* 37 (2) 99-106 (Field Crops Abstract 45 (4)309)