Original Research Article

EFFECT OF NITROGEN, PHOSPHORUS AND VARIETY ON PHYSIOLOGICAL INDICES AND NUTRIENT COMPOSITION OF LIVINGSTONE POTATO (*Plectranthus esculentus* N.E.Br.) IN GOMBE, NORTHERN GUINEA SAVANNAH, NIGERIA

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Abstract

Plectranthus esculentus N.E.Br. locally known as "rizga" is an important indigenous tuber crop in Nigeria which is currently endangered. One major factor that causes disappearance of this species, is the lower agronomic recommendations developed for growers and lack of information about nutrient contents leading to loss of interest in its cultivation. A field experiment was therefore conducted during the 2016 and 2017 rainy seasons to determine the effect of nitrogen, phosphorus and variety on physiological indices as an attempt to conserve and evaluate the potential of the crop in food security, source of income and its adaptation in the Northern Guinea Savannah of Nigeria. The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. Treatments consisted four levels of nitrogen and phosphorus (0, 60, 90 and 120 kg/ha), respectively and two varieties (vat Riyom and vat Loang'at). Results from analysis of variance showed that nitrogen and phosphorus applied at 90 kg/ha significantly produced higher physiological indices in both years. Beyond this rate, there was a decline in physiological indices resulting in decrease in starch content and dry matter accumulation. Harvest index indicated a positive relationship between the proportion of the biological yield and nutrient levels. Although, varietal differences was not significant on harvest index. This is an indication that HI is purely a genetic trait as affected by environmental factors. It was therefore concluded that, for high yield of livingstone potato, soils should be treated with a moderate application rate of 90 kg/ha nitrogen and phosphorus for enhanced physiological indices which are measures of growth and productivity per unit area of land in the Northern Guinea Savanna of Nigeria.

Keywords: Nitrogen, phosphorus, variety, physiological indices, harvest index

INTRODUCTION

Plectranthus esculentus N.E. Br. is one of the underutilized tubers indigenous to Africa and grown for its edible tubers. The crop which is locally known as rizga is currently endangered partly due to lower agronomic recommendations developed for growers and lack of information about nutrient contents leading to loss of interest in its cultivation. The effect of external environment (soil nutrients) on plant physiological processes cannot be over-emphasized. The interrelation between crop yield and variations in environment is dependent on genetic constitution of the crop. Sufficient nutrient levels are a fundamental constituent of many leaf cell components, particularly those associated with the photosynthetic apparatus, including carboxylating enzymes and proteins off membranes (Pandey, Maranville and Admon, 2000).

Nitrogen is the most limiting nutrient for potato growth, especially in sandy soils where the organic matter content is low. The root system in potato is fibrous and shallow and hence, nitrogen uptake from soils is grossly inefficient especially when there is adequate water supply (Peralta and Stockle, 2002). Nitrogen fertilizer increases the leaf area which increase the amount of solar radiation intercepted and consequently increases dry matter production by different plant parts (Krishnippa, 1989). It increases potato yields by increasing the number of tubers formed (Kotsyuk, 1995), duration of tuber bulking and nitrogen uptake by the plant (Martin, 1995). The recovery of N by the crop is usually low and much of the non-recovered N is lost through denitrification immobilization or by leaching out of the root zone. Nitrogen sustains the leaf area duration (LAD) of plants and thus maintains the persistence of the assimilatory surfaces of leaves (Kumar and Dhiman 2005).

Phosphorus is the second most important macro-nutrient limiting plant growth after nitrogen in most soils. It is a plant nutrient that intervenes in cellular energy transfer, photosynthesis and respiration and it's a component of nucleic acid, nucleotides, phospholipids and phosphorylated sugars (Marschner, 1996). Unfortunately, P is one of the least accessible nutrients in most soils especially under tropical conditions where low P availability is a big challenge to agricultural production (Shoko *et al*. 2010).

Reduction in plant biomass production or growth rate under P deficient conditions may be ascribed to either limited amount of absorbed photosynthetically active radiation (PAR) (Lukhoba *et al*.

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2006) or to a less efficient conversion of the intercepted radiation (Alt *et al.* 1999). Potato fertilization usually requires high amounts of phosphate fertilizer (60 to 80 $kgha^{-1}$ P) to achieve economically acceptable yields necessitated by the low root density of this plant (Alvarez-Sanchez *et al.* 1999). P deficiency in the plant slows apical growth, resulting in small rigid plants, reduces the formation of starch in the tubers causing necrotic spots distributed in the tuber (Pumisacho and Sherwood, 2002) and decreases CO_2 absorption capacity of leaf photosynthesis (Mengel *et al.* 2001)

Findings have shown that as the leaf area index increases beyond a critical value, net assimilation rate either remains constant or decreases due to mutual shading and other factors. Data on dry matters production of several crops indicate that less than one percent of solar radiation is utilized by crops. This study was therefore aimed at analyzing physiological indices of different livingstone potato varieties as influenced by Nitrogen and Phosphorus.

Materials and Methods

Field experiment was conducted during the rainy season (June to October) of 2015/2016 and 2016/2017 at a Community Based Research Farm Kwadon, Gombe State to determine "the effect of nitrogen, phosphorus and variety on the physiological indices of livingstone potato in Northern Guinea Savanna of Nigeria".

Biomass (dry weight) and LAI were determined at 8 and 12 WAP from each plot, an area of $2m^2$ was sampled per sampling week for total biomass determination. Dry mass was determined by oven drying the components at 80˚C to constant weight before weighing. The LAI was determined by measuring the leaf area and dividing the product by the plants canopy cover. From Biomass or dry matter accumulation and LAI, other physiological indices as CGR, RGR, NAR, LAR and LAD were computed.

Data Analysis

All data collected were subjected to statistical analysis according to Steel and Torrie (1980). Duncan Multiple Range Test was used to separate the significantly different means (Duncan, 1955).

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Results and Discussion

Leaf area, a measure of the photosynthetic capacity of the plant was significantly ($P \leq 0.05$) affected by applied nitrogen and phosphorus at all growth stages throughout the period of the experiment (Table 1). Leaf area increased with increasing nitrogen and phosphorus application up to a point (90 kg/ha) beyond which it decreased. Findings revealed that application of 90 kg/ha/N and P respectively significantly ($P \leq 0.05$) produced largest leaf area. It also revealed that further increase in nutrient levels resulted in reduced leaf area which were statistically at par with the control. The loang'at variety significantly ($P \leq 0.05$) recorded largest leaves than the Riyom. The concomitant increase in leaf area resulting from increased nutrient levels could be attributed to the fact that N concentration influence foliar expansion and elongation. This is in line with the findings of Amanulla *et al.* (2007). Moreso, the decreasing trend in leaf area above 90 kg/ha nutrient levels corroborates the findings of Sud and Sharma (2002) and Yadanar *et al.* (2009). Nitrogen significantly interacted with phosphorus throughout the period of this study thus, revealing their complementarity and essentiality in crop physiological processes.

The significant response of leaf area index to applied phosphorus in 2017 season could be due to the residual effect of applied phosphorus in the previous season. These means that livingstone potato under this treatment would maximize interception of photosynthetically active radiation (PAR) and hence have maximum net productivity. The non-significant response of leaf area index to varying levels of nitrogen and phosphorus in the first cropping season may be due to the fact that phosphorus is immobile in the soil and least accessible in most soils especially under tropical conditions where low P availability is a big challenge to agricultural production (Shoko *et al.* 2010). The non-significant response of LAI to varietal differences could be due to the inherent genetic potential of the crop to produce narrow leaves irrespective of soil amendment. Interaction between nitrogen and phosphorus on LAI was significant in 2017 indicating the complementary effect of both nutrients in plants physiological activities as reported by Salo *et al*. (2002) and Pire *et al.* (2001). Dry matter accumulation, a good growth index to express the photosynthetic efficiency of the plant was significantly ($P \leq 0.05$) affected by nitrogen and phosphorus fertilization (Table 3). Dry matter increased concomitantly with nutrient levels probably due to proliferation of more leaves and larger leaf area recorded in this treatment for efficient solar interception, enhanced photosynthesis, better partitioning and accumulation of photosynthates. This corroborates the findings of Krishnippa (1989). The reduction in dry matter recorded at nutrient levels above 90 kg/ha is in line with the findings of zelalem *et al*. (2009) who reported that "an overdose of nitrogen lowers the tuber dry matter by decreasing the starch content. This was further confirmed by the findings of Ali *et al*. (2009) who stated that "too much nitrogen results in increased susceptibility to diseases and reduced dry matter content in tubers".

The significant response of dry matter to varietal differences at 8 WAP in 2016 and 2017 seasons respectively could be due to favourable climatic conditions as manifested in sufficient soil moisture which encouraged better absorption of nutrients and their onward translocation to their productive sites. Moreso, dry matter accumulation in tubers is purely a genetic trait. This result is in line with the findings of Danbaba *et al.* (2008) who reported that dry matter production is a function of genetic and environmental factors.

The effect of nitrogen and phosphorus on crop growth rate, relative growth rate and net assimilation rate were significant in both years. These physiological indices were highest at 90 kg/ha nutrient levels and decreased with further increase in fertilization. Values for 2017 were relatively higher than those for 2016. This may be attributed to variation in agro-climatic conditions during the growth and development of the crop as manifested in frequent and high temperature surges coupled with inadequate rainfall and poor distribution pattern recorded in 2016. The decreasing trend in physiological indices above 90 kg/ha nutrient levels re-affirms the findings of Zelalem *et al*. (2009) who stated than a overdose

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of nitrogen lowers dry matter by decreasing the starch content since most of the photosynthates are used up for elaborate vegetative growth.

Leaf Area Ratio (LAI), leaf area duration (LAD) and Economic yield designated as harvest index (HI) were significantly (P≤0.05) affected by nitrogen fertilization in a similar fashion as CGR, RGR and NAR. These indices ensured constant supply of nutrients to promote vegetative growth as nitrogen played important roles in the synthesis of chlorophyll, enzymes and proteins as well as enhanced photosynthetic processes as opined by Ekinya *et al*. (2016) and Danbaba and Amadi (2008). The non significant response of LAR and LAD to phosphorus fertilization may be attributed to the fact that P encourages early senescence and maturity in crops which ultimately reduced the duration of active assimilatory surface in leaves. This is in line with the findings of Salo *et al*. (2002) and Mulubrhan (2004) who affirmed that phosphorus significantly influenced days to 50% flowering and encourages seeds, fruits and tuber formation as well as ensure tuberization in crops.

Harvest index indicated a positive relationship between the proportion of the biological yield which is of economic importance and nutrient levels. The non-significant response of varieties to HI is an indication that HI is purely a genetic trait as earlier recorded by Maitlo *et al*. (2006).

Table 1

Effect of Nitrogen, Phosphorus and variety on leaf area (cm^2) at 8, 10 and 12 WAP in 2016 and 2017

Treatment	2016			2017		
	8	**10**	**12**	**8**	**10**	**12**
Nitrogen (kg/ha)						
0	19.55^{c}	22.15^{c}	23.14^{c}	19.98^{c}	24.18^{d}	24.72^{b}
60	20.78^{b}	24.45^{b}	25.22^{b}	21.27^{b}	25.91^{b}	25.44^{b}
90	22.60^{a}	26.10^{a}	27.17^{a}	23.22^{a}	27.88^{a}	28.32^{a}
120	19.08^{c}	22.46^{c}	23.61^{c}	20.03^{c}	25.16^{c}	26.10^{b}
LS	**	**	**	**	**	**

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SE ±	0.26	0.34	0.31	0.20	0.24	0.55
Phosphorus (kg/ha)						
0	16.25^{d}	18.23^{d}	19.14^{d}	16.59^{d}	20.07^{c}	20.61^{c}
60	21.44^{b}	24.22^{b}	25.10^{b}	21.93^{b}	25.55^{b}	25.15^{b}
90	25.10^{a}	30.33^{a}	31.15^{a}	25.61^{a}	31.89^{a}	32.42^{a}
120	19.22^{c}	22.39^{c}	23.75^{c}	20.36^{c}	25.63^{b}	26.40^{b}
LS	**	**	**	**	**	**
SE ±	0.26	0.34	0.31	0.20	0.24	0.55
Variety (V)						
Vat Riyom (V_1)	19.50	22.25	23.03	19.93	24.75	24.81
Vat Loang'at (V_2)	21.51	25.33	26.54	22.32	26.82	27.48
LS	**	**	**	**	**	**
SE ±	0.18	0.24	0.22	0.14	0.17	0.39
Interaction						
P.N	**	**	**	**	**	*
P.V	NS	NS	NS	**	**	NS
N.V	NS	NS	NS	NS	NS	NS
P.N.V	NS	NS	NS	NS	*	NS

* and ** = significant at 5 and 1 percent level of probability respectively. NS = Not Significant. Means followed by the same letter(s) within a treatment group are not significantly different at 5% level of probability (Duncan's New Multiple Range Test).

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Table 2

Effect of Nitrogen, Phosphorus and Variety on Leaf Area Index (LAI) at 8, 10 and 12 WAP in 2016 and 2017

	2016			2017		
Treatment	**8**	**10**	**12**	**8**	**10**	**12**
Nitrogen (kg/ha)						
0	0.06	0.07	0.08	0.07	0.08	0.09
60	0.07	0.08	0.08	0.08	0.09	0.09
90	0.08	0.08	0.08	0.07	0.08	0.08
120	0.07	0.08	0.08	0.07	0.08	0.08

LS	NS	NS	NS	NS	NS	NS
SE±	0.003	0.003	0.004	0.004	0.003	0.004
Phosphorus (kg/ha)						
0	0.10	0.11	0.12	0.10^{a}	0.11^{a}	0.12^{a}
60	0.07	0.09	0.90	0.08^{b}	0.09^{b}	0.93^{b}
90	0.07	0.08	0.75	0.07^{c}	0.08^{c}	0.83^{b}
120	0.03	0.03	0.44	0.03^{d}	0.04^{d}	0.45^{c}
LS	NS	NS	NS	**	**	**
SE±	0.003	0.003	0.004	0.004	0.003	0.004
Variety (V)						
Vat Riyom-(V_1)	0.08	0.08	0.08	0.07	0.08	0.08
Vat Loang'at-(V_2)	0.07	0.08	0.09	0.07	0.08	0.08
LS	NS	NS	NS	NS	NS	NS
SE±	0.003	0.002	0.003	0.003	0.002	0.002
Interaction						
N.P	NS	NS	NS	**	**	**
P.V	NS	NS	NS	NS	NS	NS
N.V	NS	NS	NS	NS	**	NS
N.P. V	NS	NS	NS	NS	*	NS

* and ** = significant at 5 and 1 percent level of probability respectively. NS = Not Significant. Means followed by the same letter(s) within a treatment group are not significantly different at 5% level of probability (Duncan's New Multiple Range Test).

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Table 3

Effect of Nitrogen, Phosphorus and Variety on Dry Matter accumulation (g/plant) at 8 and 12 WAP in 2016 and 2017

Treatments	**2016**		**2017**	
	8	12	8	12
Nitrogen (kg/ha)				
0	39.40^{d}	47.63^{c}	38.44^{d}	47.31^{c}
60	48.30^{c}	60.75^{b}	43.49^{c}	64.29^{b}
90	72.00^{a}	89.41^{a}	76.83^{a}	90.50^{a}

120	69.40^{b}	88.31^{a}	71.35^{b}	89.78^{a}
LS	**	**	**	**
SE±	0.69	1.60	1.56	1.69
Phosphorus (kg/ha)				
0	53.48^{c}	67.44^{c}	54.18^{b}	68.53^{c}
60	57.80^{b}	69.79^{bc}	56.33^{b}	71.44^{bc}
90	61.30^{a}	75.46^{a}	61.20^{a}	77.11^{ab}
120	59.20a^{b}	73.44^{ab}	58.40^{ab}	74.80^{a}
LS	**	*	*	*
SE±	0.69	1.60	1.56	1.69
Variety (V)				
Vat Riyiom-(V1	54.60	69.94	55.82	72.25
Vat Loang'at-(V2)	59.90	73.11	59.23	73.6
LS	**	NS	*	NS
SE±	0.37	1.13	1.1	1.19
Interaction				
N. P	NS	NS	NS	NS
P.V	NS	NS	NS	NS
N.V	NS	NS	NS	NS
N .P.V	NS	NS	NS	NS

* and ** = significant at 5 and 1 percent level of probability respectively. NS = Not Significant. Means followed by the same letter(s) within a treatment group are not significantly different at 5% level of probability (Duncan's New Multiple Range Test).

Table 4

Effect of Nitrogen, Phosphorus and Variety on Crop Growth Rate (CGR), Relative growth Rate (RGR) and Net Assimilation rate (NAR) in 2016 and 2017

	Crop Growth Rate		**Relative Growth Rate**		**Net assimilation Rate**	
Treatments	**2016**	**2017**	**2016**	**2017**	**2016**	**2017**
Nitrogen (kg/ha)						
0	2.80^{c}	3.15^{c}	1.05^{c}	1.12^{c}	10.49^{c}	10.59^{c}
60	3.74^{b}	4.56^{b}	1.91^{b}	1.95^{b}	12.40^{b}	12.59^{b}
90	4.84^{a}	5.19^{a}	2.62^{a}	2.66^{a}	14.09^{a}	14.66^{a}
120	3.67^{b}	4.27^{b}	2.09^{b}	2.20^{b}	12.56^{b}	13.14^{b}
LS	**	**	**	**	**	**
SE±	0.11	0.13	0.10	0.12	0.22	0.28
Phosphorus Kg/ha						
0	3.49^{b}	4.13	1.50^{c}	1.53^{b}	11.82^{b}	12.25^{b}

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60	3.69^{ab}	4.12	1.88^{b}	2.06^{a}	12.26^{b}	12.55^{b}
90	3.99^{a}	4.54	2.23^{a}	2.27^{a}	13.00^{a}	13.44^{a}
120	3.88^{a}	4.38	2.06^{ab}	2.08^{a}	12.47^{ab}	12.75^{ab}
LS	*	NS	**	**	*	*
SE±	0.11	0.13	0.10	0.12	0.22	0.28
Variety (V)						
Vat Riyiom-(V1	3.63	4.19	1.65	1.73	12.12	12.52
Vat Loang'at-(V2)	3.90	4.39	2.19	2.24	12.65	12.97
LS	*	NS	**	**	*	NS
SE±	0.81	0.09	0.07	0.08	0.15	0,10
Interaction						
N.P	NS	NS	NS	NS	NS	NS
P.V	NS	NS	NS	NS	NS	NS
N.V	NS	NS	NS	NS	NS	NS
N.P.V	NS	NS	NS	NS	NS	NS

* and ** = significant at 5 and 1 percent level of probability respectively. NS = Not Significant. Means followed by the same letter(s) within a treatment group are not significantly different at 5% level of probability (Duncan's New Multiple Range Test).

Table 5

Effect of Nitrogen, Phosphorus and Variety on Leaf Area Ratio (LAR), leaf area duration (LAD) and harvest index (HI) in 2016 and 2017.

	Leaf Area Ratio		**Leaf area duration**		**Harvest index**	
Treatment	**2016**	**2017**	**2016**	**2017**	**2016**	**2017**
Nitrogen (kg/ha)						
0	1.07^{c}	1.18^{c}	15.65^{b}	19.64^{b}	0.18^{c}	0.21^{c}
60	2.35^{b}	2.52^{b}	18.16^{b}	20.37^{b}	0.98^{b}	1.07^{b}
90	3.38^{a}	3.69^{a}	26.74^{a}	27.65^{a}	1.70^{a}	1.72^{a}
120	3.65^{a}	3.50^{a}	26.34^{a}	27.47^{a}	1.60^{a}	1.61^{a}
LS	**	**	**	**	**	**
SE±	0.18	0.19	0.88	0.97	0.06	0.05
Phosphorus (kg/ha)						
0	2.32	2.48	20.11	22.43	0.97^{b}	1.04^{b}
60	2.57	2.79	21.51	23.64	1.03^{b}	1.09^{ab}
90	2.87	3.06	23.36	24.88	1.23^{a}	1.25^{a}
120	2.68	2.56	21.91	24.19	1.23^{a}	1.23^{a}
LS	NS	NS	NS	NS	*	*

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SE±	0.18	0.19	0.88	0.97	0.06	0.05
Variety (V)						
Vat Riyom-(V_1)	2.36	2.46	20.58	23.44	1.07	1.11
Vat Loang'at-(V_2)	2.86	2.98	22.87	24.12	1.16	1.19
LS	NS	NS	*	NS	NS	NS
SE±	0.12	0.13	0.62	0.69	0.04	0.34
Interaction						
N.P	NS	NS	NS	NS	NS	NS
P.V	NS	NS	NS	NS	NS	NS
N.V	NS	NS	NS	NS	NS	NS
N.P.V	NS	NS	NS	NS	NS	NS

* and ** = significant at 5 and 1 percent level of probability respectively. NS = Not Significant. Means followed by the same letter(s) within a treatment group are not significantly different at 5% level of probability (Duncan's New Multiple Range Test).

Conclusion

Findings have shown that nitrogen and phosphorus fertilization have sound and promising impact on livingstone potato's physiological indices which are measures of productivity per unit area of land. In critical fertilizer shortage times in Nigeria, farmers can still realize high biomass which will translate into high yield potential when they use a moderate rate of 90 kg/ha nitrogen and phosphorus to obtain high yields of livingstone potato on a sustained basis while maintaining the edaphic and ecological equilibrium of the area under cultivation.

Recommendations

From the foregoing, it is hereby suggested for recommendation that;

i. Soils should be treated with a moderate nitrogen application rate of 90 kg N/ha for enhanced productivity of livingstone potato in the Sudan Savanna Agro-ecological zone of Nigeria

ii. Phosphorus should also be applied pre-plant at 90 kg/ha to ensure P availability after crop emergence, avoid P-fixation in soils and enhance tuberization.

iii. The Loang'at Variety of livingstone potato should be adopted in Gombe and environs for better adaptability and increased productivity on a sustained basis.

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iv. Livingstone potato should be sown at the on-set of the rains to enable it complete it life cycle before cessation.

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