

Response of Sweetpotato [*Ipomoea batatas* (L.) Lam.] to Five Rates Each of Nitrogen and Phosphorus under Guinea and Sudan Savannah Agroecological Zones of Ghana

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Abstract

A multi-locational field experiment was conducted to evaluate the effects of increasing rates of nitrogen and phosphorus on sweetpotato growth and yield at Bawku and Nyankpala. Shoot yield increased by 31%, 63%, 94% and 125% in Bawku and 49%, 98%, 148% and 197% in Nyankpala, when nitrogen was applied at 30, 60, 90 and 120 kg·ha⁻¹, respectively. When nitrogen was applied at 30, 60, 90 and 120 kg·ha⁻¹, storage root yield increased by 30, 46, 48, and 37% in Bawku and by 13, 17, 14 and 3% in Nyankpala, respectively. The optimum nitrogen required to maximize storage root yield were 80 and 62.5 kg·ha⁻¹ for Bawku and Nyankpala, respectively, in a split application at 2 and 6 weeks after planting. Storage root yield increased by 4%, 5%, 2% and -4% in Nyankpala and by 54%, 81%, 82%, 56% in Bawku, when 40, 80, 120 and 160 kg P were applied. Optimum phosphorus required to produce the highest storage root yield in this study are 67.5 and 101.3 t·ha⁻¹ for Nyankpala and Bawku, respectively. The maximum net return to investment occurred when 60 kg N·ha⁻¹ and 40 kg P·ha⁻¹ were applied at Bawku and Nyankpala, respectively.

Keywords

Sweetpotato, Apomuden, Storage Root, Nitrogen, Phosphorus, Guinea Savannah, Sudan Savannah

1. Introduction

Sweetpotato [*Ipomoea batatas* (L.) Lam.] is the seventh most important food crop

in the world after maize, wheat, rice, potato, cassava and barley, and the fifth in the tropics, in terms of annual production [1]. In recent times, as a staple food for most tropical and subtropical countries, its cultivation and consumption are increasing due to the increasing awareness of its nutritional and health benefits. These benefits include high energy content, vitamin C and B6, beta carotene content especially for the orange-flesh cultivars/varieties, low glycemic index, protease inhibitors and antioxidants [2]-[4]. Sweetpotato fulfils several basic roles in the global food system, all of which have fundamental implications for meeting food requirements, reducing poverty, and increasing food security [5]. In a study in northern Ghana, it was concluded that the smallholder households that produce low-technology, subsistence crops, like sweetpotatoes, are more food secure than those who do not [6]. Sweetpotato production is increasing faster than most other crops in terms of production in Africa. It increased from 17.9 million tonnes (t) in 2011 to 28.8 million t in 2020 [1]. However, sweetpotato production in Ghana only increased from 130,000 t in 2011 to 139,439 t in 2020 [1] representing about 7% increase as against 38% increase production in Africa. This slow growth of the local sweetpotato industry is mainly due to the low production efficiency of the crop. Additionally, in spite of all its importance in Ghana, in 2015, only 27% of its yield potential of 56 t·ha⁻¹ was achieved [7]. In 2020, Ghana's sweetpotato yield was 2.0 t·ha⁻¹ while in Egypt and Senegal it was 34 and 36 t·ha⁻¹, respectively [1]. One of the reasons for the low productivity of the crop is low soil fertility.

Profitable crop production cannot continue without replenishing soil nutrients. Nitrogen (N) and phosphorus (P) are two of the essential macro nutrients required by crops to grow. Crop production cannot be sustained without the use of manufactured fertilizers, incorporation of N fixing crops and/or organic sources of N [8]. N fertilization improves the growth of above ground parts, production and quality of sweetpotato storage roots [9]-[15]. Deficient or excessive N application inhibits the formation of storage root (SR), resulting in reduced yield potential of sweetpotato, early senescence, overgrowth, unbalanced source-sink relationships, and low N use efficiency [12] [16]-[20]. The effective use of N to obtain maximum yields while reducing the amount of nitrate-N in the soil is very important. Hill [21] [22] observed the optimum rates ranged from 0 to 46 kg N·ha⁻¹. The response of sweetpotato to N application is cultivar dependent and these cultivars have been categorized as N-responsive, N-indifferent and N-depressive groups [23] [24]. P has widespread involvement in virtually every physiological process in plants such as in all energy-requiring reactions, modifies enzyme activity in phosphorylation, activates proteins, regulates metabolic processes, in cell signalling and division [25]. It is very important in crop soil nutrient management for achieving maximum crop yields [26]-[38]. Studies conducted in Nigeria and Papua New Guinea reported increased SR yield due to fertilizer (NPK) application [16] [39]. There is little documented information on the effects of N and P on sweetpotato in Guinea and Sudan savannah zones of Ghana. This study was carried out to investigate the interactive effect of different rates of N and P on the growth, development and yield of the orange-

fleshed sweetpotato cultivar, Apomuden, under Guinea and Sudan savannah agroecological zones of Ghana.

2. Materials and Methods

This experiment was conducted in the field at Council for Scientific and Industrial Research-Savanna Agricultural Research Institute (CSIR-SARI) at Nyankpala (9°24'N, 0°59'W, 183 m above sea level) and Manga (11°01'N, 0°16'W, 246 m above sea level), Ghana in 2015. Nyankpala is within the sub-humid tropics under Guinea savannah agroecological zone of Ghana with uni-modal rainfall regime. It has a mean annual rainfall of 1100 mm with growing season duration of 180 - 200 days. The trial site soil which is referred to as Kumayili series and categorized as savannah ochrosol, is a typical upland soil, well drained, shallow to moderately shallow (60 - 120 cm), orange-brown, sandy clay with a slightly humous sandy topsoil, overlying partly indurated plinthite [40] [41]. Bawku is within the semi-arid tropics under Sudan savannah agroecological zone of Ghana with uni-modal rainfall regime. It has a mean annual rainfall of 1000 mm with growing season duration of 150 - 160 days.

2.1. Experimental Design and Treatments

Treatments consisted of factorial arrangement of five rates each of N (0, 30, 60, 90 and 120 kg·ha⁻¹) and P (0, 40, 80, 120 and 160 kg·ha⁻¹) in randomized complete block design with four replications. Determination of the N and P rates were based on previous reports from similar studies and the location soil mean N and P contents as contents as well as sweetpotato N and P nutrient requirements. Field grown planting materials (slips) with about four nodes were planted into four row plots (4 × 6 m) at a spacing of 100 by 30 cm to obtain a plant population density of about 33,333 plants·ha⁻¹. Apomuden, an orange-fleshed sweetpotato variety was used as the test crop. Each slip was planted with two nodes underground and the other two nodes above the soil surface. The N was split applied as recommended by Barber *et al.* [42]. At two weeks after planting (WAP), one half of the N rates, as sulphate of ammonia [(NH₄)₂SO₄] with full rate of P as triple super phosphate [Ca(H₂PO₄)₂·H₂O] were applied by banding along the row and covered with soil and the other half of the N rates were applied at 6 WAP. Weeds were controlled at 2 and 6 WAP to ensure a clean field within the first 6 WAP as recommended by Seem *et al.* [43].

2.2. Soil Sampling and Analysis

Composite soil samples were taken from depths of 0 - 15 cm and 15 - 30 cm prior to planting at both locations. These samples were air dried, ground, sieved with 2 mm mesh and analyzed at CSIR-SARI's Soil Chemistry laboratory. Soil total N was determined by Kjeldhal method [44], available P by Bray I procedure [45], exchangeable K and magnesium by ammonium acetate extraction determined by Atomic Absorption Spectrophotometry (AAS) [46], soil pH was determined in

0.01 M CaCl₂ solution in 1:2.5 soil:solution ratio and soil organic carbon determined by wet combustion method [47]. The soil analysis result and the location weather data during the growing period are presented in **Table 1** and **Table 2**, respectively. The Nyankpala experiment was harvested after 96 days after planting (DAP) while the Bawku study was harvested 85 DAP.

2.3. Measurements and Statistical Analysis

Lengths of vines were measured and numbers of leaves on vines were counted from four randomly tagged plants in each plot for the first four weeks after treatment application. Shoot and SR yield as well as total biomass were taken at harvest. Leaves, stems (vines with petioles) and roots were oven-dried at 80 over 72 h and then weighed to determine individual component dry weights before summing up to obtain total biomass.

The experimental data were subjected to analysis of variance using the General Linear Model procedure of the Statistical Analysis System [48] to determine main factor effects and treatment interactions. Means were separated by Fisher's protected LSD test at the 0.05 level of probability. Best-fit equations were determined using coefficient of variation and root mean square error. Graphical analyses were carried out using SigmaPlot 11.0 [49].

Table 1. Pre-planting physico-chemical properties of soil at Nyankpala and Bawku.

Soil depth (cm)	pH (0.01 M CaCl ₂)	Sand	Silt	Clay	Org. C	Total N	Bray I P	Exch K	Exch Ca	Exch Mg
				%			mg/kg	Cmol+/kg		
0 - 15	5.94	61.48	6.4	32.12	0.156	0.013	3.693	39	1.64	1.16
15 - 30	5.98	67.48	2.4	30.12	0.195	0.016	11.333	36	1.76	1.08
Bawku										
0 - 15	5.97	71.7	21.8	6.5	0.141	0.008	2.922	35	1.33	1.11
15 - 30	6.21	80.8	13.8	5.4	0.173	0.010	5.851	31	1.40	0.89

*Analysis made by soil chemistry laboratory, CSIR-SARI, Nyankpala, Ghana.

Table 2. Monthly precipitation, mean daily temperatures (T_{ave}) and mean daily relative humidity in the months of July, August, September and October 2015 at Nyankpala and Bawku.

Month	Rainfall mm	T _{ave} C	Relative Humidity %	Rainfall mm	T _{ave} C	Relative Humidity %
July	146.4	27.5	75	112.8	28.12	82
August	180.5	27.4	80	284.8	27.8	86
September	227.5	27.4	83	251.2	29	84
October	124.3	28.5	80	45.7	29.5	78

2.4. Partial Budget Analysis

Partial budget analysis was used to assess the net benefit due to N or P based fertilizer applications at the two locations. The economic viability of the N and P treatments was assessed based on the investments made with comparison to the untreated checks/control plots. Prices for the analysis were based on the market rate of the N and P based fertilizers. Also, value of production was based on the output prices of sweetpotatoes at the market prices. The assumption underlying this analysis was that, all other costs were constant and the costs that vary were used to calculate the input cost. Hence, value of increased yields due to N and P fertilizers was calculated using the following:

$$V_{yield} = P_{mkt} \times (q_{t1} - q_{t0})$$

where p_{market} is the market price of sweetpotato (GHS) and q_{t1} is the output of treated plot ($\text{kg}\cdot\text{ha}^{-1}$) and q_{t0} is the output of untreated check/control plot ($\text{kg}\cdot\text{ha}^{-1}$).

The total variable cost of N or P based fertilizer application was calculated as:

$$TVC_{t1} = (P_{t1} \times q_{tn}) + Lab_{t1}$$

where TVC_{t1} is the total variable cost (GHS), P_{t1} is the market price of N or P fertilizers used, q_{tn} is the quantity of N or P fertilizers per hectare ($\text{kg}\cdot\text{ha}^{-1}$) and the labour cost for applications (GHS ha^{-1}).

The net benefit was calculated using the following:

$$\text{Net benefit due to fertilizer application} = V_{yield} - TVC_{t1}$$

where V_{yield} the value of increased yield due to N or P based fertilizers and TVC_{t1} is total variable cost of fertilizer and its application.

The returns to fertilizer application were then calculated using the following:

$$\text{Returns to N or P fertilizer} = \frac{V_{yield} (\text{GHS/ha})}{TVC_{t1} (\text{GHS/ha})}$$

3. Results and Discussion

The N and P status of the soils at the time of planting were very low and therefore the application of these nutrients triggered a response by the crop. Soils in a natural state are deficient in N for crop growth and a response to P is not expected if the soil tests > 25 ppm [8] [50]. Pre-planting physico-chemical soil analysis results and weather data during the experiment at both locations are presented in **Table 1** and **Table 2**. The soil at the Nyankpala site is a sandy clay loam while the Bawku site has a sandy loam soil. Analysis of variance and significance levels on the interactive effects of increasing rates of N and P on sweetpotato measured parameters are presented in **Table 3**.

3.1. Vine Length and Number of Leaves per Plant

There was no significant interaction between N and P on vine growth ($p = 0.7243$) and leaf addition ($p = 0.0644$) within the first four weeks after treatment

Table 3. Analysis of variance and significance levels on the effect of N and P applications on field grown “Apomuden” sweetpotato number of leaves·plant⁻¹ (LN), vine length·plant⁻¹ (VL), shoot yield·ha⁻¹ (SY), number of Storage Roots per plant (SRs) and SR yield·ha⁻¹ (SRY) at Nyankpala and Bawku.

Source of variation	Measured parameters				
	LN	VL	SY	SRs	SRY
Location (L)	***	***	***	ns	***
Nitrogen (N)	***	***	***	***	***
Phosphorus (P)	ns	ns	ns	***	***
L*N	***	ns	ns	ns	ns
L* P	ns	ns	**	ns	***
N*P	**	ns	ns	**	ns
L* N * P	ns	ns	ns	ns	ns

*Significant at the 0.05 probability level, **Significant at the 0.01 probability level. ***Significant at the 0.001 probability level, ns, not significant at the 0.05 probability level.

application at Nyankpala and Bawku (**Table 3**). But, while the main effect of P was not significant on vine growth ($p = 0.0681$) and leaf addition ($p = 0.1105$), the main effect of N was however, significant on vine growth ($p < 0.0001$) and leaf addition ($p < 0.0001$) (**Figures 1(A)-1(D)**). The trends of the responses of sweetpotato vine length and number of leaves within the first four weeks after treatment application to increasing rates of N are linear at both locations (**Figures 1(A)-1(D)**). No significant difference was recorded with number of leaves·plant⁻¹ at Nyankpala, but significant differences existed at Bawku. All N treated plots were significantly different from the untreated checks over the first four weeks after treatment application.

At Bawku, the application of N at 30, 60, 90 and 120 kg·ha⁻¹ resulted in a significantly higher vine growth over the first four week period after treatment application, when compared to the untreated check (**Figure 1(A)**). Vine growth was less when no N was applied; it grew at 11.1 cm·plant⁻¹ kg N·ha⁻¹, but when 30, 60, 90 and 120 kg N·ha⁻¹ were applied; it grew at 13.9, 15.4, 17.32 and 15.4 cm·plant⁻¹ kg N·ha⁻¹, respectively (**Figure 1(A)**). The application of 90 kg N·ha⁻¹ produced the highest rate of vine growth in this study at Bawku. At Nyankpala, vines grew at the rate of 6.1, 6.4, 47, 39 and 52 cm·plant⁻¹ when N was applied at 0, 30, 60, 90 and 120 kg·ha⁻¹, respectively (**Figure 1(C)**). The highest rate of vine growth in Nyankpala was obtained when 120 kg N was applied. Like vine length, leaf addition plant⁻¹ displayed a linear response for all levels of N within the first four weeks after treatment application at both Bawku and Nyankpala. At Bawku, number of leaves increased at a rate of 4, 5, 6, 7 and 5 leaves plant⁻¹ kg N·ha⁻¹. Like vine growth in Bawku, the applications of 30, 60, 90 and 120 kg N·ha⁻¹ produced significantly higher number of leaves within the first four weeks after treatment application in comparison to the untreated check (**Figure 1(B)**). At Nyankpala

and within four weeks after treatment application, number of leaves increased at a rate of 6, 7, 8, 7 and 7 leaves plant⁻¹ week⁻¹ at 0, 30, 60, 90 and 120 kg N·ha⁻¹ applied, respectively (**Figure 1(D)**). At this location, the highest rate of leaf development occurred at 60 kg N·ha⁻¹.

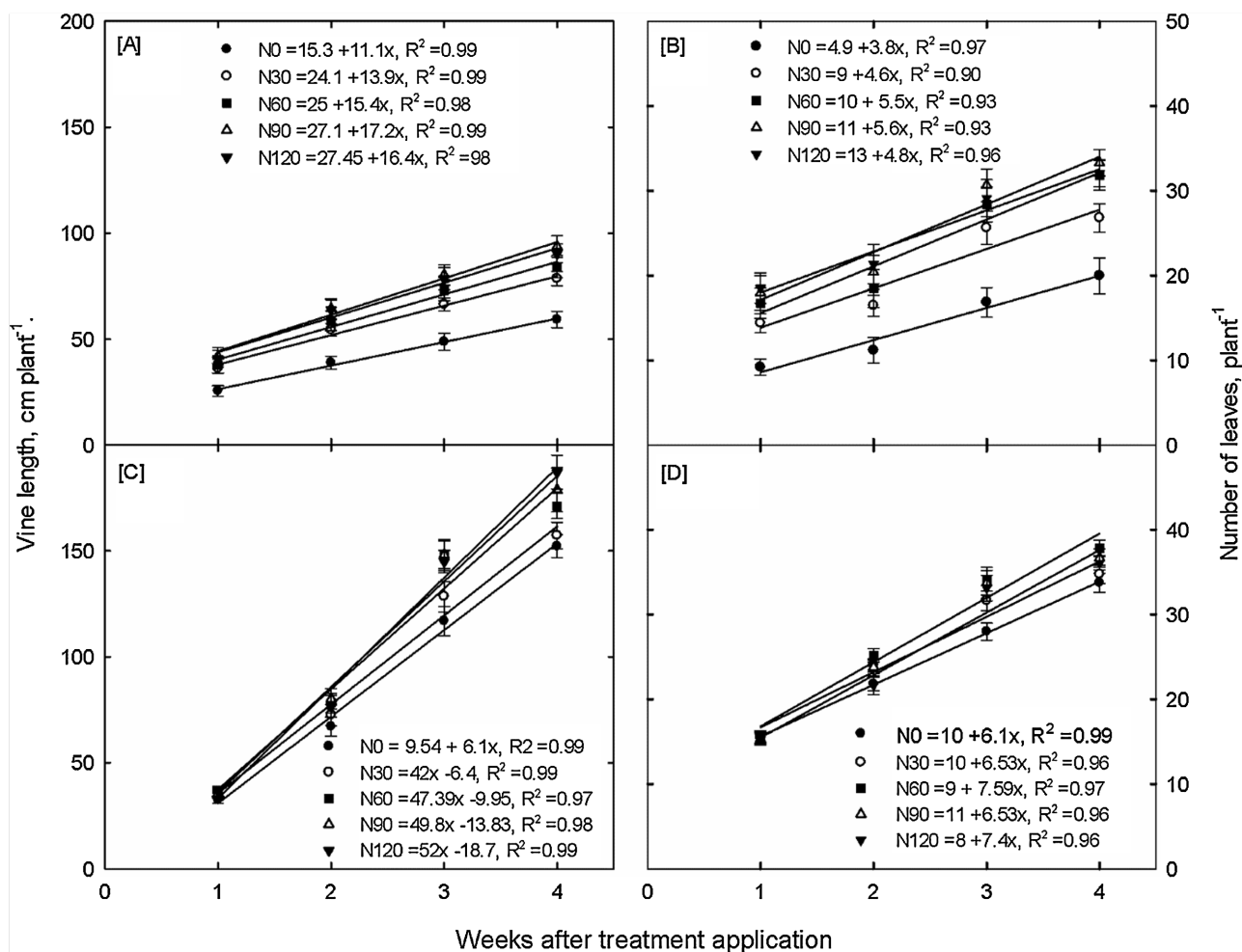


Figure 1. Effects of increasing rates of nitrogen on vine length (A) and (C) and number of leaves (B) and (D) per plant over the first four weeks after treatment application of field grown “Apomodén” sweetpotato at Nyankpala (C) and (D) and Bawku (A) and (B). Values represent the mean of four plants and the error bars are \pm SE of the mean.

3.2. Shoot Yield, Storage Root Yield and Total Biomass

Like vine growth and number of leaves per plant, there was no interaction between N and P for shoot yield at both locations (**Table 3**). However, the main effect of N was significant for shoot yield ($p < 0.0001$). Similar to vine growth and leaf development plant⁻¹ during the first month after treatment application, shoot yield increased linearly in both locations when N increased from 30 to 120 kg·ha⁻¹ at 20 and 100 kg N·ha⁻¹ kg⁻¹ N applied in Bawku and Nyankpala, respectively (**Figure 2(A)**). Shoot yield increased by 31, 63, 94 and 125% in Bawku and 49, 98, 148 and 197% in Nyankpala, when N was applied at 30, 60, 90 and 120 kg·ha⁻¹, related to the untreated check. Our results are similar to earlier studies where N application

was observed to promote shoot growth [12] [51] [52] and excess N application beyond optimal levels tends to promote shoot growth at the expense of storage root formation and development. The optimum N required to maximize shoot yield in both locations were not reached in this study.

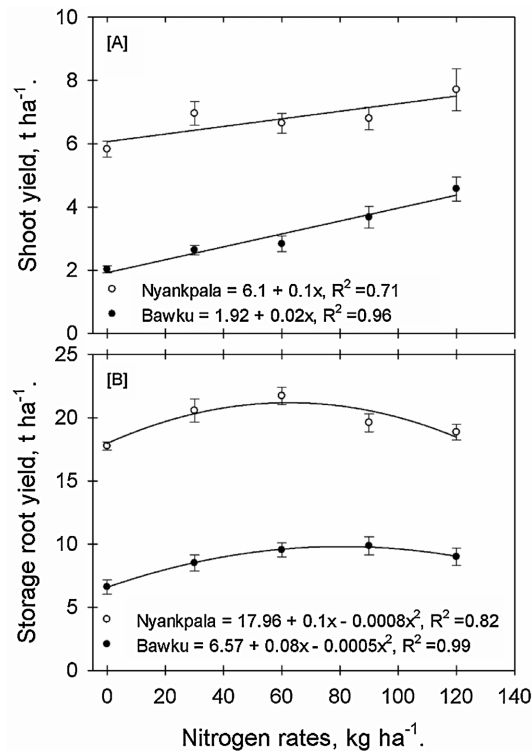


Figure 2. Effect of increasing rates of N on storage root (B) and shoot (A) yields of field grown “Apomoden” sweetpotato at Nyankpala and Bawku. Values represent the mean and the error bars are \pm SE of the mean.

There was no N by P interaction ($p = 0.7488$) for SR yield at both locations. However, significant N ($p < 0.0001$) and P ($p = 0.0001$) main effects were observed for SR yield (Table 1). When N rate increased from 20 to 120 kg·ha⁻¹, there was a quadratic increase in SR yield at both locations (Figure 2(B)). In comparison with the untreated check, when N was applied at 30, 60, 90 and 120 kg·ha⁻¹, SR yield increased by 30%, 46%, 48%, and 37% in Bawku and by 13%, 17%, 14% and 3% in Nyankpala. Judicious N fertilization results in high SR yield while excessive fertilization leads to a reduction in yield. Moderate N application promotes the formation of anomalous cambium resulting in initiation of SRs and suppression of root lignification subsequently causing maximization of SR number per plant and development [10] [15] [53], and excessive N supply inhibits root thickening or SR formation by reducing the formation of regular vascular cambium, anomalous cambium and promoting lignification of adventitious roots thereby causing a decrease in SR yield [15] [20] [54]. It has been reported from similar studies that, sweetpotato SR yield increased with increasing rates of N up to a point after which it starts to decline [47] [51] [55]-[60].

In this study, the optimum N required to maximize SR yield are 80 and 62.5 kg·ha⁻¹ for Bawku and Nyankpala, respectively, in a split application at 2 and 6 weeks after transplanting. This is similar to N recommendation in other jurisdictions. Recommended N for sweetpotato production in Virginia for instance is 28 kg·ha⁻¹ at transplanting and 28 to 56 kg·ha⁻¹ at 4 to 5 weeks after transplanting [61] [62], though, this was updated in a later study to about 35 kg·ha⁻¹ 2 to 3 weeks after transplanting for ‘Beauregard’ sweetpotato [63]. It must however, be noted that sweetpotato response to N application is cultivar dependent [23] [24].

P and location significant interaction ($p < 0.0001$) occurred for SR yield. The trend of the response of sweetpotato SR yield to increasing rates of P at both locations are quadratic with coefficient of determination values of 0.82 and 0.99 for Nyankpala and Bawku, respectively (Figure 3). When compared to the untreated check, SR yield increased by 4%, 5%, 2% and -4% in Nyankpala and by 54%, 81%, 82%, 56% in Bawku, when 40, 80, 120 and 160 kg P were applied. In related studies, P has been found to increase sweetpotato SR yield [64] [65]. Optimum P required to produce the highest SR yield in this study are 67.5 and 101.25 t·ha⁻¹ for Nyankpala and Bawku, respectively. Our finding is similar to the report by Dumbuya *et al.* [66] that found 60 kg·ha⁻¹ as the optimum P rate to maximize growth and SR yield of sweetpotato in the semi-deciduous forest agroecological zone of Ghana.

Like N effects on shoot yield, the mean storage root yield was significantly greater at Nyankpala than at Bawku with or without N or P application (Figure 2(A) and Figure 3). Differences in soil, climatic characteristics and field management history could affect N uptake and utilization efficiencies in these two locations. The Nyankpala site has a sandy clay loam soil which is relatively fertile than that of Bawku (sandy loam soil) as well as better distribution and greater amount of rainfall during the crop growing period (Table 1 and Table 2). Bawku is noted for high rainfall variability and frequent droughts [67] as well as poor soil fertility [68] [69].

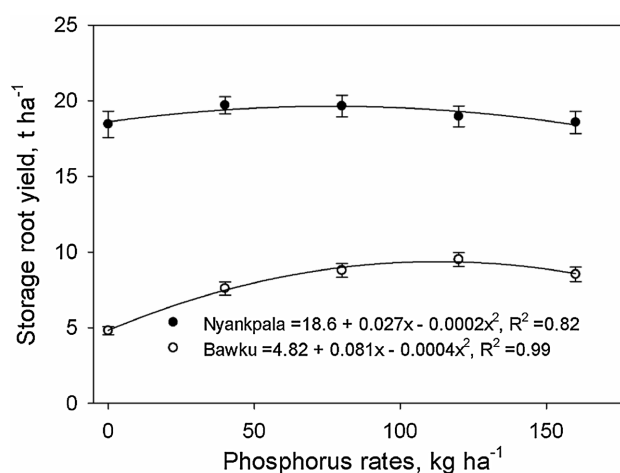


Figure 3. Effect of increasing rates of phosphorus on storage root yield of field grown “Apomodan” sweetpotato at Nyankpala and Bawku in 2015. Values represent the mean and the error bars are \pm SE of the mean.

3.3. Partial Budget Analysis

3.3.1. N-Fertilizer

The results of a partial budget for Nitrogen based fertilizer, as shown in **Table 4** below, gave a positive value of increased yield for all treatments (30, 60, 90 and 120 kg·ha⁻¹) compared to the untreated check/control. This translates to positive net returns on investing in Nitrogen fertilizer application on sweetpotatoes at both locations. The net returns to N fertilizer is more than one (1) for all the N-rates at both locations. Among the N-rates, 30 kg·ha⁻¹ N gave the highest net returns to the N-application at both locations. The results show diminishing net returns as the N-rate increases with the increasing cost per hectare.

3.3.2. P-Fertilizer

The results of the partial budget analysis on P-fertilizer rates effects is shown in **Table 5** below. The results gave positive net returns to all the P-rates at both locations except that of 120 kg·ha⁻¹ of P at Nyankpala. The results of the net returns at Nyankpala defied economic logic to some extent. This is because, the expected diminishing returns observed in the N-rates above is not shown but rather a decreasing returns as the P-rate increases. However, at Nyankpala, the net returns to P-fertilizer, is higher for rates 40 kg·ha⁻¹, 80 kg·ha⁻¹ and 120 kg·ha⁻¹ but was less than one for 160 kg·ha⁻¹.

At Bawku, all the net returns on the different rates of P were positive. The implication is that, increasing P-fertilizers increases the value of sweetpotato due to increased yield over the untreated check/control. The net returns in Bawku

Table 4. Partial budget analysis for N-rates (kg·ha⁻¹) applied to “Apomuden” sweetpotato at Nyankpala and Bawku.

Site	Nitrogen rates	Output			Inputs			Net benefit due to N-Fertilizer	Net Returns to Nitrogen fertilizer
		Yield	Increased yield due to N application over untreated check/control	Value of increased yield	Cost of N-Fertilizer	Labour charges for N-fertilizer Application	Total cost		
	kg·ha ⁻¹					GHS·ha ⁻¹			
Nyankpala	0	17,746.9	0						
	30	20,543.8	2796.9	19,578.3	192	100	292	19,286.30	67.05
	60	21,711	3964.1	27,748.7	384	200	584	27,164.70	47.51
	90	19,590	1843.1	12,901.7	576	300	876	12,025.70	14.73
	120	18,839.5	1092.6	7648.2	768	400	1,168	6,480.20	6.55
Bawku	0	6594.4	0						
	30	8494.4	1900	13,300	192	100	292	13,008.00	45.55
	60	9533.3	2938.9	20,572.3	384	200	584	19,988.30	35.23
	90	9855	3260.6	22,824.2	576	300	876	21,948.20	26.06
	120	8983.3	2388.9	16,722.3	768	400	1,168	15,554.30	14.32

Table 5. Partial budget analysis of P-rates applied to “Apomuden” sweetpotato at Nyankpala and Bawku.

Site	Phosphorus rates	Output			Inputs			Net benefit due to P-Fertilizer	Net Returns to Phosphorus fertilizer
		Yield	Increased yield due to P-application over untreated/control	Value of increased yield	Cost of P-Fertilizer	Labour charges for P-fertilizer Application	Total cost		
		kg·ha ⁻¹				GHS·ha ⁻¹			
Nyankpala	0	18,447	0						
	40	19,705.9	1258.9	8812.3	320	100	420	8392.30	20.98
	80	19,654.2	1207.2	8450.4	640	200	840	7610.40	10.06
	120	18,961.6	514.6	3602.2	960	300	1260	2342.20	2.86
	160	18,564.7	117.7	823.9	1280	400	1680	-856.10	(0.49)
Bawku	0	4802.8	0						
	40	7586.1	2783.3	19,483.1	320	100	420	19,063.10	46.39
	80	8788.9	3986.1	27,902.7	640	200	840	27,062.70	33.22
	120	9505.5	4702.7	32,918.9	960	300	1260	31,658.90	26.13
	160	8527.7	3724.9	26,074.3	1280	400	1680	24,394.30	15.52

followed the decreasing returns to P-fertilizers as increasing rates increases cost but the net returns reduces as the rates continue to increase. The net returns to different rates of P-fertilizers is more than unity and very high. The implication is that, at each of the rates of P-fertilizer application, the production of sweetpotato is profitable but the profitability reduces as you increase the rate from 40 - 80 kg·ha⁻¹ etc.

4. Conclusions

The result of this study shows that “Apomuden” sweetpotato is an N-responsive variety based on the classification given by Haynes [23] and Wilson [24]. While at Nyankpala, the split application of 60 and 120 kg N·ha⁻¹ led to greater vine growth and development one month after basal N application, at Bawku, 90 kg N·ha⁻¹ resulted in the highest vine growth and leaf addition.

Overall, with or without the application of N and P, the mean SR yield in Bawku was significantly less than that in Nyankpala as depicted by the graphs. N increased shoot and SR yields in both locations. P increased SR yield in both locations though, that of Nyankpala was very minimal. At Bawku and Nyankpala, the optimum N required to maximize SR yield were 80 and 62.5 kg·ha⁻¹, respectively, in a split application at 2 and 6 weeks after transplanting. Optimum P required to maximize SR yield in this study were 67.5 and 101.25 t·ha⁻¹ for Nyankpala and Bawku, respectively.

Generally, the analysis shows that N and P fertilizers will increase sweetpotato

profitability when applied. However, the N fertilizer rate of 60 kg·ha⁻¹ gave the highest net returns than the other rates at both locations. P fertilizer however, showed that if farmers applied above the 40 kg·ha⁻¹ rate, the profitability reduces as that is manifested in the net returns to P fertilizer. The revelation is that both N and P-based fertilizers will improve yields of sweetpotatoes and hence improve farm income of small holders if the recommendation is adopted at both locations. To maximize “Apomuden” sweetpotato SR yield, appropriate or adequate N and P rates are 80 and 101 kg·ha⁻¹ for Bawku, and 63 and 68 kg·ha⁻¹ for Nyankpala, respectively. However, 60 and 40 P kg·ha⁻¹ are recommended to be incorporated into a good agronomic practice program for a profitable sweetpotato production enterprises in the Guinea and Sudan agroecological zones of Ghana.

Data Availability

Data available upon request from the authors.

Author Contributions

IAA, EEC, and PEA conceived the research. IAA, ETC, PA and KA set up the experiment. IAA, KA and IY collected, analysed the data and drafted the manuscript. KA, JA-D, IS, IY, JY, GYM, MA, and AA edited, revised, and made significant contributions.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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