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Determination of optimum level of NPK for cultivation of sweetpotato in Samoa

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ABSTRACT

Establishment of a sound fertiliser dose is necessary for achieving higher yield, soil fertility protection and environmental sustainability. Currently, there is no data pertaining to the optimum fertiliser requirement for sweetpotato under Samoan situation. To achieve this, an experiment was conducted to determine the optimum NPK levels for three sweetpotato cultivars under screen-house and field conditions in Samoa. The experiment includes four levels of NPK in kg/ha equivalent (control, 30:30:30, 60:60:60, and 90:90:90) and three improved sweetpotato cultivars (IB/PH/03, IB/PR/12, and IB/PR/13). Results revealed that each cultivar exhibited remarkably varied responses to NPK levels. Yield of IB/PH/03 increased consistently with increasing NPK levels indicating that, the applied NPK levels was insufficient to determine optimum NPK level. Cultivar IB/PR/13 followed a typical crop response curve, however, IB/PR/12 failed to produce significantly higher yield with increased level of NPK. Based on a quadratic model, the putative optimum NPK level for IB/PR/13 and IB/PR/12 was determined - 49-49-49 and 42-42-42 kg/ha respectively, however, the most profitable NPK levels were 30-30-30 and 18-18-18 kg/ha, respectively. Although the profitable NPK level was the highest level for IB/PH/03, it has not been possible to determine the optimum NPK level correctly. Thus, further studies are suggested to test higher NPK dose for IB/PH/03 and other varieties of sweetpotato under wider soil conditions in order to verify the result. This study would be a good basis for future study in a wide range of sols in Samoa and sweetpotato cultivars to achieve conclusive findings

Keywords: Crop response curve, Fertiliser, Nutrient utilisation, Sweetpotato, Samoa

INTRODUCTION

Fertiliser application in Samoa is not a common practice (Chand, 2002) even for the most extensively cultivated crop taro due to inherently very fertile soil and practicing traditional shifting cultivation (Siose *et al.*, 2018; Pierre-Louis *et al.*, 2021). However, increasing population has resulted in intensification of cropping, soil fertility depletion and declining crop yields (Chand, 2002), so this situation demands fertiliser application for sustaining food security in Samoa. It is easy to discern therefore, that there would be less application of fertiliser to lesser important crops such as sweetpotato in Samoa. To date, there is no existing information pertaining fertiliser use in sweetpotato, a crop that the government of Samoa had recently sought to promote for an enhanced food security as an alternative of currently staple taro. Sweetpotato is a short duration crop (3-4 months), does not require lot of water and nutrients for production (Asoro and Carpena 2005, Lese *et al.*, 2018). Sweetpotato is a very hardy crop having very high adaptability to adverse climatic conditions such as drought and marginal soil (Motsa *et al.*, 2015; Gweyi -Onyango *et al.*, 2021) and grow quickly ensuring people to have access to food before, during and after disaster (Lese *et al.*, 2018). It can be noted that, in times of natural disasters like the Category 5 Tropical Cyclone, it was the first crop supplied to farmers for rehabilitation. It is therefore necessary to develop fertilisation schemes suitable to local conditions for maximization of sweetpotato production in Samoa.

Optimum sweetpotato yield in response to nitrogen (N), phosphorus (P) and potassium (K) fertiliser has been documented on a wide range of agro-environments. Regardless, the NPK rates varies from 35-45 kg N, 50-100 kg P_2O_5 and 85-170 kg K_2O per hectare. In other studies, a ‘moderate’ dose of 50-75 kg N ha^{-1} (Nair *et al.*, 1996), 25-50 Kg P_2O_5 ha^{-1} (Mohanty *et al.*, 2005) and ‘moderate’ rate of 75-100 kg K_2O ha^{-1} (Mukhopadhyay *et al.*, 1990; Nair *et al.*, 1996) was proven optimal in India. Furthermore, a comparatively lower rate of 150 kg/ha NPK (15:15:15) yielded better than 300 and 400 kg/ha in Nigeria, Africa (Mukhtar *et al.*, 2010). The optimum NPK levels for sweetpotato varies with locations, agroecosystems and yield goals.

The discrepancies in the determined optimum rates of NPK is largely attributed to the variation in the tested cultivars, edaphic and climatic conditions (O’Sullivan *et al.*, 1997). This implies that determination of optimum fertiliser rate of sweetpotato under condition where it unknown is a necessity for increased production.

The government’s effort to diversify crop production resulted in sweetpotato being prioritised have recently received positive responses in people favouring the crop as a supplementary food, particularly the old and the young generation (Losefa, T. Pers. Comm., 2015). This portrays a predictable increasing consumption demand. Thus, the envisaged intensifying production requires the determination of the optimum NPK fertiliser rate for higher sweetpotato production. Therefore, this study aimed at determining the

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optimum NPK fertiliser levels for improved sweetpotato cultivars in pots under semi-protected condition (screen house) and natural environment in Samoa as a preliminary study.

MATERIALS AND METHODS

Study site and soil preparation

This study was conducted at the University of the South Pacific, School of Agriculture and Food Technology (USP-SAFT) farm (Figure 1). This area characterised with a tropical climate having a yearly temperature and rainfall of 29 °C and 3500 mm, respectively. The study was conducted during onset of the rainy season of year 2015.

Composite soil samples belonging to the Inceptisol soil order from within the farm were collected at 15 cm depth with a shovel, homogenised and air dried at room temperature. When dried, polythene pots (size PB 28) as experimental units were filled with 10 kg of < 1 cm sieved soil. A subsample was finely ground to 0.2 mm size for the characterisation of soil properties (Table 1). This soil is classified as fine oxidic isohyperthemic Typic Humitropept. (Morrison *et al*., 1986).

Table 1. Some Physical and chemical characteristics of the soil

Soil Characteristics	Values	Methods	References
Texture		Hydrometer	Bouyoucos (1962)
Clay (%)	38		
Silt (%)	31		
Sand (%)	31		
Textural name	Clay loam		
Organic C (%)	2.83	Wet Oxidation	Walkley and Black (1934)
Total N (%)	0.25	Kjeldhal	Bremner (1996)
Available P (mg kg^{-1})	12.6	$NaHCO_3$ extraction	Olsen *et al.* (1954)
Exchangeable Ca (cmol(+) kg^{-1}	6.33	NaH_4OAC	Daly et al. (1984);
Exchangeable Mg (cmol(+) kg^{-1}	3.11		Blakemore *et al.* (1987)
Exchangeable K (cmol(+) kg^{-1}	0.27		
Extractable Fe (mg kg^{-1})	59.6	DTPA*	Lindsay and Norvell (1978)
Extractable Mn (mg kg^{-1})	88.8		
Extractable Cu (mg kg^{-1})	3.65		
Extractable Zn (mg kg^{-1})	4.67		

*Diethylenetriaminepenta-acetic acid.

Experimental setup and treatments

A preliminary fertiliser trial before the application of one single fertiliser rate on the field necessitated this pot experiment. While at this stage, two conditions were selected; a screen-house and natural (field) condition. The screen- house, made of a wooden frame of 2.5 meter height, about 10m wide and 20 m long was enclosed entirely with a knitted cloth (50 % green) to avoid insect infestation that also can filters 50 % of incidence solar radiation. The other condition was a field condition where another set of experimental units were arranged adjacent to the screen-house.

At each condition, identical set-up of treatment combinations of four levels of NPK and three cultivars of sweetpotato were arranged in a randomised complete block design (RCBD) with four replications. The NPK fertiliser was a blend of urea (46 % N), NPK (12:5:20) and super phosphate (9.7%) mixed well and applied in kg/ha equivalents rates including: 1) control, 2) 30-30-30, 3) 60-60-60, and 4) 90-90-90. High dose of P and K fertiliser (similar to N rate) were applied as the studied soil is rich in allophane like minerals that makes very prone to P fixation and inherently it is poor in K bearing minerals as originated from basaltic parent materials. In addition, NPK fertilizer is the most available fertilizer in Samoa and super phosphate and muriate of potash is not commonly available in the market. Three newly introduced improved cultivars (IB/PR/12, IB/PR/13, and IB/PH/03) were selected for this study. In each pot, vine tips of 30 cm long were planted with two subterranean nodes buried under the soil surface followed by watering to field capacity level. Two weeks after planting (WAP), NPK fertiliser was applied in band placement and covered lightly with soil. Water was supplied when required to sustain the crop.

Data collection and analysis

The data collected included plant height and number of vines per plant recorded monthly until harvest, i.e., 16 weeks after planting. The vine length was measured using a tape meter measuring vine length from soil surface to tip of the longest vine, whereas the number of vines was determined by counting. At harvest, leaf area was calculated by multiplying the height by the width of 30 leaves; 10 leaves each from the base, middle and tip portion of the vine. The same leaves were used for determining the chlorophyll content. Chlorophyll content in leaf was measured using a Minolta SPAD 502 meter (Spectrum Technologies, Inc., Plainfield, IL, USA). The storage roots were carefully removed from pots, washed and weighed for fresh weight. An oven dry subsample was finely ground (< 1 mm) for NPK content (%) determination following the procedures described by Blakemore *et al*. (1987) and Daly *et al*. (1984) whence NPK uptake was calculated by multiplying with dry matter content (g per plant). All the data were subjected to analysis of variance (ANOVA) using a Statistical Tool for Agricultural Research, (STAR, 2014) developed based on R-statistic software. Where significant differences were detected, treatment means were separated using LSD test at *α=0.05* confidence level. Data from each condition were analysed separately.

RESULTS

Vegetative growth

a. Vine length

The main effect of NPK treatments on vine length was found significant during the early vegetative growth stages (4-8 WAP) under screen-house condition but not at the later growth stages (Figure 1A). The shortest vine length was recorded at the control treatment. However, under natural field environment, NPK did not influence vine length of sweetpotato in any of the growth stages (Figure 1B). Longer vines at 8 WAP under screen-house reflect rapid vine elongation, but growth tends to diminish rather rapidly relative to those at field condition. The cultivar effect was pronounced significantly at all periodic measurements under both conditions with IB/PH/03 markedly the shortest of all except at harvest under screen- house condition (Figures 2A and B). Cultivar IB/PR/12 had the longest vine from 4-12 WAP under screen house condition, while IB/PR/13 recorded the longest vine at harvest under both conditions. Cultivars IB/PR/12 and IB/PH/03 exhibited diminishing growths, while IB/PR/13 showed actively growing vine even at harvest.

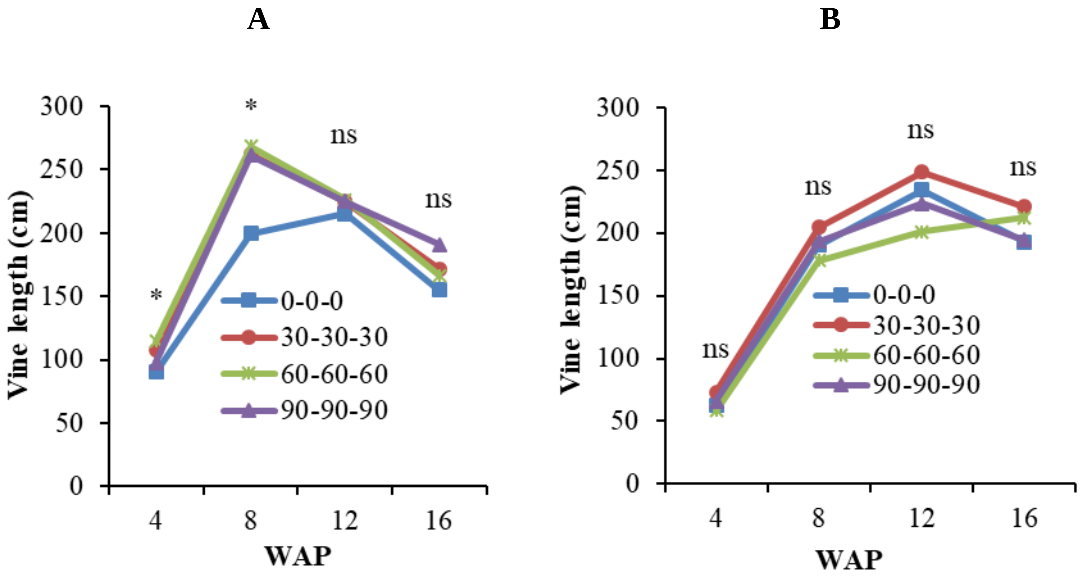

Figure 1 Sweetpotato vine length as affected by NPK under screen house condition (A) and natural environment (B). * and ns represent significantly different and not significant at *P=0.05*, respectively at each sequential measurement among the treatments.

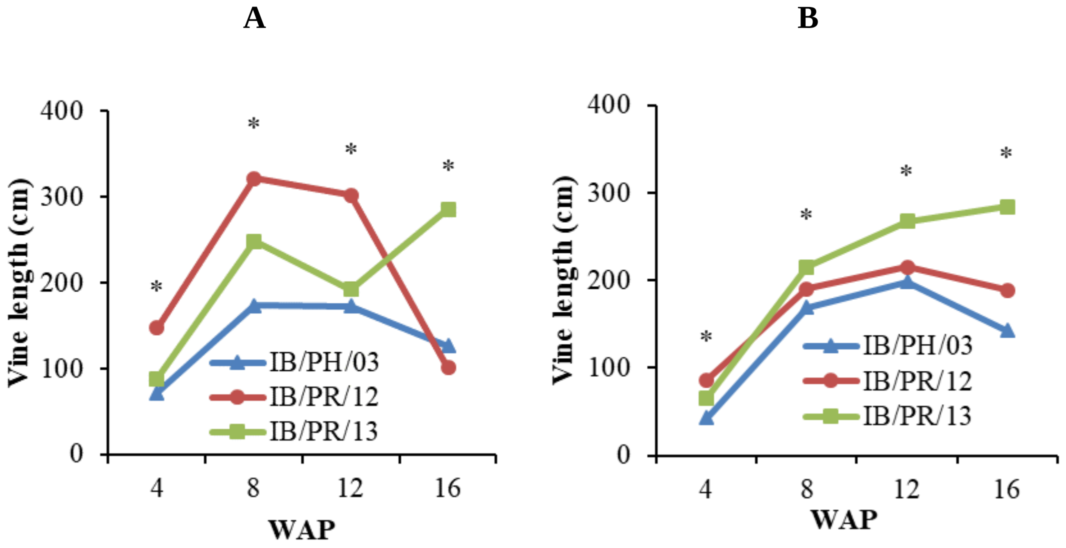

Figure 2 Sweetpotato vine length as affected by cultivars under screen house condition (A) and natural environment (B). * and ns represent significantly different and not significant at *P=0.05*, respectively at each sequential measurement among the treatments

b. Number of vines

The effect of NPK fertiliser treatments on number of vines was found significant both in screen- house and field conditions except for 4 WAP under field condition (Figures 3 A and B). A more visible effect of NPK over control was observed under screen-house condition compared to field condition. Prolific vine production was relatively greater under field condition than under screen-house conditions. Vine production declined drastically from 12-16 WAP under both conditions except in control at harvest under screen-house condition, indicating rapid plant senescence. The cultivar effect also markedly influenced the number of vines produced in sweetpotato under both conditions with more vines profusely produced by the cultivar IB/PH/03 (Figures 4 A and B). All cultivars showed similar production patterns with diminishing vine numbers at harvest except IB/PR/13 under screen-house condition indicating reduced vegetative growth in plant as the crop approached maturity.

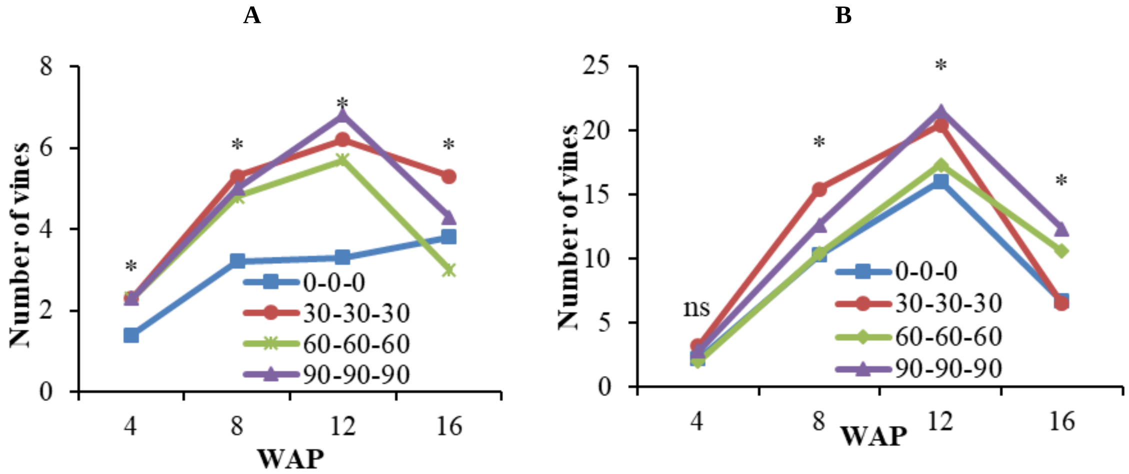

Figure 3 The effect of NPK treatments on the number of vines under screen house condition (A) and natural environment (B). * and ns represent significantly different and not significant at *P=0.05*, respectively at each sequential measurement among the treatments.

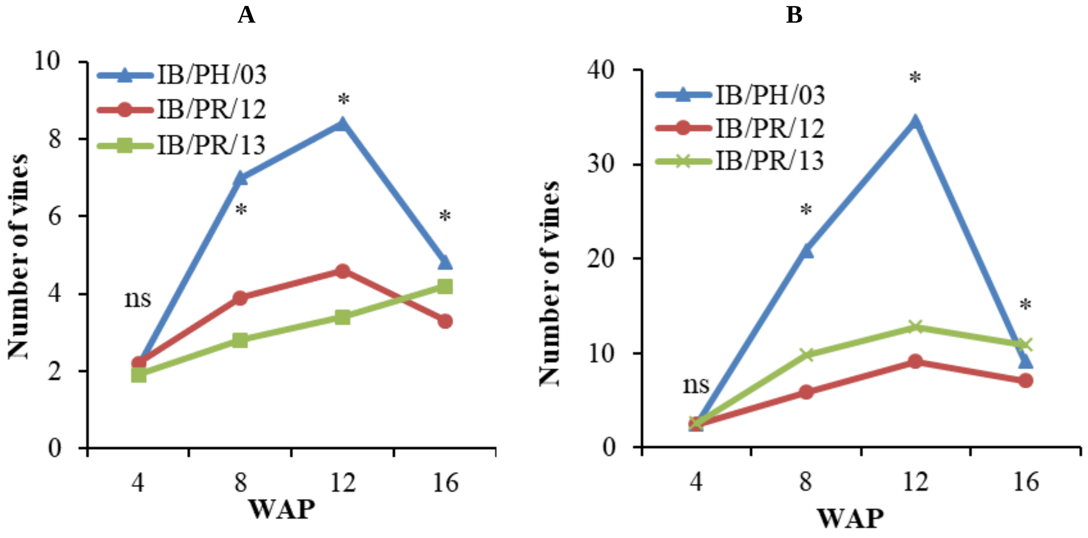

Figure 4 Number of vines as affected by cultivar types under screen house condition (A) and natural environment (B). * and ns represent significantly different and not significant at *P=0.05*, respectively at each sequential measurement among the treatments.

c. Leaf area and leaf chlorophyll content

The differences in leaf area and chlorophyll content (SPAD) during harvest was found significant with the cultivars and NPK levels in both screen- house and field conditions except for leaf chlorophyll content at field condition (Table 2).

Table 2 Leaf area and chlorophyll content at harvest of three cultivars of sweetpotato

Treatments	**Leaf area (cm^2)**		**Chlorophyll content (SPAD)**	
	Screen house	**Field condition**	**Screen house**	**Field condition**
NPK				
0-0-0	45.9b	41.3b	39.3b	36.1a
30-30-30	57.5a	42.6b	39.1b	35.5a
60-60-60	48.7b	45.4ab	45.6a	32.3a
90-90-90	52.8ab	49.8a	42.1ab	36.3a
LSD (0.05)	5.3	5.4	3.6	4.2
Cultivars				
IB/PH/03	50.8b	37.2c	37.7c	33.0b
IB/PR/12	45.2b	45.1b	45.6a	38.9a
IB/PR/13	57.8a	51.9a	41.1b	33.1b
LSD (0.05)	5.3	4.7	3.6	4.2

In each column, treatment means at each condition with similar letters not significantly different at *P=0.05*.

Under both conditions, application of NPK increased leaf area over control. However, the response varied between the two conditions. Leaf area was consistently increased with the increase level of NPK rate under field condition, whereas in screen house condition the 30-30-30 kg ha^{-1} rate topped the treatments. Chlorophyll content increased with increasing NPK rates under screen- house condition while no marked difference recorded under field condition. Cultivar-wise, IB/PR/13 had the broadest leaf area regardless of the conditions. IB/PH/03 produced the second largest leaves under screen-house condition, but relegate to the least under field condition. In addition, leaf quality in terms of chlorophyll content, IB/PR/12 had the highest value while IB/PH/03 had the lowest in both conditions.

Storage root yield

a. Screen house condition

The main and interaction effects of NPK levels and cultivars on storage root yield under screen house condition were found significant (Table 3). Cultivar responded variedly. The yield of cultivar IB/PH/03 responded positively to increasing NPK levels with the significantly highest yield (372 g plant^{-1}) obtained at the highest NPK level, although this did not statistically differ from yield obtained at the second highest NPK level (369 g plant^{-1}). Cultivar IB/PR/12 did not show any significant response to NPK levels. Cultivar IB/PR/13 produced its significantly highest yield at the 30-30-30 kg ha^{-1} rate, though this was statistically equivalent to that obtained at the highest NPK level. Comparing between cultivars at each level of NPK, cultivar IB/PR/13 significantly dominated root yield at the lower NPK levels, while IB/PH/03 out-yielded all cultivars at the higher rates.

Table 3 Storage root yield (g plant^{-1}) of sweetpotato in response to NPK and cultivar differences under screen- house condition

	CULTIVAR		
NPK	**IB/PH/03**	**IB/PR/12**	**IB/PR/13**
0-0-0	119.5cB	78.1aB	187.1bA
30-30-30	263.0bA	80.7aB	282.2aA
60-60-60	368.5aA	76.4aC	191.3bB
90-90-90	372.0aA	66.8aC	249.2aB

Within a column treatment means followed by similar lowercase letters and within a row the mean values followed by uppercase letters, are not significantly different at P=0.05; LSD=44.0.

b. Field condition

An interaction effect of NPK x cultivar was also found significant under field condition (Table 4). Within-cultivar wise, the yield of IB/PH/03 increased significantly at each incremental NPK level with the highest yield (1216 g plant^{-1}) produced at the highest level, an increase in yield by 215 % in relation to control. On the other hand, like the screen-house condition, cultivar IB/PR/12 failed to show significant response to NPK application, although NPK treated plants showed higher arithmetic yield means. Cultivar IB/PR/13 increased in response to NPK, however, unlike IB/PH/03, the significantly greatest yield (1136 g plant^{-1}) at the lower NPK level of 30-30-30 kg ha^{-1}; an increase of 326% in yield comparison to control. Beyond this level, incremented NPK levels resulted in a markedly declined yield.

Between cultivars at each level of NPK, IB/PH/03 was found superior at the lowest and highest NPK level while cultivar IB/PR/13 dominated the others its highest root yield at the 30-30-30 kg ha^{-1} level. At the 60-60-60 kg ha^{-1} level, this cultivar jointly dominated with IB/PH/03 (statistically similar) over IB/PR/12.

Table 4 Storage root yield (g plant^{-1}) of sweetpotato in response to NPK and cultivar differences under field condition

	CULTIVAR		
NPK	**IB/PH/03**	**IB/PR/12**	**IB/PR/13**
0-0-0	386.7dA	166.6aB	266.8dB
30-30-30	635.2cB	251.3aC	1135.8aA
60-60-60	743.3bA	205.9aB	789.6bA
90-90-90	1216.3aA	188.7aC	573.5cB

Within a column treatment means followed by similar lowercase letters and within a row the mean values followed by uppercase letters, are not significantly different at P=0.05; LSD=107.5.

Nutrient uptake

Nutrient (NPK) uptake in storage roots followed the similar trend as in storage root yield ascribing higher nutrient uptake resulted from higher yield. NPK application levels significantly increased nutrient uptake in storage roots of IB/PR/13 and IB/PH/03 but not IB/PR/12 in both conditions (Tables 5 and 6). Again, cultivar IB/PR/12 remained inferior to IB/PH/03 and IB/PR/13 at all levels of NPK.

Table 5 NPK uptake and utilization in storage root of sweetpotato under screen house condition

NPK	**Nutrient uptake (g plant $^{-1}$)**			**Nutrient utilization in storage root (%)**		
	IB/PH/03	**IB/PR/12**	**IB/PR/13**	**IB/PH/03**	**IB/PR/12**	**IB/PR/13**
				Nitrogen		
0-0-0	0.37bA	0.24aA	0.49bA			
30-30-30	0.75aA	0.25aB	0.66abA	52.8	1.4	23.6
60-60-60	0.96aA	0.28aB	0.51abB	41.0	2.8	1.5
90-90-90	0.96aA	0.22aB	0.75aA	30.3	-0.9	12.0
				Phosphorus		
0-0-0	0.10cAB	0.06aB	0.13bA			
30-30-30	0.19bA	0.06aB	0.20aA	3.5	0.0	2.7
60-60-60	0.25aA	0.05aC	0.13bB	2.9	-0.2	0.0
90-90-90	0.24aA	0.05aC	0.16abB	1.8	-0.1	0.4
				Potassium		
0-0-0	0.24cAB	0.14aB	0.35bA			
30-30-30	0.64bA	0.17aB	0.57aA	1.6	1.9	13.8
60-60-60	0.87aA	0.19aC	0.46abA	3.3	1.5	3.4
90-90-90	0.67bA	0.14aB	0.58aA	4.9	0.0	4.7

Within a column treatment means followed by similar lowercase letters and within a row the mean values followed by uppercase letters are not significantly different for N, P and K at P=0.05.

Table 6 NPK uptake and utilization in storage root of sweetpotato under field condition

NPK	**Nutrient uptake (g plant $^{-1}$)**			**Nutrient utilization in storage root (%)**		
	IB/PH/03	**IB/PR/12**	**IB/PR/13**	**IB/PH/03**	**IB/PR/12**	**IB/PR/13**
				Nitrogen		
0-0-0	2.0cA	1.1aA	1.3aA			
30-30-30	3.5bB	1.2aC	5.3aA	206.3	13.9	555.6
60-60-60	4.0bA	1.2aB	4.8aA	138.9	6.9	243.1
90-90-90	6.7aA	1.5aB	3.5bC	217.6	18.5	101.9
				Phosphorus		
0-0-0	0.25cA	0.12aB	0.17dAB			
30-30-30	0.31bcB	0.14aC	0.62aA	2.3	0.8	19.2
60-60-60	0.40bA	0.12aB	0.46bA	2.9	0.0	6.5
90-90-90	0.76aA	0.12aC	0.30cB	6.5	0.0	2.3
				Potassium		
0-0-0	0.76dA	0.32aB	0.56cAB			
30-30-30	1.17cB	0.44aC	2.29aA	25.6	7.5	108.1
60-60-60	1.74bA	0.47aB	2.04aA	30.1	4.6	45.4
90-90-90	2.42aA	0.38aC	1.33bB	33.9	1.2	15.7

Within a column treatment means followed by similar lowercase letters and within a row the mean values followed by uppercase letters are not significantly different for N, P and K at P=0.05.

DISCUSSION

Effects of NPK rates and cultivars on vegetative growth

The mechanism influencing the non-significant effect of different levels of NPK application on vine length in the latter growth stages under screen- house condition and the entire growth stage under field condition (Figures 1 A and B) is a mystery because longer vines was expected when fertiliser is applied. Perhaps this signified high adaptability of sweetpotato to the soil when no fertiliser is applied. However, vine proliferation in response to NPK application evidently marked the nutritious function of the additional nutrients (Agbede, 2010) that resulted in a luxurious growth. In particular, N influencing rapid meristematic activities resulting in longer vine growth and higher branching in sweetpotato when higher N is applied (Nair and Nair, 1995). Higher rate of plant growth was also attributed to the increased nitrogen supply (Walker *et al*., 2001; Hartemink *et al*., 2001). Activation of photosynthesis and metabolic process in plants thus increasing plant growth as a function of P (Purekar *et al*., 1992) may also have influenced vine proliferation. Although Saif El-Dean *et al*. (2011) found increased sweetpotato vine length in response to P fertiliser, other workers (Marschner, 1995; Kareem, 2013a; Dumbuya *et al*., 2016) reported otherwise. However, potash application at different rates did not affect vine length (Nair and Nair, 1995; Trehan *et al*., 2009).

The significant effect of cultivar types on vine growth and vine numbers is evidently a function of genetic variation. Rationally, IB/PH/03 is a short but branchy type cultivar, whereas IB/PR/13 and IB/PR/12 are of long trailing vines but less branching type.

The marked increase in leaf parameters in response to NPK application might be due to the fact that extra protein from access N supply stimulates foliage growth. Furthermore, Hassan *et al*. (2005) reported of increased leaf area in sweetpotato when increasing P is applied. Although high levels of K suppressed leaf growth (Kareem, 2013b), enhanced availability of N influenced indirectly by higher K levels stimulating leaf protein synthesis (NA, 1998) may also contribute to this result.

Obviously, relatively broader leaves at the screen-house condition than the field condition is indicative of early plant senescence at the latter condition, as reflected also at the chlorophyll contents, offsetting the NPK effect. Higher leaf area and chlorophyll content in sweetpotato under shade was also reported by Johnston and Onwueme (1988). Nonetheless, gradual leaf area reduction synchronises with crop maturity.

Genotypic variation among the cultivars is attributed to the difference in leaf areas and chlorophyll contents. In both conditions, cultivar IB/PR/12 remained superior in chlorophyll content. Leaf sizes of IB/PH/03 reduced the most in field condition in relation to that under screen house condition implying a greater degree of leaf senescence. However, chlorophyll content of IB/PR/13 appeared to deteriorate more than other cultivars.

Effects of NPK rates and cultivars on storage root yield

Improved yield through NPK application could be attributed to the incremented NPK contents of the soil as the inherent N, P, and K levels were categorised *low* (Blakemore *et al*., 1981). Quick supply of N, P & K enables rapid NPK uptake by plant, thus improving crop growth and ultimately the yield.

Both positive and no effect of added P on crop production including sweetpotato are reported (Norman *et al*., 1995; Sioose *et al*., 2017). Study by Dumbuya *et al*. (2016) confirmed the positive effect of P in sweetpotato production. Furthermore, in a missing nutrient experiment, significant sweetpotato vine growth and storage root reduction was noted when P was made deficient (Issaka *et al*., 2014; Siose *et al*., 2017).

The significance of potassium in photosynthesis, protein metabolism, translocation of photosynthates from leaves to roots in tuber crops where carbohydrates are the main storage material (Trehan *et al*., 2009) could potentially attribute to higher root yield. Like any root crop, sweetpotato required comparably higher K quantities than cereal (O'Sullivan *et al*., 1997) and have a greater detrimental effect on root yield when deficient compared to N and P (Bourke, 1985). Increased sweetpotato storage root has been reported attributable to increased plant nutrient following fertiliser application (Agbede, 2010; Onwudike, 2010; Haliru *et al*., 2015; Dumbuya *et al*., 2016).

The positive effect of NPK fertiliser on luxuriant vegetative performance in sweetpotato might have resulted in higher yield. Significantly higher stem numbers (Figure 3) implying higher number of leaves of significantly larger leaf sizes (Table 2) could have resulted in increased root bulking from higher rates of assimilate synthesis in the leaves.

Yield variations between cultivars in respond to NPK signify the inherent differences in the genetic composition of each cultivar. Comparably lower and a consistently insignificant increase in yield of IB/PR/12 with increasing fertiliser application in both conditions denotes inferiority of the cultivar. Indeed, the highest yield of this cultivar is lower than the yield of other two cultivars that obtained in control (no fertiliser application) utilising inherent soil fertility. It indicates that inherent soil nutrient is sufficient for this cultivar for obtaining its optimum yield, thus no influence of fertiliser treatments. However, the significantly higher chlorophyll content at harvest (Table 2) despite the lowest yield could imply that the cultivar is investing higher assimilates on organs other than storage roots, in this case the foliar quality. Therefore, the cultivar is to be culled from existing stocks if storage root yield is the main objective of cultivation. On the other hand, cultivar IB/PH/03 increased sweetpotato yield linearly with NPK levels without diminishing yield and produced the highest root yield at the highest NPK level. This implied that the rates deployed are insufficient to determine the optimum NPK level for this cultivar. Although it was the shortest amongst the cultivars, more vines hence more leaves produced could possibly resulted in higher yield. Sweetpotato cultivar with shorter vines was reported to produce higher storage root over the longer vine cultivars (Kareem, 2013a). Perhaps the shorter assimilate translocation distance from source to sink is a better morphological trait. Cultivar IB/PR/13 is marked distinctly from all the cultivars based on its highly responsive to lower NPK rate of 30-30-30 kg ha^{-1} resulting in highest yield across the cultivars at this level. This could be attributed to the comparatively higher nutrient utilisation of the cultivar (Tables 5 and 6).

The relative higher yield and consistent responses to NPK under field condition could be also attributed to the maximum utilization of sunlight. Clearly, the partially filtered solar radiation under screen- house hampered photosynthesis affecting yield of the crop. Sweetpotato yield was also found reduced when exposed to varying levels of light intensities (Chipungahelo *et al*., 2010). These workers found that the greatest growth and yield were recorded at 100 % light intensity or full exposure to sunlight equivalent to field condition in this study. Mwanga and Zamora (1988) also reported that shading was responsible for reduced yield of sweetpotato relative to full solar radiation. This result ascertained that the Alafua field conditions under the underpinning abiotic factor are relatively conducive for sweetpotato production in Samoa.

Crop growth response curve

Better and consistent responses to the treatments and higher yield under field condition was considered a better reflection of the actual field results. Therefore, a crop response curve was constructed plotting storage root yield of each cultivar recorded only under field condition against NPK levels by using a quadratic model ($y = cx^2 + bx + a$) (Figure 5). The fitness of the curves was 0.96, 0.77 and 0.68 for the cultivar IB/PH/03, IB/PR/13 and IB/PR/12, respectively (Figure 5). Crop response curves clearly showed that storage root yields were declined with higher levels of NPK application for cultivars IB/PR/13 and IB/PR/12 but it did not attain the peak for IB/PH/03.

If the target yield was set at 95% of maximum yield, the NPK requirement reduced by 4 kg/ha (86-86-86 kg ha^{-1}) for IB/PH/03 with a yield compromise of 62 kg/ha but 16 (26-26-26 kg ha^{-1}) and 13 (36-36-36 kg ha^{-1}) kg ha^{-1} with a yield compromise of 12 and 52 kg/ha for IB/PR/12 and IB/PR/13, respectively. This indicate that investment on fertiliser for cultivation of IB/PH/03 is more profitable (15.5 kg/ha more yield with an increment of 1 kg/ha NPK application) followed by IB/PR/13 (4 kg/ha more yield with an increment of 1 kg/ha NPK application) and IB/PR/12 (0.75 kg/ha more yield with an increment of 1 kg/ha NPK application.

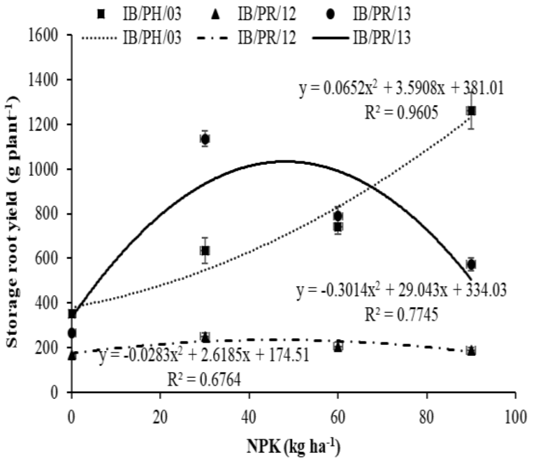

Figure 5 Yield response curves of sweetpotato cultivars against the levels of NPK fertilizer application.

If the farmers like to reduce his yield goal further down to 90% of maximum yield, then the farmers will able to save 11 (75-75-75 kg ha^{-1}), 8 (18-18-18 kg ha^{-1}) and 6 (30-30-30 kg ha^{-1}) kg/ha NPK fertiliser for IB/PH/03, IB/PR/12 and IB/PR/13, respectively. In this case, the trend of profitability changes as follows: IB/PH/13 (10.3 kg/ha more yield with increment of 1 kg/ha NPK application)> IB/PR/03 (5.6 kg/ha more yield with an increment of 1 kg/ha NPK application)> IB/PR/12 (1.5 kg/ha more yield with an increment of 1 kg/ha NPK application). IB/PH/03 significantly out-yielded the other cultivars, even when considering targeted yield at 95 % and 90 % of the yield.

Table 7 Optimum NPK requirement for obtaining 90, 95, and 100% of maximum storage yield in different sweetpotato cultivars under field condition (corresponding yield are presented in parenthesis)

Cultivar	**NPK requirement for near maximum yield (Kg/ha)**		
	100%	**95%**	**90**
IB/PH/03	90-90-90a (1232)	86-86-86a (1170)	75-75-75a (1109)
IB/PR/12	42-42-42c (237)	26-26-26c (225)	18-18-18c (21)
IB/PR/13	49-49-49b (1034)	36-36-36b (982)	30-30-30b (931)

Within columns, treatment means with similar letters are not significantly different at P=0.05.

However, it would be economically sensible to select and promote a cultivar with a greater yield output on minimum NPK input on a large scale farm. Base on this data, it could be concluded that 100% yield goal seems more profitable for cultivar IB/PH/03 while 95% for cultivar IB/PR/13 and 90% for cultivar IB/PR/12.

Nutrient Uptake and utilization

Relatively low nutrient uptake under screen house condition could explain low yield attained, thus soil NPK status is expected to improve. However, post-harvest soil analysis (Table 8) showed relatively low soil NPK contents under screen house condition. Nutrients lost might be due to excess soil moisture under shade condition of the screen house. Forest soil having more shade situated side by side to grassland soil of same parent material leached more nutrients (Foth, 1990). Under shade conditions, increased soil moisture content is considered a possibility for potential leaching in nutrients (Dodd *et al.*, 2005).

Table 8 NPK content in post-harvest soil

NPK	**Total N (%)**	**Available P (mg/kg)**	**Exchangeable K (cmol/kg)**
		Screen house	
0-0-0	0.27a	4.86b	0.16b
30-30-30	0.29a	5.88b	0.18b
60-60-60	0.28a	8.61a	0.26a
90-90-90	0.29a	9.50a	0.23ab
		Field condition	
0-0-0	0.26b	9.1c	0.20c
30-30-30	0.28a	12.3b	0.37b
60-60-60	0.28a	16.3a	0.41ab
90-90-90	0.27ab	14.8a	0.46a

Within columns, treatment means with similar letters are not significantly different at P=0.05.

Under screen house condition, nitrogen and phosphorus utilisation was greater in IB/PH/03 while IB/PR/13 utilised K better than all the cultivars. The latter cultivar characteristically utilised higher nutrient at the lower NPK level (30-30-30 kg ha^{-1}), similar to the former cultivar in regards to N and P utilisation. However, IB/PH/03 increase its K utilisation rates with increasing NPK application rates but it is opposite in case of N utilisation in storage roots. Considering all the three nutrients and cultivars, this cultivar utilised more N ranging from 32-53% for its storage root development. Cultivar IB/PR/12 utilised the least of the applied NPK.

Under field condition, surprisingly cultivar IB/PH/03 and IB/PR/13 utilised several times (1-5 times) higher N than the applied amount that was not the case under semi-protected screened house condition. However, the post-harvest soil N content does not justify a drastic decline in N content. This additional N probably comes from rainfall or biological fixation. The experimental area belongs to tropical climate receiving more than 3500 mm rainfall annually. Therefore, rainwater may have supplied a considerable amount of N. Nutrient use efficiency was greatest for N, followed by K and the least with P. Like the screen house condition, cultivar IB/PR/13 showed its greatest nutrient utilization when NPK was applied at the lower rate (30-30-30 kg ha^{-1}). Cultivar IB/PH/03 mostly utilized more nutrients at higher levels of NPK application. Cultivar IB/PR/12 had the least nutrient utilization with N and K being utilised better than P.

Utilisation of P both under screen- house as well as field conditions was very low for all the three cultivars indicating that most of the applied P was fixed and become unavailable for plant utilization in spite of applying higher doses. Indeed, P fixation is a very common phenomenon in volcanic soils (Weil and Brady, 2017) to which Samoa soils are capable of fixing 50-100% of the applied P fertilisers (Asghar, 1988).

Regardless of the conditions, post-harvest soil P and K content were significantly enhanced through NPK application (Table 8) to enabling the subsequent crop a beneficiary. Agbede (2010) and Onwudike (2010) have also noted the increased nutrient content as a result of NPK application.

CONCLUSION

This study demonstrated that sweetpotato yield responses to NPK application levels varied remarkably with three cultivars. The yield increased almost linearly with NPK levels for cultivar IB/PH/03 while cultivar IB/PR/13 attained the highest yield at 30-30-30 kg ha^{-1} NPK ha^{-1}. Cultivar IB/PR/12 did not respond to NPK application. Such inconsistent result warrants further investigation. Cultivar IB/PR/13 and IB/PH/03 utilized N and K better while the P utilization rate was very low for all the cultivars. NPK application was found helpful for increased soil NPK nutrient contents. Crop under field condition receiving full sunlight had relative higher yield than those produced in the screen -house. Since there is a wide range of soil types in Samoa, determination of optimum NPK levels with the varied soil types and new cultivars is crucial for verification of these findings and site-specific recommendation for farmers.

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