INTEGRATED USE OF NPK FERTILIZER, CATTLE MANURE AND MANAGEMENT OF LEAF HARVEST FREQUENCY IMPROVES YIELD AND ECONOMIC RETURNS OF BUTTERNUT

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Abstract

Butternut (*Cucurbita moschata* Duch. ex Poir) is an important vegetable, where its tender leaves and mature fruits are used in human diets and income generation. However, frequent leaf harvest for consumption with limited or no soil nutrient replenishment affect its yield and economic production. To address this, experiment was conducted at the Agricultural Training Centre (ATC-Matuga-Mkongani), to determine the effect of combined use of NPK fertilizer (17:17:17), cattle manure and frequency of leaf harvest on yield and economic benefits of dual-purpose butternut. A randomized complete block design with three replications was used in a split-split plot arrangement. NPK was applied as the main plot, at 0, 250, 500, and 750 kg ha^{-1}. Cattle manure was applied as the sub-plot, at 0, 2,500, 5,000, and 7,500 kg ha^{-1}. Leaf harvest frequency was applied as the sub-sub plot, at 2, 4, 6 and 8 weekly harvest interval, 8 weeks after planting. Data was collected on soil nutrient status, yield and economic returns. The data were subjected to analysis of variance and means separated with Tukey's test, at $\alpha = 0.05$. Integrated use of NPK fertilizer and cattle manure helped to improve soil nutrient status (C, N, P, K) even at more frequent leaf harvest (4-week intervals). Yield and economic returns of butternut was also highest when 250 kg ha^{-1} of NPK and/or 2500 kg ha^{-1} of cattle manure was applied, irrespective of leaf harvest frequency. Combined application of lower rates of NPK (250 kg ha^{-1}) and/or cattle manure (2,500 kg ha^{-1}), even at higher leaf harvest frequency (4-week intervals) may help farmers to harvest butternut leaves during production and still get better fruit yield and economic returns.

Keywords: Butternut squash; crop yield; economic benefits; plant nutrition; leaf harvest

INTRODUCTION

Butternut (*Cucurbita moschata* Duch. ex Poir) is a dual-purpose vegetable, where it's tender leaves and mature fruit are important in human diets and for commercial production (Van Eerd, 2010). Butternut leaves are harvested during the vegetative growth and fruit are harvested when mature. The high demand of butternut leaves for consumption has brought about excessive defoliation during production (Isutsa and Mwaura, 2017). Leaf harvest frequency have been identified as critical management practices that affect plant yield and quality in cucurbits (Mwaura et al., 2014). Asiegbu (1988) observed that 3 to 4-week leaf harvesting intervals was better than 6 to 8-weeks for obtaining higher yields of edible and marketable leaf of fluted pumpkin (*Telfairia* *occidentalis* Hook F.), which a closely related to butternut. Leaf harvest can affect plant growth and biomass production in many ways. For instance, leaves form photosynthetic tissue, hence harvesting means reduction in production of photo-assimilates necessary for crop growth (Isutsa and Mallowa, 2013).

Excess leaf harvest may also lead to deficiency of essential nutrients in the soil because nutrients absorbed by the plant are removed through the harvested plant parts (Isutsa and Mallowa, 2013). These nutrients are lost because they cannot be recycled back into the soil (Mwaura et al., 2014). Nutrients in soil will therefore need to be supplemented to ensure optimal plant growth. Amount and type of fertilizer affect growth and development of curcubits such as butternut (Agbaje et al., 2012). Cucurbits are also affected by soil physical and chemical characteristics (Clementina, 2013). Agrochemical and biochemical studies have indicated NPK fertilizer as the most effective and fast acting factors of variations in the chemical composition of plants and other crop qualities (Oloyede et al., 2013). However, Fanadzo et al. (2010) reported that improper chemical fertilizer application in butternut affects chemical, physical and biological properties of soil, resulting low yield and quality. In addition, inorganic fertilizers are expensive and not affordable to many resource poor farmers in Sub-Saharan Africa (Morris et al., 2007). Farmers therefore realize the need for soil amendments by using available resources such as organic manure, in order to improve their soil for better crop production (Awodun, 2007).

The use of organic fertilizer as a source of nutrients to crops has received comprehensive study (Clementina, 2013). Organic fertilizer improves soil's physical, chemical and biological conditions, which in turn improves crop growing environment and culminate into a better economic production of plants (Awodun, 2007). Mensah and Okonwu (2012) observed that soils supplied with inorganic fertilizer tend to leach nutrients faster, especially if not amended with organic manure. However, organic fertilizer used alone do not have sufficient soil requirements because of their slow nutrient release nature, and therefore required in large amounts. Thus, organic manure fortified with adequate amounts of inorganic fertilizer may be a better option (Oloyede, 2012). The use of organic manure to supplement inorganic fertilizer use helps to reduce the high cost of soil mineral input. Studies have indicated that organic fertilizer reduces the needs of chemical fertilizer, which will lead to lower production cost and indirectly increases income (Van Eerd, 2010).

The use of inorganic and organic fertilizers is among the ways of increasing nutrient status of both soil and plants grown (Awodun, 2007). Combined use of inorganic fertilizer and organic manure also supplies plant needs through modification of soil physico-chemical and biological composition. Inorganic fertilizer and organic manure have been reported to maintain ideal carbon to nitrogen ratio to support soil microbial activities and therefore releasing more nutrients for plant uptake (Clementina, 2013). This will promote higher plant growth, healthier crops and better yield, quality and higher economic returns (Van Eerd, 2010). Although butternut leaves are harvested for consumption, there is little information on leaf harvest frequency and soil nutrient management to ensure optimal leaf harvest frequency and maximum fruit yield and economic returns. Farmers mainly rely on blanket recommendation rates for all cucurbits (Anonymous, 2017). However, it is important to note that different crops have different nutrient requirements. This has resulted in low fruit yield and poor-quality fruit. The situation is further complicated given that butternut leaves are harvested for consumption. Therefore, many growers have often complained that butternut is no longer feasible for commercial production. Therefore, objective of the study was to determine the effect of combined use of NPK fertilizer (17:17:17), cattle manure and leaf harvest frequency on yield and economic benefits of dual-purpose butternut.

MATERIALS AND METHODS

Site description

The study was conducted at the Agricultural Training Centre Matuga-Mkongani between April to July, 2016 (season one) and April to July, 2017 (season two). The farm lies at latitude 4°16' South and longitudes 39°57' East, with an altitude of approximately 132 m above sea level. Average minimum and maximum monthly temperatures are 22.8 °C and 30 °C, respectively, with a total average bimodal annual rainfall of 800 to 1200 mm. The soils are predominantly sandy-clay with a pH of 6.6. Evapotranspiration rate is 2400 mm/year (Jaetzold et al., 2012).

Plant material

Hybrid butternut seeds cv. Waltham, purchased from East Africa Seed Company (Mombasa, Kenya) were planted. The seeds were dressed with a combination of fungicides (Thiram 75% WP) and insecticide (Azadirachtin) to prevent soil-borne diseases and insects attack. The cv. Waltham was chosen because it's popular as a dual-purpose vegetable where both its leaves and mature fruit are consumed (Anonymous, 2017).

Experimental design and treatment application

The experiment was laid in a randomized complete block design with three replications. The treatments were arranged in a split-split plot design. There were three factors, which included NPK (17:17:17) at 0, 250, 500 and 750 kg ha^{-1}, as the main plot factor; organic fertilizer in the form of cattle manure applied at 0, 2500, 5000 and 7500 kg ha^{-1}, as the sub-plot factor; and leaf harvest frequency applied at 2, 4, 6 and 8 week harvest interval, as the sub-sub plot factor. NPK (17:17:17) compound fertilizer (Ccbn group, Spain) was purchased from agrovet (Mombasa, Kenya). Leaf harvesting started 8 weeks after planting with 6 leaves being harvested per plant.

The experimental field was subdivided into three equal blocks measuring 57 × 3 m separated by a 3 m path. Each block was divided into 64 main plots measuring 1.5 × 3 m, separated by a 1.0 m path. NPK fertilizer and cattle manure rates were measured using a weighing machine. The amount of NPK fertilizer applied per plot was; 0, 225 g (12.5 g/plant), 450 g (25 g/plant) and 675 g (37.5 g/plant) representing 0, 250, 500 and 750 kg ha^{-1}, respectively, while cattle manure was applied at 0, 2.25 kg (125 g/plant), 4.5 kg (250 g/plant) and 6.75 kg (375 g/plant) representing, 0, 2500, 5000 and 7500 kg ha^{-1}, respectively.

Field preparation, plant establishment and maintenance

The field was ploughed and harrowed once before planting for every production season. Two seeds were planted at a depth of 2.5 cm per hill at a spacing of 1.5 × 0.5 m. The seedlings were later thinned to one per hill, two weeks after sowing to give 18 plants per main plot. Each sub-sub-plot consisted of a single row of six plants spaced at 0.5 m from one plant to another. Three plants were tagged for data collection in each plot.

The crop was rain fed with occasional manual irrigation using 10-L watering can twice per week both morning and evening during dry spells. NPK (17:17:17) fertilizer was applied in each of the 64 plots in two equal splits, as a basal and top dressed, as per treatments. First split application was done at planting then repeated four weeks later. Cattle manure was applied in each of the 64 plots once as basal at planting. Weeding was carried out manually using hand hoe once per week until flowering stage. Thereafter, weeding frequency was reduced to two weeks until the end of cropping season. Four weeks after sowing, the crops were sprayed three times with lambda-cyahalothrin 'Karate' (insecticide) and benomyl (benlate) fungicide at the rates of 2 l ha^{-1} and 1.5 kg ha^{-1}, respectively, at 4, 6 and 8 weeks after planting to contain the highly destructive melon fly (*Bactrocera cucurbitae* Conquillent) and protect the plants against other insect pests and fungal diseases. To reduce sun scotching and to ensure uniform appealing skin colour at harvesting, the fruit were turned (rotated) regularly and were also covered with dry grass at maturity (during the last 3 weeks).

Data collection

Pre-plant samples of cattle manure and soil were analysed for the following parameters: Total nitrogen contents was analysed using the Kjeldahl method as described by Okalebo et al. (2002). Phosphorus was analysed calorimetrically with a Jemway 6100 spectrophotometer following standard procedures (Anonymous, 2005). Sodium and potassium were analysed by flame photometer following standard procedures (Anonymous, 2005). The Ca, Mg, Zn, Fe, Mn, B, and Mo contents were analysed after wet digestion with a mix of nitric, sulphuric and hydrochloric acids using atomic absorption spectro-photometer (Model SP9, Pye Unicam Ltd., Cambridge, England) (Okalebo et al., 2002). Organic carbon was analysed by wet oxidation using a modified method of Walkley-Black (Okalebo et al., 2002). Soil and manure pH content were determined in water using a pH meter (Hanna precision pH meter, Model pH 213, Merck KGaA, Darmstadt, Germany) (Okalebo et al., 2002). Soil and cattle manure moisture content was determined by the gravimetric method where a subsample of fresh, sieved, composite sample of a fresh soil core was weighed, oven dried until there was no further mass loss, and then reweighed.

Fruit were harvested from each treatment and weighed. The weight of the harvested fruit per plot was extrapolated to determine yield per hectare. Profit analysis and cost benefit ratio was done to assess the profitability of the use of NPK fertilizer, cattle manure and leaf harvest frequency in butternut production as computed by Alemayehu et al. (2020) and Saidi et al. (2010) as shown by the formulae:

$$Cost\ Benefit\ Analysis = \frac{Gross\ income - Variable\ costs}{Variable\ costs}$$

This factored all production costs, including cost of buying fertilizer and organic manure, as well as income from selling butternut leaves and fruit.

Data analysis

The collected data was subjected to analysis of variance at $\alpha = 0.05$ using SAS (SAS Institute, 2009) and means were separated using Tukey's test at $\alpha = 0.05$.

RESULTS

Pre-plant soil and cattle manure analysis

Pre-plant soil and cattle manure showed varied soil physico-chemical properties. Cattle manure and pre-plant soil had sufficient macro- and micro-elements to support growth of butternut plants. However, this was much higher in cattle manure than in pre-plant soil, except for pH and Na content which was higher in pre-plant soil (Table 1).

Effect of NPK, cattle manure and weekly leaf harvest frequency on butternut yield

Interaction effect was observed between NPK fertilizer and cattle manure on butternut fruit yield (Figure 1A). The highest fruit yield (82%) was obtained by combining NPK at 250 kg ha^{-1} with cattle manure at 2,500 kg ha^{-1} compared with where no NPK or cattle manure was applied. Interaction effect was observed between NPK fertilizer and leaf harvest frequency on butternut fruit yield (Figure 1B). The highest butternut fruit yield (141%) was observed when 250 kg ha^{-1} of NPK was applied at leaf harvest frequency of 4-week intervals compared with where no NPK fertilizer was applied at leaf harvest frequency of 2- or 8-week intervals. Interaction effect was observed between cattle manure and leaf harvest frequency on butternut fruit yield (Figure 1C). The highest butternut fruit yield (141%) was observed when 2,500 kg ha^{-1} of cattle manure was applied at leaf harvest frequency of 4-week intervals compared with where no NPK fertilizer was applied at leaf harvest frequency of 2- or 8-week intervals. Cattle manure, NPK fertilizer and leaf harvest frequency had interaction effect on butternut fruit yield (Figure 1D). The highest fruit yield was observed by combining 250 kg ha^{-1} of NPK fertilizer with 2,500 kg ha^{-1} of cattle manure at 2-, 4-, or 6-week intervals of leaf harvest frequency while the lowest was observed when no NPK or cattle manure was applied at leaf harvest frequency of 2-week intervals.

Table 1: Chemical analysis of cattle manure and pre-plant soil

Variables	Cattle manure	Soil pre-plant
pH	6.6±1.2*	7.9±1.2
Moisture (%)	12.5±1.0	7.6±0.9
C (g·kg^{-1})	0.4±0.0	0.2±0.0
N (g·kg^{-1})	19.4±1.0	12.5±1.4
P (g·kg^{-1})	0.47±0.0	0.42±0.0
K (g·kg^{-1})	0.02±0.0	0.01±0.0
Ca (g·kg^{-1})	0.44±0.0	0.29±0.0
Mg (g·kg^{-1})	0.77±0.0	0.70±0.0
Zn (g·kg^{-1})	0.30±0.0	0.26±0.0
Fe (g·kg^{-1})	0.09±0.0	0.07±0.0
Cu (g·kg^{-1})	0.05±0.0	0.04±0.0
Na (g kg^{-1})	0.24±0.0	0.65±0.0
Mn (g·kg^{-1})	0.59±0.0	0.57±0.0
B (g·kg^{-1})	0.03±0.0	0.01±0.0
Mo (g·kg^{-1})	0.04±0.0	0.01±0.0

*Values represent means ± standard deviations.

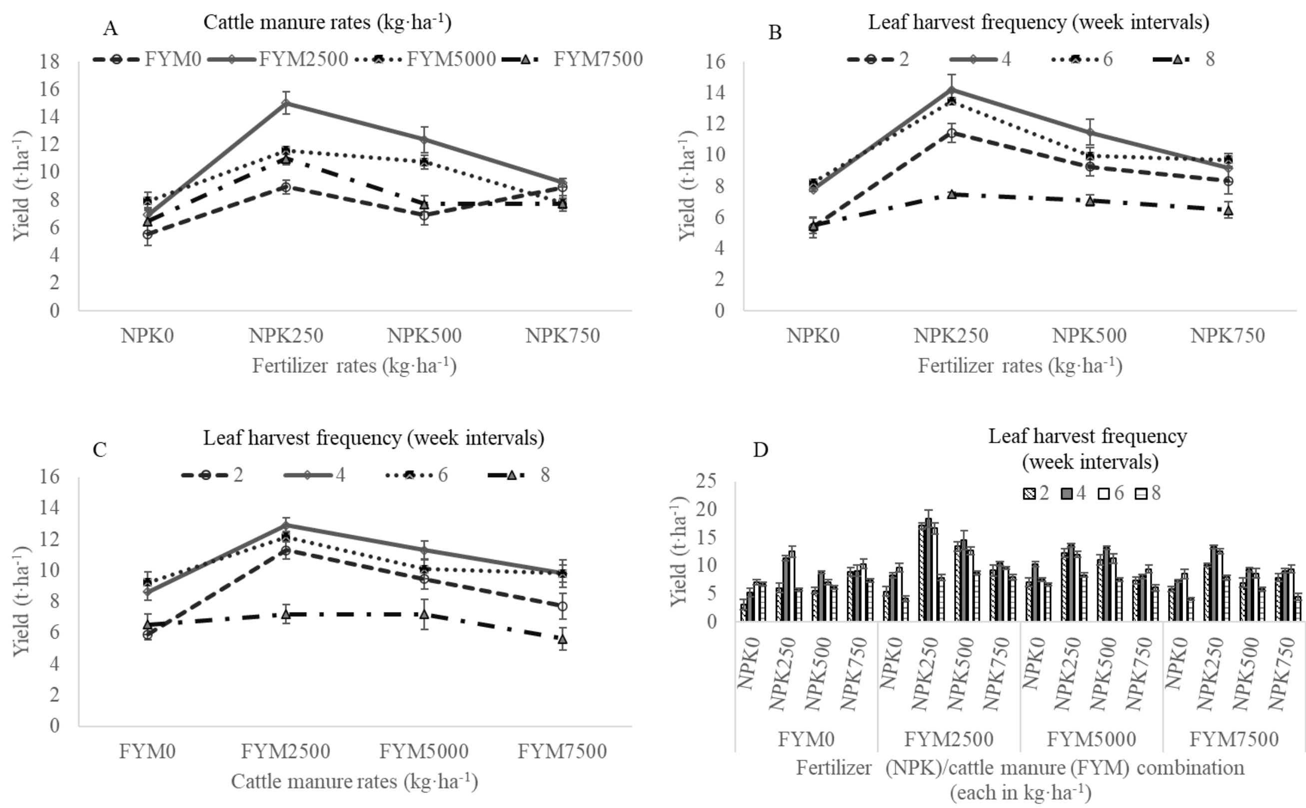

Figure 1: Interaction effect of NPK fertilizer, cattle manure, and leaf harvest frequency on butternut fruit yield. Points represent means ± standard deviations

NPK fertilizer had effect on butternut fruit yield (Figure 2A). Application of NPK fertilizer at 250 kg ha^{-1} resulted in the highest fruit yield (73%) compared with where no NPK fertilizer was applied. Cattle manure had effect on butternut fruit yield (Figure 2B). Application of cattle manure at 2,500 kg ha^{-1} resulted in the highest fruit yield (43%) compared with where no cattle manure was applied. Leaf harvest frequency had effect on butternut fruit yield (Figure 2C). Leaf harvest frequency of 4-week intervals had the highest fruit yield (62%) compared with leaf harvest frequency of 8-week intervals.

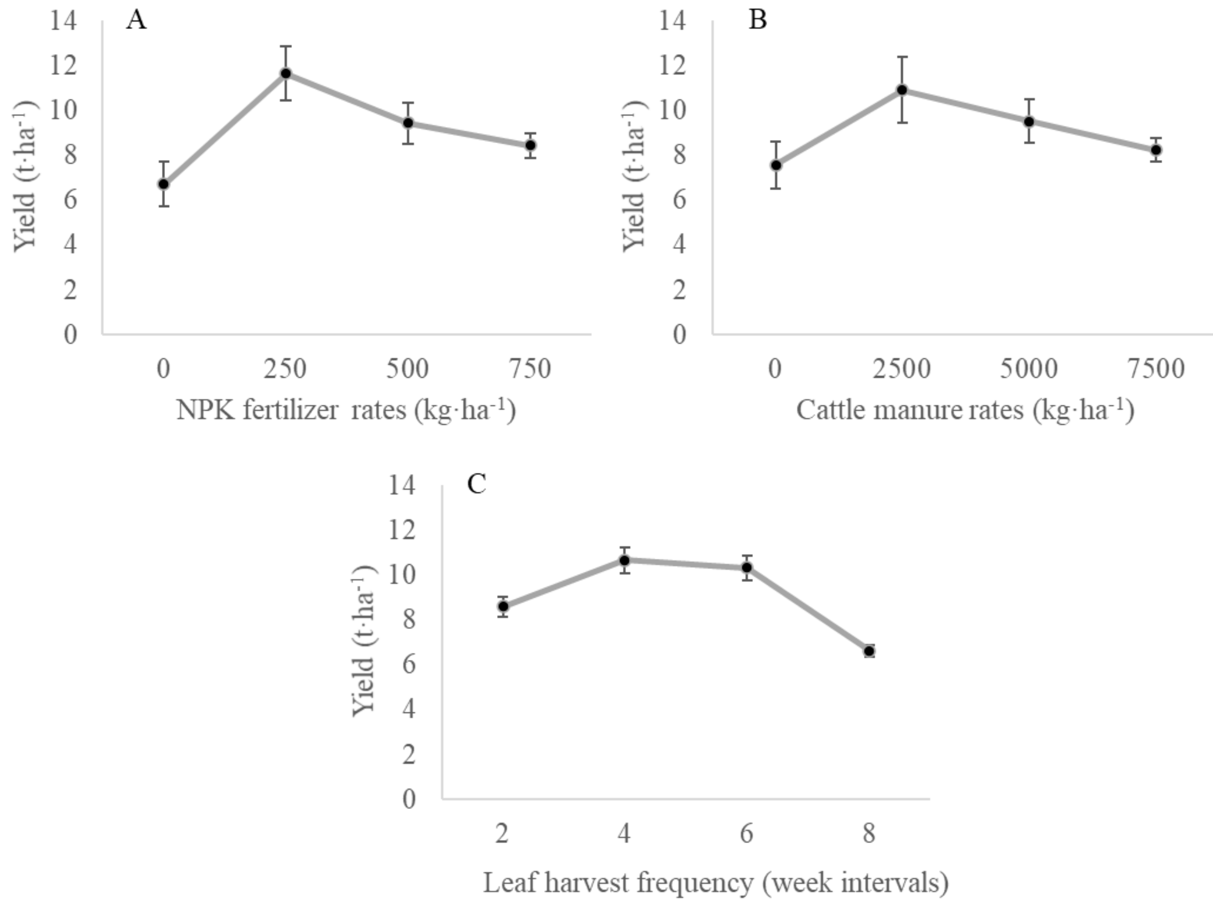

Figure 2: Main effects of NPK fertilizer, cattle manure and leaf harvest frequency on butternut fruit yield. Points represent means ± standard deviations

Effect of NPK, cattle manure and leaf harvest frequency on soil chemical properties after butternut harvest

NPK fertilizer and cattle manure had interaction effect on soil C and K after butternut production. Soil C was highest when 750 kg ha^{-1} of NPK was combined with 7,500 kg ha^{-1} of cattle manure and lowest when no NPK or cattle manure was applied (Figure 3A). Soil K was highest when 2,500 kg ha^{-1} of cattle manure was combined with 500 or 750 kg ha^{-1} of NPK and lowest when no NPK or cattle manure was applied (Figure 3B).

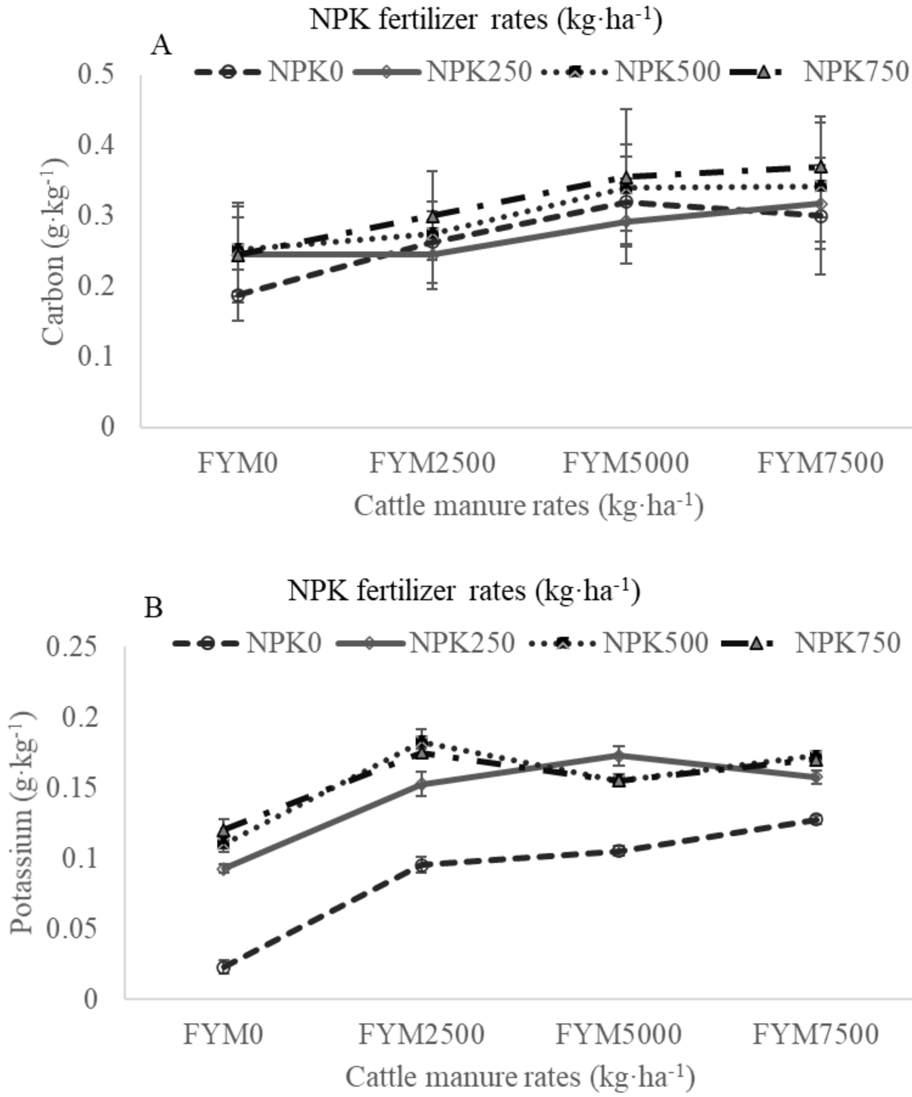

Figure 3: Interaction effect of NPK fertilizer and cattle manure on soil C, N, P and K contents after butternut harvest. Points represent means ± standard deviations

NPK fertilizer and leaf harvest frequency had interaction effect on soil C and K after butternut production. Soil C was highest when 750 kg ha^{-1} of NPK was applied at 8-week intervals of leaf harvest frequency and lowest when no NPK was applied at 2-week intervals of leaf harvest frequency (Figure 4A). Soil K was highest when 750 kg ha^{-1} of NPK was applied at 8-week intervals of leaf harvest frequency and lowest when no NPK was applied at 4-week intervals of leaf harvest frequency (Figure 4B).

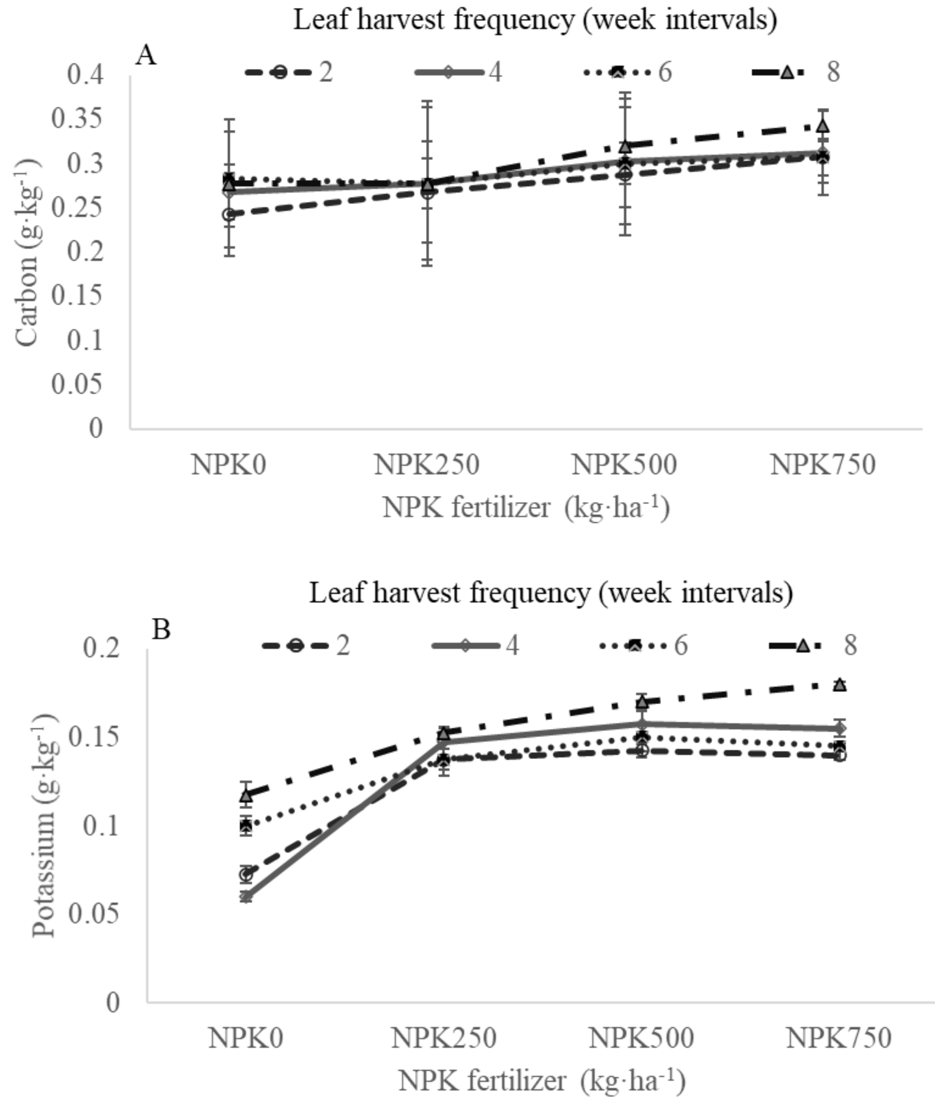

Figure 4: Interaction effect of NPK fertilizer and leaf harvest frequency on soil C, N, P and K contents after butternut harvest. Points represent means ± standard deviations

Cattle manure and leaf harvest frequency had interaction effect on soil C, P, and K after butternut production. Soil C was highest when 5,000 kg ha^{-1} of cattle manure was applied at 6-week intervals of leaf harvest frequency and lowest when no cattle manure was applied at 2-week intervals of leaf harvest frequency (Figure 5A). Soil P was highest when 7,500 kg ha^{-1} of cattle manure was applied at 8-week intervals of leaf harvest frequency and lowest when no cattle manure was applied at 2-week intervals of leaf harvest frequency (Figure 5B). Soil K was highest when 7,500 kg ha^{-1} of cattle manure was applied at 8-week intervals of leaf harvest frequency and lowest when no cattle manure was applied at 2-week intervals of leaf harvest frequency (Figure 5C).

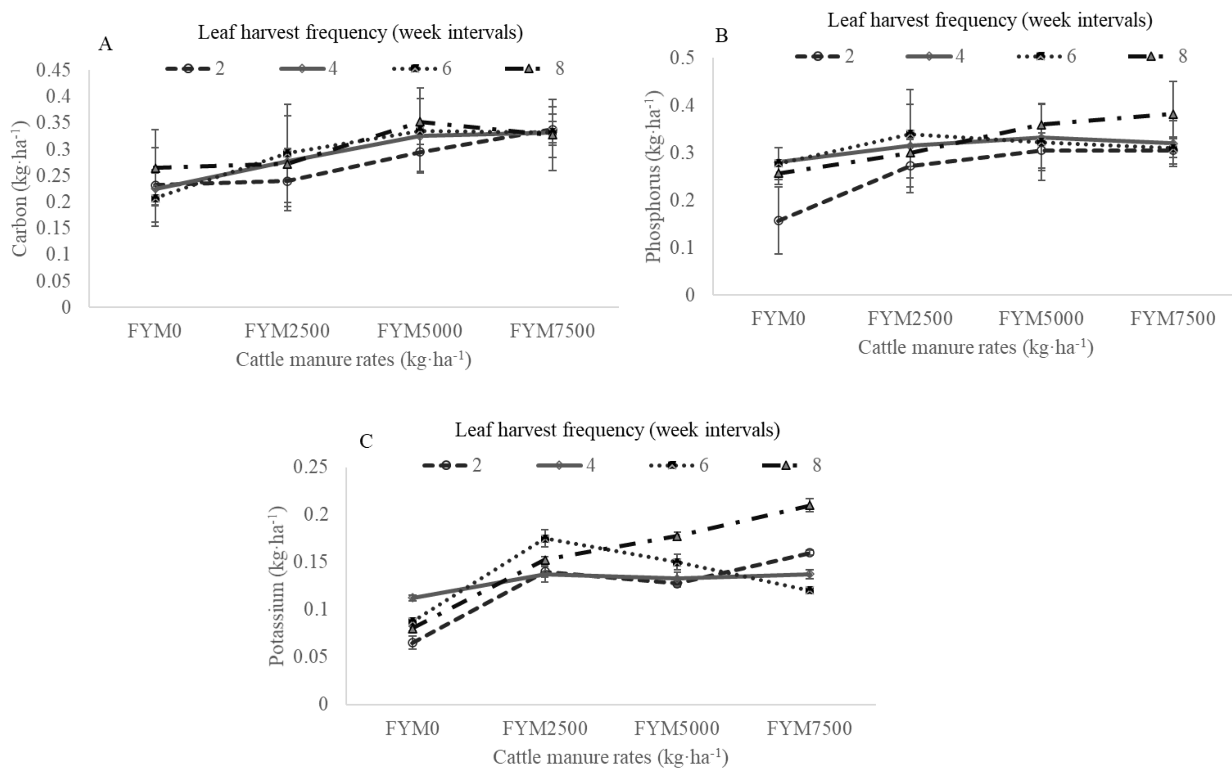

Figure 5: Interaction effect of cattle manure and leaf harvest frequency on soil C, N, P and K contents after butternut harvest. Points represent means ± standard deviations

Soil K was affected by NPK fertilizer after butternut production whereby plots where NPK fertilizer was applied, regardless of the rates had highest K content (67%) compared with plots where no NPK fertilizer was applied. (Table 2A). Cattle manure had effect on soil C, N, P and K after butternut production (Table 2B). Generally, C and N content were highest where cattle manure was applied at 5,000 or 7,500 kg ha^{-1} and lowest where cattle manure was applied at 2,500 kg ha^{-1} or not applied at all. Leaf harvest frequency had effect on soil P and K (Table 2C). Soil P was highest when butternut leaves were harvested at 4-, 6-, or 8-week intervals compared with 2-week intervals. Soil K was highest when leaves were harvested at 8-week intervals compared with 2-, 4-, or 6-week intervals.

Effect of NPK, cattle manure and leaf harvest frequency on butternut economic returns

Production of butternut using NPK fertilizer, cattle manure and frequency of leaf harvest was analysed for its return on investment. The highest profit and cost-benefit analysis was observed when 250 kg ha^{-1} of NPK fertilizer was combined with 2,500 kg ha^{-1} of cattle manure at 2-week intervals of leaf harvest frequency. The lowest profit and cost-benefit analysis was observed when 750 kg ha^{-1} of NPK fertilizer was combined with 7,500 kg ha^{-1} of cattle manure at 8-week intervals of leaf harvest frequency (Table 3).

Table 2: Main effect of NPK fertilizer, cattle manure application rates and leaf harvest frequency on soil pH, mineral elements content after butternut harvest

	pH	C (g kg^{-1})	N (g kg^{-1})	P (g kg^{-1})	K (g kg^{-1})
		A. NPK fertilizer rates (kg·ha^{-1})			
0	6.4a	0.27a	13.0a	0.26a	0.09b
250	6.5a	0.28a	14.0a	0.29a	0.14a
500	5.7a	0.30a	14.5a	0.32a	0.16a
750	5.3a	0.32a	14.9a	0.33a	0.16a
		B. Cattle manure rates (kg·ha^{-1})			
0	5.9a	0.23b	11.6b	0.24b	0.09b
2500	6.1a	0.27b	13.4ab	0.31a	0.15a
5000	6.0a	0.33a	15.2a	0.33a	0.15a
7500	6.0a	0.33a	16.2a	0.33a	0.16a
		C. Leaf harvest frequency (week intervals)			
2	5.9a	0.28a	14.0a	0.26b	0.12b
4	6.0a	0.29a	14.4a	0.31a	0.13b
6	6.0a	0.29a	13.5a	0.31a	0.13b
8	6.0a	0.30a	14.5a	0.33a	0.16a

*Means followed by the same letter within a column are not significantly different according to Tukey's test ($\alpha = 0.05$)

Table 3: Cost-benefit analysis of three factor effects of using NPK fertilizer, cattle manure and frequency of leaf harvest on butternut production

FYM (kg·ha^{-1})^{z}	NPK (kg·ha^{-1})^{y}	LHF (week intervals)^{x}	Total cost (KES)^{w}	Total yield (t·ha^{-1})^{v}	Gross income (KES)^{u}	Net profit (KES)^{t}	Cost-benefit ratio^{s}
0	0	2	45,000	4.7	234,967	189,967	4.2
		4	42,000	6.0	302,217	260,217	6.2
		6	40,000	7.5	372,850	332,850	8.3
		8	35,000	7.0	348,533	313,533	9.0
	250	2	51,000	7.7	383,750	332,750	6.5
		4	50,000	12.2	608,300	558,300	11.2
		6	49,000	12.9	645,550	596,550	12.2
		8	40,000	6.0	298,800	258,800	6.5
	500	2	52,000	7.2	359,800	307,800	5.9
		4	46,000	9.6	480,700	434,700	9.5
		6	44,000	7.5	374,050	330,050	7.5
		8	43,000	6.3	315,750	272,750	6.3
	750	2	72,000	10.5	523,400	451,400	6.3
		4	66,000	9.9	495,550	429,550	6.5
		6	64,000	10.7	536,450	472,450	7.4
		8	63,000	7.5	375,150	312,150	5.0
2500	0	2	43,000	7.1	354,050	311,050	7.2
		4	37,000	9.1	454,633	417,633	11.3
		6	35,000	10.1	506,200	471,200	13.5
		8	34,000	4.4	218,817	184,817	5.4
	250	2	63,000	18.7	937,100	874,100	13.9
		4	57,000	19.2	959,200	902,200	15.8
		6	55,000	17.1	852,550	797,550	14.5
		8	54,000	8.1	402,750	348,750	6.5
	500	2	83,000	15.0	751,600	668,600	8.1
		4	77,000	15.4	767,650	690,650	9.0
		6	75,000	13.1	654,950	579,950	7.7
		8	74,000	8.9	446,050	372,050	5.0
	750	2	103,000	10.8	538,000	435,000	4.2
		4	97,000	11.2	558,900	461,900	4.8
		6	95,000	10.0	499,800	404,800	4.3
		8	94,000	8.1	404,250	310,250	3.3
5000	0	2	74,000	8.7	432,850	358,850	4.8
		4	68,000	11.1	556,200	488,200	7.2
		6	66,000	8.0	398,300	332,300	5.0
		8	65,000	6.9	344,900	279,900	4.3
	250	2	94,000	13.9	697,350	603,350	6.4
		4	88,000	14.5	723,150	635,150	7.2
		6	86,000	12.4	621,300	535,300	6.2
		8	85,000	8.5	424,550	339,550	4.0
	500	2	114,500	12.6	631,600	517,100	4.5
		4	108,500	14.0	698,850	590,350	5.4
		6	106,000	11.7	586,150	480,150	4.5
		8	105,000	7.7	384,550	279,550	2.7
	750	2	134,000	9.0	449,600	315,600	2.4
		4	128,000	8.9	445,500	317,500	2.5
		6	126,000	9.8	490,650	364,650	2.9
		8	125,000	6.3	314,817	189,817	1.5
7500	0	2	105,000	7.5	372,533	267,533	2.5
		4	99,000	8.1	407,050	308,050	3.1
		6	97,000	8.9	447,350	350,350	3.6
		8	96,000	4.3	214,917	118,917	1.2
	250	2	125,000	11.8	588,000	463,000	3.7
		4	119,000	14.2	708,900	589,900	5.0
		6	117,000	13.0	649,800	532,800	4.6
		8	116,000	8.1	404,250	288,250	2.5
	500	2	145,000	8.6	428,850	283,850	2.0
		4	139,000	10.2	507,650	368,650	2.7
		6	137,000	9.0	452,250	315,250	2.3
		8	136,000	6.0	301,800	165,800	1.2
	750	2	165,000	9.5	475,800	310,800	1.9
		4	159,000	9.9	497,350	338,350	2.1
		6	157,000	9.8	491,850	334,850	2.1
		8	156,000	4.7	232,683	76,683	0.5

^{z}FYM = cattle manure; ^{y}NPK = NPK fertilizer; ^{x}LHF = leaf harvest frequency; ^{w}Total variable cost involves cost of buying NPK fertilizer (KES 70/kg), cost of cattle manure (KES 2.40/kg), and labour cost (KES 1500/harvest); ^{v}Yield includes fruit and leaf yield; ^{u}Gross income is the income from sales of butternut leaves and fruit (KES 50/kg); ^{t}Net profit is the difference between variable cost and gross income; ^{s}Cost-benefit ratio is net profit divide by variable cost, KES = Kenyan Shillings

Production of butternut using NPK fertilizer and cattle manure was analysed for its return on investment. The highest profit and cost-benefit ratio was observed when 250 kg ha^{-1} of NPK fertilizer was combined with 2,500 kg ha^{-1} of cattle manure and lowest when 750 kg ha^{-1} of NPK fertilizer was combined with 7,500 kg ha^{-1} of cattle manure. Production of butternut using NPK fertilizer and frequency of leaf harvest was analysed for its return on investment. The highest profit and cost-benefit ratio was observed when 250 kg ha^{-1} of NPK fertilizer was applied at 2-week intervals of leaf harvest frequency and lowest when 750 kg ha^{-1} of NPK fertilizer was applied at 8-week intervals of leaf harvest frequency. Production of butternut using cattle manure and frequency of leaf harvest was analysed for its return on investment. The highest profit and cost-benefit ratio was observed when 2,500 kg ha^{-1} of cattle manure was applied at 2-week intervals of leaf harvest frequency and lowest when 7,500 kg ha^{-1} of cattle manure was applied at 8-week intervals of leaf harvest frequency (Table 4).

Main effect of using NPK fertilizer analysed for its return on investment. The highest profit and cost-benefit ratio was observed when NPK was applied at 250 kg ha^{-1} while the lowest was observed at 750 kg ha^{-1} of NPK fertilizer. Main effect of using cattle manure was analysed for its return on investment. The highest profit and cost-benefit ratio was observed when cattle manure was applied at 2,500 kg ha^{-1} while the lowest was observed at 7,500 kg ha^{-1} of cattle manure. Main effect of frequency of butternut leaf harvest was analysed for its return on investment. The highest profit and cost-benefit ratio was observed at 4-week intervals of leaf harvest frequency and lowest at 8-week intervals of leaf harvest frequency (Table 5).

Table 4: Cost-benefit analysis of two factor effects of using NPK fertilizer, cattle manure and frequency of leaf harvest on butternut production

$NPK^z \times FYM^y$	Profit^x (KES)	Cost-benefit ratio^w	NPK × LHF^v	Profit (KES)	Cost-benefit ratio	FYM × LHF	Profit (KES)	Cost-benefit ratio
NPK_0FYM_0	274,142	6.9	NPK_0LHF_2	281,850	4.7	FYM_0LHF_2	320,479	5.7
NPK_0FYM_{2500}	346,175	9.4	NPK_0LHF_4	368,525	6.9	FYM_0LHF_4	420,692	8.3
NPK_0FYM_{5000}	364,813	5.3	NPK_0LHF_6	371,675	7.6	FYM_0LHF_6	432,975	8.8
NPK_0FYM_{7500}	261,213	2.6	NPK_0LHF_8	224,292	5.0	FYM_0LHF_8	289,308	6.7
$NPK_{250}FYM_0$	436,600	9.1	$NPK_{250}LHF_2$	568,300	7.6	$FYM_{2500}LHF_2$	572,188	8.3
$NPK_{250}FYM_{2500}$	730,650	12.7	$NPK_{250}LHF_4$	671,388	9.8	$FYM_{2500}LHF_4$	618,096	10.2
$NPK_{250}FYM_{5000}$	528,338	6.0	$NPK_{250}LHF_6$	615,550	9.4	$FYM_{2500}LHF_6$	563,375	10.0
$NPK_{250}FYM_{7500}$	468,488	3.9	$NPK_{250}LHF_8$	308,838	4.9	$FYM_{2500}LHF_8$	303,967	5.1
$NPK_{500}FYM_0$	336,325	7.3	$NPK_{500}LHF_2$	444,338	5.1	$FYM_{5000}LHF_2$	448,725	4.5
$NPK_{500}FYM_{2500}$	577,813	7.4	$NPK_{500}LHF_4$	521,088	6.6	$FYM_{5000}LHF_4$	507,800	5.6
$NPK_{500}FYM_{5000}$	466,788	4.3	$NPK_{500}LHF_6$	426,350	5.5	$FYM_{5000}LHF_6$	428,100	4.7
$NPK_{500}FYM_{7500}$	283,388	2.0	$NPK_{500}LHF_8$	272,538	3.8	$FYM_{5000}LHF_8$	272,204	3.1
$NPK_{750}FYM_0$	416,388	6.3	$NPK_{750}LHF_2$	378,200	3.7	$FYM_{7500}LHF_2$	331,296	2.5
$NPK_{750}FYM_{2500}$	402,988	4.1	$NPK_{750}LHF_4$	386,825	4.0	$FYM_{7500}LHF_4$	401,238	3.2
$NPK_{750}FYM_{5000}$	296,892	2.3	$NPK_{750}LHF_6$	394,188	4.2	$FYM_{7500}LHF_6$	383,313	3.1
$NPK_{750}FYM_{7500}$	265,171	1.7	$NPK_{750}LHF_8$	222,225	2.6	$FYM_{7500}LHF_8$	162,413	1.4

^{z}NPK = NPK fertilizer, ^{y}FYM = cattle manure, ^{x}Profit is the difference between variable cost and gross income; ^{w}Cost-benefit ratio is net profit divide by variable cost, ^{v}LHF = leaf harvest frequency, KES = Kenyan Shillings

Table 5: Cost-benefit analysis of main effects of using NPK fertilizer, cattle manure and frequency of leaf harvest on butternut production

NPK[z] ($kg \cdot ha^{-1}$)	Profit[y] (KES)	Cost-benefit ratio[x]	FYM[w] ($kg \cdot ha^{-1}$)	Profit (KES)	Cost-benefit ratio	LHF[v] (week intervals)	Profit (KES)	Cost-benefit ratio
0	311,585	6.1	0	365,864	7.4	2	418,172	5.3
250	541,019	7.9	2,500	514,406	8.4	4	486,956	6.8
500	416,078	5.3	5,000	414,207	4.5	6	451,941	6.7
750	345,359	3.6	7,500	319,565	2.6	6	256,973	4.1

[z]NPK = NPK fertilizer, [y]Profit is the difference between variable cost and gross income; [x]Cost-benefit ratio is net profit divide by variable cost, [w]FYM = cattle manure, [v]LHF = leaf harvest frequency, KES = Kenyan Shillings.

DISCUSSION

Effective and economic crop production through nutrient and leaf harvest management begins with an understanding of the nutrient requirements of the crop being grown and the nutrient status of the soil. The nutrient management and leaf harvest frequency may vary with management practices, type of the crop or variety being grown (Van Eerd and O'Reilly, 2009). In the present study, the effect of NPK fertilizer, cattle manure and leaf harvest frequency was evaluated on yield and economic returns of butternut. Integrating NPK and cattle manure improved the soil nutrient status (C, N, P and K), hence growth of butternut. This was attributed to nutrient released from the NPK fertilizer and cattle manure. Previous studies have shown that organic fertilizers such as cattle, contain significant amount of nutrients and influences plant growth and production via improving chemical, physical and biological properties of soil (Awodun, 2007). In addition, availability and uptake of nutrients is enhanced during biodegradation of organic manure (Nerson, 2008). Inorganic fertilizers like NPK contain significant amounts of nutrients (N, P, and K), which is released to the soil (Oloyede et al., 2013). Natsheh and Mousa (2014), also observed that combined use of organic and inorganic fertilizer improved soil nutrient status (N, P, K, C and C:N) after cucumber (*Cucumis sativa* L.) harvest, which is closely related to butternut.

In other studies, more soil mineral nitrogen was observed after butternut harvest with application of 110 to 220 kg N ha^{-1} treatments compared with non-fertilized control treatment (Van Eerd, 2010). Mahmoud et al. (2009) also observed that soil nitrogen, phosphorus and organic matter content significantly increased with increase of organic nitrogen after cucumber harvest. Mahmoud et al. (2009) observed that increase in nitrogen uptake was greater when compost manure was mixed with synthetic nitrogenous fertilizer as compared to 100% manure or 100% synthetic fertilizer. Clementina (2013) reported that use of organic fertilizers together with chemical fertilizers, had a higher positive effect on microbial biomass and hence soil health, compared to the use of organic or inorganic fertilizers alone.

Soil microorganisms need carbon substrate from organic manure for growth and energy. They utilize ready nitrogen from inorganic fertilizer, which results in the formation of soil organic nitrogen. Part of the nitrogen bound in the more recalcitrant forms in the organic inputs also build up soil humic substance (Clementina, 2013). Clementina (2013) noted that inorganic fertilizers do not contain such carbon sources, and therefore much of the nitrogen from fertilizer is not used by crops and go into waste through leaching and de-nitrification losses. Organic additions therefore provide the carbon necessary to reduce the depletion of nitrogen in soils (Awodun, 2007). The joint organic and inorganic nitrogen replenishment strategy provides both nitrogen and carbon inputs that gradually increase soil nitrogen and carbon status (Clementina, 2013). The high nitrogen content in NPK fertilizer (17% N, 17 % P, and 17% K) and high carbon content in cattle manure (0.4 $g \cdot kg^{-1}$) may be important in maintaining proper carbon to nitrogen ratio during mineralization. Therefore, the improved soil properties can be attributed to synergistic effects of both cattle manure and NPK fertilizer with respect to nutrient availability, soil physical properties and microbial activities.

Yield and economic returns of butternut production was improved by combining moderate amounts of NPK fertilizer (250-500 $kg \cdot ha^{-1}$) with cattle manure (2,500-5,000 $kg \cdot ha^{-1}$) irrespective of leaf harvest frequency. According to Warncke (2007), cucurbits such as butternut generally accumulate nutrients in the vegetative parts and fruit by between 65.8 to 172.6 kg of nitrogen (N), 13.6 to 20.4 kg in the form of phosphate (P_2O_5) and 72.6 to 81.6 kg in the form of potassium (K_2O) per acre. However, the actual amounts may vary depending on yield. This means that combining lower rate of NPK fertilizer and cattle manure was sufficient to support butternut growth. In agreement with the results, Clementina (2013) observed that use of NPK fertilizer and cattle manure significantly improved yield of pumpkin (*Cucurbita Maxima* L.). Mahmoud et al. (2009) observed that cucumber yield was higher with 75% mineral N + 25% organic N treatments compared to other treatments. They also confirmed that composted organic wastes can be used to substitute for around 25% of chemical nitrogen fertilizers. Van Eerd (2010) observed that applying more than 220 kg N ha^{-1} of nitrogen fertilizer only minimally increased plant N content and resulted in unnecessary higher input costs with no yield advantage. In the present study, harvesting leaves more frequently (4-week intervals) was found to be economically viable, probably based on the interactive effects with NPK and cattle that boosted the growth of butternut plants. In this study, combined use of lower rates of NPK and cattle manure may reduce the cost of butternut production while still maximising on yield and profit.

CONCLUSION AND RECEOMMENDATION

Integrated application of 250 kg ha^{-1} of NPK and/or 2500 kg ha^{-1} of cattle manure helped to facilitate more frequent leaf harvest while still maintaining higher fruit yield which translated to high monetary value and lower production cost. There is demand for butternut fruit as well as leaves for consumption and commercialization due to their nutritional value. Harvesting butternut fruit as well as leaves from the same plant is a primary goal for farmers, which allows them to exploit the nutritional and economic benefits of both. Use of butternut leaves not only means that farmers maximise on the nutritional benefits they obtain from growing butternut, but also ensures that food is available earlier in the season to poor households in the form of leaves of young shoots. The crop is thus used throughout its entire growing period, beginning with the highly nutritious tender leaves in the growing period. However, frequent leaf harvesting practices by farmers are among the leading causes of poor fruit yield and quality, as well as profitability in butternut production. High returns on crops is based on number and fresh weight of the harvested produce. However, this problem can be solved by application of lower rates of NPK and/or cattle manure as observed in the study.

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