RESPONSE OF STRAWBERRY QUALITY AND PROFITABILITY TO FARMYARD MANURE AND TRIPLE SUPER PHOSPHATE UNDER TROPICAL HIGH ALTITUDE CONDITIONS

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Abstract
Quality of strawberries in the tropics is partly limited by poor soil fertility, while profitability of different nutrient management strategies has not been established. The present study determined the effect of 0, 18, 36, and 54 t/ha farmyard manure (FYM) and triple super phosphate (TSP), equivalent to 0, 17, 34 and 68 kg/ha phosphorus (P) on quality and profitability of strawberries. The study was done in three seasons on field 3 of Tatton farm-Njoro, Kenya. The design was split-plots embedded in randomised complete blocks, replicated three times. The FYM and TSP were broadcasted to main plots and sub-plots, respectively. Each treatment had 10 plants, spaced at 0.3 m $\times$ 0.45 m in 0.6 m $\times$ 1.5 m plots, mulched with black polyfilm and irrigated with drip lines. Berry fruit size, brix index and storage life were determined from 26 to 42 weeks after planting (WAP). Profitability was calculated using berry yield-income and input-costs at the end of the study. Results varied depending on response variable. High FYM and TSP significantly ($P < 0.05$) increased fruit size, but lowered storage life. High FYM significantly lowered brix index. Low FYM plus moderate P significantly lowered fruit size. Thus, 54 t/ha FYM plus 34 kg/ha P and 36 t/ha FYM plus 17 kg/ha P are recommended for large-sized and sweetest, long-storing berries, respectively. Manure alone increased profitability more than TSP alone. Highest FYM and TSP did not always result in highest profitability. The relationship between treatments and profitability was sigmoid, and dependent on site and season. Thus, profitable strawberry mineral nutrition packages will have to be developed for each site and season in Kenya.

Key words: Brix index, fragaria, fruit size, phosphorus, storage life, high altitude tropics

1.0 Introduction

Strawberry (*Fragaria x ananassa* Duch.) is a small fruit crop of great nutritional and medicinal value (Maas *et al.,* 1991). Strawberries are among the most popular fruits consumed worldwide (Jackson and David, 1985; Food and Agricultural Organisation, 2001). The versatility of strawberries in fresh and processed forms has played a pivotal role in their wide adoption in foods (Jackson and David, 1985). The berries are important sources of vitamin C, which averages 21 mg/kg of fresh fruits and this level is second to that of black currants (75 mg/kg) (Jackson and David, 1985; Macer, 1973). The berries contain about four International Units of carotene, which is converted to vitamin A, 12.4 µg/kg riboflavin, which makes them second to tomatoes, and 81 µg/kg each for nicotinic and pantothenic acids (Macer, 1973). The berries also contain medicinal values, as in ellagic acid, which is an anti-carcinogen that inhibits the ability of the human immune-deficiency virus to bind on deoxyribonucleic acid (Maas *et al.,* 1991).

The cultivated strawberry is a hybrid of *F. virginiana and F. chiloensis*. The plant is a herbaceous perennial that produces roots, leaves and flowers from the crown, which is a compressed stem. Strawberry flowers are borne on a cymose inflorescence that opens sequentially. Mature strawberries are expanded receptacles covered by achenes. The strawberry root system is small, restricting the rooting zone and making the crop a poor forager for nutrients. Consequently, the strawberry grows best and produces highest returns when the nutrient content in the rooting zone is boosted through optimal fertilisation (MacNaeidhe, 2001).

Strawberry plantations remain productive for two to three years, and a heavy dressing of farmyard manure (FYM) is needed to supply adequate nutrients over this productivity period (MacNaeidhe, 2001). For example, with a standard plant population of 27,000 plants/ha, 38 kg N and 5 kg P are removed annually from the soil (MacNaeidhe, 2001). Although the nutrient uptake is low, strawberry plants benefit from high level of soil fertility (MacNaeidhe, 2001). Strawberries grow well in soils having a pH of 5.6 to 6.5. However, if organic matter is high, they can grow satisfactorily at a wider pH range of 5 to 7 (Childers, 1983; Anonymous, 2001).

The enormous uses of strawberries have led to their popularity in many parts of the world, including Kenya. However, production in Kenya has been declining and Rono (1995) suggests that poor mineral nutrition is one of the constraining factors in the north of the Rift Valley Province. In Kenya, yields of 90,181 kg in 1997, 43,942 kg in 2000, and 31,759 kg in 2001 have been reported (Horticultural Crop Development Authority, 2002a). Demand for increased hectarage, yield, quality and profitability in Kenya poses a great challenge to growers (Horticultural Crop Development Authority, 2002b).

Little is documented about effects of integrating FYM and TSP on quality and profitability of strawberries under Kenyan agroecological conditions. Determining appropriate rates of inorganic fertilisers and alternative sources of plant nutrition ensures adequate nutrients for plants, balance of inputs, conservation of nutrient-resources for economic and profitable production, and prevention of contamination of the environment by non-utilised nutrients

Brady and Weil, 1999). Kenyan growers have been relying on limited personal experience, or on fertiliser information from other regions, especially the USA and Europe, resulting in low production and quality because of varying soil and climatic conditions. Furthermore, documented information to validate visual observations and enable making of low-risk decisions is lacking. Therefore, the objectives of this study were to determine the effects of FYM and TSP on strawberry quality under tropical high altitude conditions, and to perform a cost-benefit analysis for the TSP and cattle FYM that shall be applied in deciding the best source of nutrients for strawberries.

2.0 Materials and Methods

The current research was conducted in the Horticultural Research Field 3, located on Tatton Farm at Egerton University, Njoro, Kenya. The farm is located at latitude 0°23' south, longitude 35°35' east, and 2,238 m above sea level. The soils on the farm are well-drained sandy loam-Vintric mollic Andosols (Jaetzold and Schmidt, 2006). Mean annual rainfall is 1,000 mm, although not uniformly distributed and maximum temperature ranges from 19°C to 22°C, whereas minimum temperature ranges from 5°C to 8°C.

The experiment consisted of split-plots in randomised complete block design, replicated three times. Manure (0, 18, 36 and 54 t/ha) formed main plots, whereas TSP (corresponding to 0, 17, 34 and 68 kg/ha P) formed sub-plots. Cattle farmyard manure was used because of its relative ready availability to farmers, whereas TSP is essential in root growth (Marschner, 1986; Pritts, 1998). The inherent manure characteristics were as follows: 8.7 pH (H_20) at 1:2.5 (soil: water), 1.33% total N, 0.63% total P, and 1.5% total K. Ten plants were planted in double rows in each sub-plot and spaced at 0.3 m x 0.45 m. The entire experiment was performed three times over three seasons (August 2003 to July 2004; February 2004 to January 2005, and July 2005 to June 2006) to test seasonal stability.

Land was prepared by ploughing, harrowing and hand pulverising to a fine tilth to ensure uniform water distribution and root growth. Carbofuran (6 kg/ha) was incorporated into the soil to eliminate nematodes and other harmful soil microorganisms. Beds measuring 0.6 m wide and 7.5 m long were raised to a height of 0.2 m. Trenches measuring 0.5 m wide and 0.5 m deep were dug and polyethylene sheets placed underneath to avoid interference of adjacent plots through mobile nutrients in manure. Triple super phosphate and FYM were incorporated into the soil during bed-shaping stage. Irrigation drip lines were laid on top of beds, which were then covered with black polyfilm mulch to smother weeds and keep berries clean.

Strawberry stock runners were obtained from the National Horticultural Research Centre of the Kenya Agricultural Research Institute at Thika and multiplied in plots on Tatton Farm. The runners were harvested the previous evening and prepared for planting the next morning. Senesced and dead roots and leaves were pruned, followed by standardisation of runners. The harvested runners were kept moist throughout until planting time. The polyfilm mulch was slit open at designated points where runners of uniform size (age and foliage) were inserted into the soil. Subsequently, standard cultural practices (Galletta and Himelrick, 1990) were applied uniformly to all plots, followed by periodic assessment of treatment effects.

Quality referred to attributes or characteristics that made strawberries attractive to eat or desirable for conversion into jam, juice, ice-cream and other products, i.e., the extent to which the product met requirements of consumers (Teranishe and Barrera-Beritez, 1981). Quality (berry size, total soluble solids (brix index) and storage life were determined for five months on a monthly basis. Berry size was determined by measuring the diameter of the broad basal end of five randomly selected berries from each treatment, using a ruler. The sizes were grouped into three quality grades of low, high and very high quality berries, corresponding to 1 cm, 1.1 to 2 cm, and above 2 cm, respectively (Teranishe and Barrera-Berritez, 1981).

Brix index of five randomly selected ripe berries from each treatment was measured using a hand-held refractometer. Berries with 3% to 6% brix index were regarded as having high quality (Teranishe and Barrera-Berritez, 1981).
Storage life referred to the shelf-life of 10 berries randomly selected from each treatment and kept in a refrigerator maintained at $2 \pm 1^{o}C$. The berries that remained firm and without rot for 7 to 10, 5 to 7, 3 to 5, and ≤ 2 days were considered to be of the best, better, good and poor storage life, respectively (Jackson and David, 1985).

Profit (net income) referred to the difference between gross income (returns) and avoidable (variable) costs (Abbott and Makeham, 1979; Ministry of Agriculture, 1994). It is the proper criterion for farm management decisions, because only avoidable costs are considered (Table 1). Thus;

profit /ha = yield x selling price - (costs of TSP + FYM + other inputs)................................ (1)

Table 1: Values used to calculate the economic returns of triple super phosphate (TSP) and cattle FYM applied alone or in combination for strawberry production

Item	Actual values (KES)
Price of FYM	400 tonne^{-1}
Price of TSP fertiliser	40 kg^{-1}
Transport cost for TSP fertiliser	50 per 50 kg bag
Mulch	70,000 ha^{-1}
Insecticides and fungicides	35,000 ha^{-1}
Land preparation (ploughing, harrowing and bed-shaping)	4,250 ha^{-1}
Maintenance (weeding, spraying etc.) + harvesting costs	12,000 ha^{-1}
Price of strawberries	200 kg^{-1}

KES = Kenya Shillings.
Source: Ministry of Agriculture (2006), Horticultural Crops Development Authority (2002b), and own compilation.

To recommend technologies capable of improving farmers' income, it is important to consider a realistic estimate of net income rather than yield alone. Therefore, economicreturns from the application of each treatment were calculated based on partial-budgeting procedure, which considered only added costs and added benefits compared to the control treatment. Added costs included all expenses incurred in buying, collecting, transporting and applying inputs, while added benefits referred to the income that would be realised if berries were sold in local markets.

Cost of fertiliser, and transport were determined from local market survey data. The cost of manure used was KES 400 per tonne (Ministry of Agriculture, 2006). Labour was valued at local current wage rate of KES 100 per day. Strawberries were priced at KES 200 per kg (Horticultural Crops Development Authority, 2002 b).

Harvested yields in each treatment were reduced by 20% to adjust to realistic values that reflect yields under farmers' harvesting, weeding and other management practices (Amanuel *et al*., 1998). The net income was determined as the difference between gross income and added costs.

Data were pooled and reported together where there was no significant difference over the three experimental seasons. Data were subjected to analysis of variance using the MSTAT-C computer software to determine the effect of FYM and TSP on strawberry quality response. Where the F-test was significant at $P = 0.05$, mean separation was done using the least significant difference.

4.0 Results and Discussion

4.1 Nutrient Analysis

Initial soil analysis yielded 5.8 pH at 1:2.5 (soil: water), 0.24% total N, 0.21% available P, and 4.5% available K. The initial manure analysis yielded 8.7 pH at 1:2.5 (soil: water), 1.33% total N, 0.63% total P, and 1.5% total K. Soil analysis at six months post-planting (Table 2) yielded 5.52-6.60 pH, 0.17-0.32% total N, 50-81 ppm available P and 625-1000 ppm available K, being the range from the lowest to the highest value. Leaf tissue nutrients (Table 2) from the lowest to the highest values were: 0.79-1.79% total N, 0.14-0.32% total P, and 0.14-0.30% total K.

George and Albregts (1994) reported that sufficiency ranges for recently matured, whole strawberry leaves were: 3-3.5% total N, 0.2-0.4% total P, and 1.5-2.5% total K. Therefore, nutrient uptake for phosphorus was sufficient, whereas for potassium and nitrogen was insufficient. This could be as a result of increased phosphorus availability from triple super phosphate and farmyard manure interaction. George and Albregts (1994) also noted that soils have high available phosphorus when P exceeds 60 ppm and high potassium when K exceeds 125 ppm, which was the case with the soil for the present study. This could be the reason why the crops extracted sufficient amounts of P. All post-planting pH values (ranging from 5.52 to 6.60) were suitable for good growth of strawberry plants (Childers, 1983; Anonymous, 2001).

Table 2: Soil and leaf tissue nutrient contents

Soil analysis	Farmyard manure (t/ha)				
pH	0	18	36	54	Mean
0 kg/ha P	5.84	5.93	6.04	5.70	5.88
17 kg/ha P	6.11	5.76	6.60	6.50	6.24
34 kg/ha P	6.46	6.11	6.11	6.22	6.23
68 kg/ha P	6.07	6.20	5.52	6.30	6.02
Mean	6.12	6.00	6.07	6.18	
N total (%)	0	18	36	54	Mean
0 kg/ha P	0.25	0.24	0.23	0.25	0.24
17 kg/ha P	0.23	0.27	0.23	0.24	0.24
34 kg/ha P	0.19	0.32	0.28	0.21	0.25
68 kg/ha P	0.22	0.25	0.17	0.23	0.22
Mean	0.22	0.27	0.23	0.23	
P available (%)	0	18	36	54	Mean
0 kg/ha P	0.0070	0.0074	0.0063	0.0050	0.0064
17 kg/ha P	0.0054	0.0049	0.0070	0.0063	0.0059
34 kg/ha P	0.0054	0.0055	0.0064	0.0081	0.0063
68 kg/ha P	0.0055	0.0070	0.0065	0.0068	0.0064
Mean	0.0058	0.0062	0.0065	0.0065	
K available (%)	0	18	36	54	Mean
0 kg/ha P	0.0738	0.0675	0.0988	0.0838	0.0809
17 kg/ha P	0.0713	0.0863	0.0863	0.0775	0.0803
34 kg/ha P	0.0738	0.0888	0.0813	0.1000	0.0859
68 kg/ha P	0.0813	0.0625	0.0963	0.0675	0.0769
Mean	0.0750	0.0763	0.0906	0.0822	
Leaf tissue analysis	Farmyard manure (t/ha)				
N total (%)	0	18	36	54	Mean
0 kg/ha P	1.03	0.92	1.67	1.79	1.35
17 kg/ha P	0.97	1.79	1.72	0.92	1.35
34 kg/ha P	0.97	1.72	1.64	0.79	1.28
68 kg/ha P	1.46	0.85	0.92	0.95	1.05
Mean	1.11	1.32	1.49	1.11	
P total (%)	0	18	36	54	Mean
0 kg/ha P	0.32	0.18	0.18	0.23	0.23
17 kg/ha P	0.26	0.18	0.22	0.23	0.22
34 kg/ha P	0.23	0.2 3	0.14	0.26	0.22
68 kg/ha P	0.17	0.22	0.25	0.23	0.22
Mean	0.25	0.20	0.20	0.24	
K total (%)	0	18	36	54	Mean
0 kg/ha P	0.30	0.23	0.14	0.20	0.22
17 kg/ha P	0.25	0.23	0.15	0.25	0.22
34 kg/ha P	0.20	0.21	0.21	0.25	0.22
68 kg/ha P	0.23	0.21	0.20	0.21	0.21
Mean	0.25	0.22	0.18	0.23	

4.2 Effect of FYM and TSP on Fruit Size

Fruit size response to FYM had an oscillating trend, as evidenced by large-sized fruits at the beginning, followed by small-sized fruits in the middle, and then large-sized fruits again at the end of the season (Table 3). Small-sized fruits were attributed to competition for photoassimilates among the many fruits in the middle of the growing season (MacNaeidhe, 2001).

Table 3: Effect of FYM on fruit size (cm/fruit) at 30 weeks after planting

Season 1	**Time (weeks after planting)**				
FYM (t/ha)	26	30	34	38	42
0	1.70[b*]	1.86	1.70	1.41	1.78
18	1.66[b]	1.68	1.62	1.40	1.71
36	1.58[b]	1.51	1.67	1.48	1.66
54	1.88a	1.72	1.71	1.50	1.88
Season 2	**Time (weeks after planting)**				
FYM (t/ha)	26	30	34	38	42
0	1.48	1.56	1.50	1.49	1.62
18	1.48	1.67	1.48	1.53	1.53
36	1.54	1.61	1.43	1.53	1.56
54	1.50	1.68	1.52	1.47	1.64

**Means followed by the same letter or no letter, within a column of each season are not significantly different at P=0.05, according to the LSD test.*

There was a significant ($P < 0.05$) effect of FYM on fruit size at 26 WAP (Table 2). On the other hand, there was no significant ($P > 0.05$) effect of TSP on fruit size (Figure 1). The 54 t/ha FYM resulted in the biggest fruits at 26 WAP, probably through promotion of an optimum number of leaves to feed the fruits before leaves became too many and shaded each other (Stoskopf, 1981). Also, high FYM could have increased P uptake, P use efficiency and improved soil physical properties, water holding capacity and root cation exchange capacity that then enhanced the size of fruits. Shaded leaves do not photosynthesise much, but become parasitic on photosynthetically active leaves, as well as sinks that rob fruits off photoassimilates (Stoskopf, 1981). This result is also in agreement with that of MacNaeidhe (2001), who observed a reduction in fruit size and quality as too many crowns were formed. These relationships explained why the 0 t/ha FYM generally promoted bigger fruits late in the season. High FYM rates also probably acted through provision of high potassium that promoted translocation of photoassimilates to strawberry fruits (Marschner, 1986), making them grow bigger.

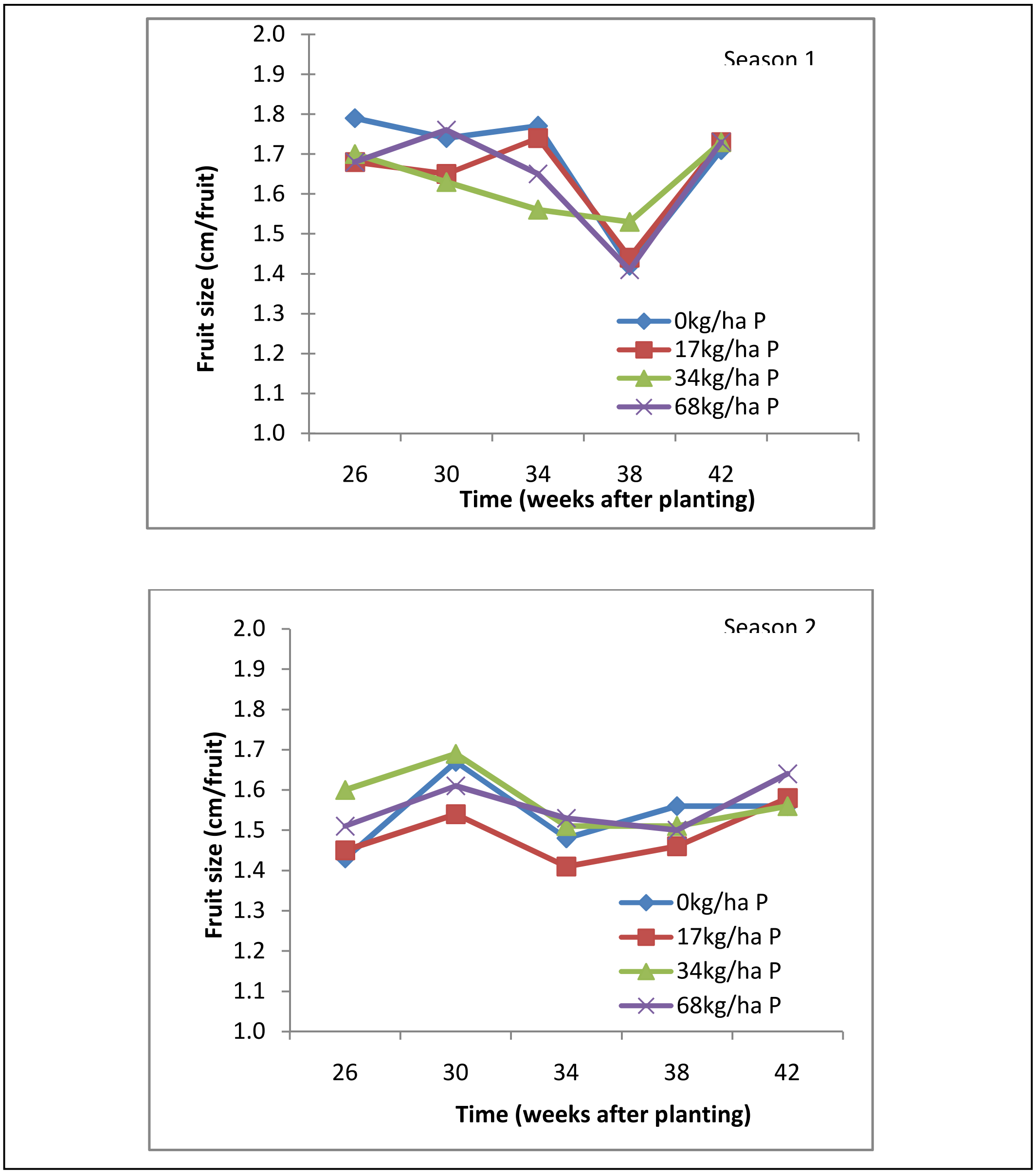

Figure 1: Effect of triple super phosphate on a fruit size for seasons 1 and 2

The effect of interaction between FYM and TSP on fruit size was significant ($P < 0.05$) in the first season (Table 4). The 0 t/ha FYM and 0 kg/ha P resulted in the largest fruits (2 cm), while 36 t/ha FYM and 17 kg/ha P produced the smallest fruits (1.3 cm). Teranishe and Barrera-Berritez (1981) reported that once a threshold is reached, further increase in fruits per plant reduces fruit size due to competition for photosynthates. This could be the reason why strawberry plants receiving low FYM and TSP also yielded large-sized berries.

Table 4: Effect of FYM and TSP on fruit size (cm/fruit)

	FYM (t/ha)				
P (kg/ha)	0	18	36	54	Means for P
0	2.0^{a*}	1.9^{abc}	1.7^{abcde}	1.3^{e}	1.7
17	1.7^{abcde}	1.7^{abcde}	1.3^{e}	1.9^{abc}	1.7
34	1.9^{abc}	1.6^{bcde}	1.5^{bcde}	1.5^{cde}	1.6
68	1.8^{abc}	1.8^{abc}	1.6^{bcde}	1.8^{abc}	1.8
Means for FYM	1.9	1.7	1.5	1.7	

**Interaction means followed by the same letter are not significantly different at P=0.05, according to the LSD test.*

4.3 Effect of FYM and TSP on Brix Index

In the second season, high FYM significantly lowered brix index at 34 WAP (Table 5). The effect was attributed to the large-size that the high FYM induced in the berries. Large berries tend to have more water content than sugar content (Faust, 1989). This is because the water in the large fleshy part dilutes out the little sugar in the small rind surface (Pritts, 1998).

Table 5: Effect of FYM on brix index (% sugar) over time. Yield, costs (in '000), and income (in '000) of strawberry cultivar Fern in response to FYM and TSP

Season 1					
	Time (weeks after planting)				
FYM (t/ha)	26	30	34	38	42
0	6.1	7.1	7.7	3.1	4.5
18	6.7	7.2	7.5	3.0	4.4
36	6.0	7.1	7.7	3.3	4.6
54	6.7	7.6	8.3	5.7	4.9
Season 2					
	Time (weeks after planting)				
FYM (t/ha)	26	30	34	38	42
0	6.8	7.1	6.0^{ab*}	6.0	7.0
18	6.6	7.4	6.3^{a}	6.1	7.3
36	6.8	7.2	5.9^{ab}	5.9	7.1
54	6.7	7.0	5.7^{b}	6.1	7.0

**Means followed by the same letter or no letter, within a column of each season are not significantly different at P=0.05, according to LSD test.*

In the present study, TSP did not have a significant effect ($P > 0.05$) on the brix index of strawberry fruits (Figure 2). All the tested TSP rates yielded brix index values that were similar within each sampling week.

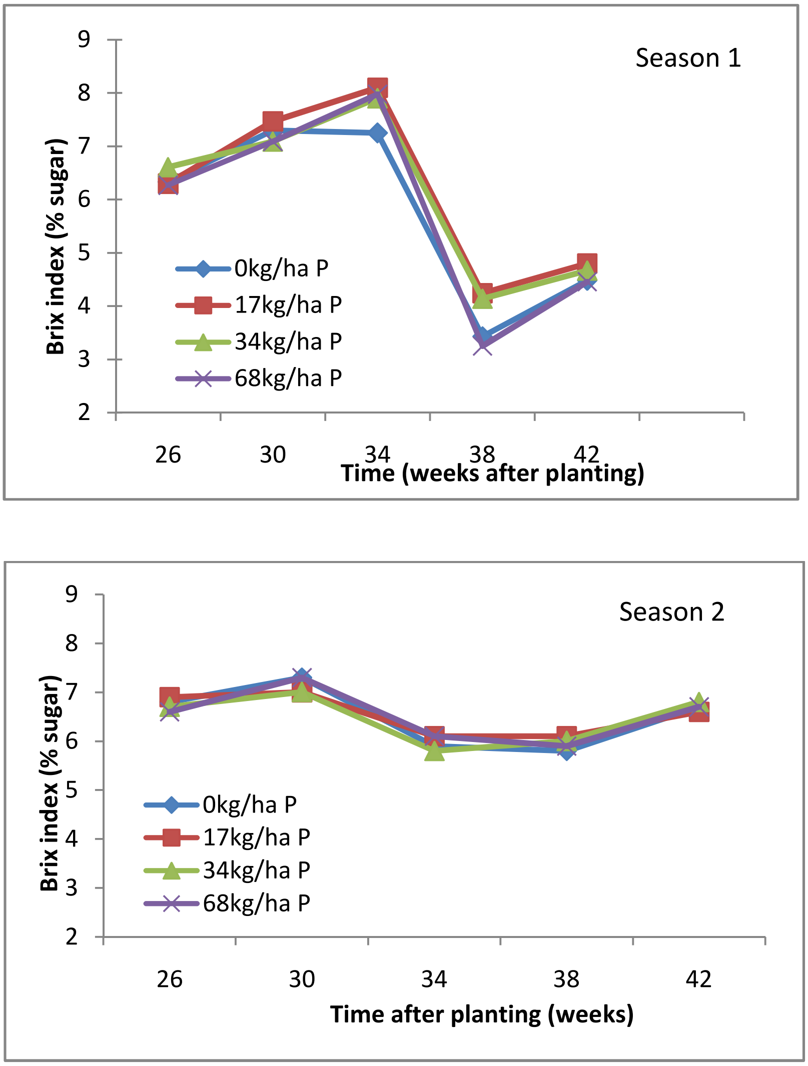

Figure 2: Effect of TSP on brix index (% sugar) for seasons 1 and 2

4.4 Effect of FYM and TSP on Storage Life of Strawberries

Manure did not significantly ($P > 0.05$) influence storage life of strawberries (Table 6). Nevertheless, all FYM levels led to over 10-days storage life, which is considered best quality (Jackson and David, 1985; Faust, 1989; Pritts, 1998).

Table 6: Effect of TSP on fruit shelf-life (days postharvest) over time

FYM (t/ha)	**Time (weeks after planting)**	
	26	34
0	11*	12
18	12	13
36	12	13
54	11	12

**Means followed by no letter within a column are not significantly different at P = 0.05, according to the LSD test.*

At 26 WAP, the 17 kg/ha P significantly ($P < 0.05$) increased fruit storage life (Table 7). This significant effect was associated with the role of P in promoting cell division, membrane development, crop maturity, and branching of roots, which are closely associated with enhanced fruit firmness and storage life (Faust, 1989; Mikkelesen, 1989; Albert *et al.,* 1995; Pritts, 1998). The effect of interaction between FYM and TSP on storage life of strawberries was not significant in both seasons ($P > 0.05$).

Table 7: Effect of FYM on fruit shelf life (days postharvest) over time

	Time (weeks after planting)	
P (kg/ha)	26	34
0	11^{b}*	12
17	13^{a}	13
34	11^{b}	12
68	11^{b}	12

**Means followed by the same letter or no letter, within a column are not significantly different at P = 0.05, according to the LSD test.*

4.5 Economic Returns (Profitability) of FYM and TSP

The effect of FYM, TSP and their interaction on profitability (net income) of strawberries was not significant ($P > 0.05$) (Table 8). Nevertheless, profitability varied across seasons and experimental plots (Table 8). Mutiro and Murwira (2004) reported that application of FYM and TSP can reduce risks of economic losses and increase financial returns. Application of other nutrients together with P has also been shown to influence strawberry productivity (May and Pritts, 1993: Pritts, 1998). However, if soil analysis shows sufficient content of a given nutrient it will be uneconomical to apply that nutrient. This fact was evident in the present study whose soil had adequate inherent K and P, making the control (0 kg/ha P) plots rank among the best treatments in terms of yield and net income (Table 7).

Table 8: Yield, costs (in '000), and income (in '000) of strawberry cultivar Fern in response to FYM and TSP

Season 1																
FYM (t/ha)	0				18				36				54			
P (kg/ha)	0	17	34	68	0	17	34	68	0	17	34	68	0	17	34	68
Yield (t/ha)	1.60	1.50	1.47	1.70	1.52	1.85	1.40	1.20	1.38	1.74	1.61	1.75	1.66	1.59	1.63	1.40
Adjusted yield (80%)	1.28	1.20	1.18	1.36	1.22	1.48	1.12	0.96	1.10	1.39	1.29	1.40	1.33	1.27	1.30	1.15
Gross income (KES)	256	240	236	272	244	296	224	192	220	278	258	280	266	254	260	230
Variable costs (KES)	57.3	57.3	57.3	57.4	64.4	64.5	64.5	64.6	71.7	71.7	71.7	71.8	78.9	78.9	78.9	79.0
Net income (KES)	198	183	179	215	180	232	160	127	150	207	186	198	187	176	182	151
Season 2																
FYM (t/ha)	0				18				36				54			
P (kg/ha)	0	17	34	68	0	17	34	68	0	17	34	68	0	17	34	68
Yield (t/ha)	2.90	2.13	2.20	2.23	1.80	1.93	2.33	3.03	1.93	1.60	2.70	1.5	2.67	2.40	2.57	2.07
Adjusted yield (80%)	2.32	1.70	1.76	1.78	1.44	1.54	1.86	2.42	1.54	1.28	2.16	1.2	2.14	1.92	2.06	1.66
Gross income (KES)	464	340	352	356	288	308	372	484	308	256	432	240	428	384	412	332
Variable costs (KES)	57.3	57.3	57.3	57.4	64.4	64.5	64.5	64.6	71.7	71.7	71.7	71.8	78.9	78.9	78.9	79.0
Net income (KES)	407	283	295	299	224	244	307	419	236	184	360	168	349	305	333	253

**Means followed by no letter, within a row are not significantly different at P=0.05, according to the LSD test.*

4.6 Conclusions and Recommendations

The present results indicate that combination of high FYM and moderate TSP can substantially increase certain quality attributes of strawberries. Significant interactive effects on fruit size of strawberries proved this fact. Triple super phosphate significantly and positively influenced fruit shelf life. Therefore, TSP is an important source of P for enhancing quality of strawberries.

Generally, FYM increased profitability more than TSP alone, while higher rates of FYM and TSP did not always result in higher economic returns for strawberries. Therefore, it is appropriate when organic and inorganic sources are used in combination to exploit their synergy and other benefits. Farmers should also develop profitable mineral nutrition packages for each strawberry variety, cultivar, soil, season and region.

Further research should be done using other sources of P apart from cattle FYM and TSP because manure quality determines the quantity to apply to attain required P concentration. Also it should be carried out with: many strawberry varieties, repeated application of these nutrient sources, replanting in sites treated with these nutrient sources, and with nutrient deficient soils, because the effect of FYM and TSP seemed to be soil-dependent. In addition, trials excluding use of any mulch that could modify the effect of applied nutrients should be undertaken. Black polythene mulch is detrimental to plant growth when temperatures are high and should not be used, especially during hot seasons.

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