EFFECTS OF INTEGRATED NUTRIENT SOURCES ON GROWTH AND YIELD OF STRAWBERRY GROWN UNDER TROPICAL HIGH ALTITUDE CONDITIONS

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ABSTRACT

Strawberries are popular both in fresh and processed forms because of their enormous values. Low soil fertility is among major factors constraining strawberry productivity in Kenya. Consequently, effects of cattle farmyard manure (FYM) (0, 18, 36, and 54t/ha) in combination with triple super phosphate (TSP), equivalent to 0, 17, 34 and 68kg/ha phosphorus on strawberry productivity, were tested in split plots embedded in randomized complete block design, replicated three times. Farmyard manure formed main plots, whereas TSP formed sub-plots. Each treatment had 10 plants spaced at 0.3m×0.45m in double rows per plot, measuring 0.6m×1.5m. The plots were mulched with black polyfilm, irrigated with 2.5.cm diameter drip lines, and separated with a 0.5m trench. The study was done in three seasons (August 2003-July 2004, Feb. 2004-Jan. 2005, and July 2005-June 2006). Each season was conducted in new plots. Growth and fruit yield were assessed from 3 to 6 and 6 to 12 month after planting, respectively. Since seasons 1 and 2 data were not significantly different they were pooled and reported as season 1, whereas the different season 3 data were reported separately as season 2. Generally, the 54t/ha FYM promoted the highest growth, although not significantly different. Phosphorus (P) significantly ($P<0.05$) increased root biomass, and root: shoot biomass ratio. The effects of FYM, P and interaction on fruit yield were not consistent. The 36 and 54t/ha FYM resulted in the highest fruit weight in seasons 1 and 2, respectively. Phosphorus did not significantly ($P>0.05$) influence fruit weight, although 17 and 34kg/ha P yielded highest in seasons 1 and 2, respectively. The effect of interaction on cumulative yield was not significant in both seasons. Thus the observed variation was also attributed to soil and seasonal effects. Based on the current results, 36 t/ha to 54t/ha FYM and 17 kg/ha to 34kg/ha P are recommended for enhancing strawberry productivity under conditions similar to the ones for the present study. Phosphorus should only be applied where soil tests show deficiency.

Key words: *Fragaria*, Fruit Yield, Manure, Phosphorus, Plant growth, Productivity, Tropical highlands

INTRODUCTION

Strawberry (*Fragaria ananassa* Duch.) is a small fruit crop and a hybrid of *F. virginiana* and *F. chiloensis*. Its species and cultivars are classified as short-day, day-neutral, or long-day and can grow well within 10^{o}C to 30^{o}C (Galletta and Himelrick, 1990). According to MacNaeidhe (2001) strawberry plants are herbaceous perennials that produce roots, leaves and flowers from the crown, which is a compressed stem. The root system is small, restricting the rooting zone and hence nutrients in the soil are boosted through optimal fertilization. Strawberry plantations remain productive for two to three years and a relatively heavy dressing of manure is needed to supply adequate nutrients over this period. Strawberry plants remove fewer nutrients from the soil than other crops. A standard population of 27,000plants/ha, removes 38kg N and 5kg P annually from the soil. However, the strawberry crop benefits from high level of soil fertility. Strawberries grow well in soils with a pH of 5 to 7 if organic matter is high (Childers, 1983; Anonymous, 2001).

Well-decomposed farmyard manure helps improve soil physical properties and fertility (Hoover et al., 2003; Brady and Weil, 1999; Tisdale et al., 1993). High doses of lime and phosphatic fertilizer are characteristically required to obtain good strawberry growth on highly acidic soils. However, addition of FYM to such soils can reduce aluminum toxicity, thus lowering lime requirement and improving phosphorus availability. Aluminum toxicity inhibits root growth through impedance of both cell elongation and division (Haynes and Mokobolate, 2001). Nutrients in FYM are released over a long period of time (Macer, 1973), making FYM a main source of nutrition for strawberry plantations for two to three years (MacNaeidhe, 2001).

Nitrogen, humus and other elements in manure stimulate leaf growth the following season, enabling the strawberry plants to support a large crop (Childers, 1983). Nitrogen is the element with profound influence on growth of strawberry plants (Campbell, 2002). It is required for growth, bud formation (Hayden, 1999), and stimulation of primary growth of absorbing roots (Faust, 1989). Adequate N increases weight of roots by 50%, leading to 200% increase in absorbing root surface. Nitrogen influences gibberellic acid (GA) synthesis, which in turn promotes cytokinin production in roots. Cytokinins translocated from roots maintain a high rate of shoot growth, and hence high GA-producing sites that promote shoot growth, but prevent flower bud formation (Marschner, 1986). Excess N suppresses root growth (Childers, 1983; Faust, 1989), through promotion of vigorous shoot growth. Although manure has higher contents of organic N and P, there is need to supplement the organic P with inorganic P.

Strawberries have both enormous nutritional and medicinal values (Maas et al. 1991). World production of strawberries increased from 2,438,000 tonnes in 1991 to 2,987,000 tonnes in 1999 (Food and Agricultural Organisation, 2001). However, yields in Kenya have been declining from 90,181kg in 1997 to 43,942kg in 2000 to 31,759kg in 2001 (Horticultural Crops Development Authority, 2002a). Mineral nutrition is one of the major constraints (Rono, 1995). Demand for increased hectarage and yield poses a great challenge to Kenyan growers (Horticultural Crops Development Authority, 2002b).

Little is documented about integrated phosphorus fertilizer and farmyard manure requirements by strawberry plants under Kenyan high altitude conditions. Information from other areas cannot apply directly because of varying soil and climatic conditions. Kenyan growers have been relying on fertilizer information from other regions, especially the USA and Europe, or on limited personal experience (Rono, 1995). Furthermore, documented data to confirm visual observations, to enable low-risk decisions to be made, is lacking. Thus, the objective of the present research was to study the effects of integrating FYM and TSP in enhancing growth and fruit yield of strawberry plants grown under high altitude conditions in Kenya.

MATERIALS AND METHODS

The research was conducted on Tatton Farm of Egerton University, Njoro, Kenya, which lies at latitude 0°23’ S, longitude 35°35’ E, and 2,238 m above sea level. The soils on the farm are well-drained, deep, friable, silty clay loam classified as haplic Phaeozem (Jaetzold and Schmidt, 1983). Mean annual rainfall is 1,000 mm, but erratic. Maximum and minimum temperatures range from 19^{o}C to 22^{o}C and 5^{o}C to 8^{o}C, respectively.

The experiment was conducted in split-plots, embedded in randomized complete block design, replicated three times. Treatments were: 0, 18, 36 or 54t/ha well-decomposed cattle FYM, assigned to main plots, while TSP equivalent to 0, 17, 34 or 68kg/ha P formed sub-plots. Main plots measured 8mx1.1m each, whereas sub-plots measured 2mx1.1m each. Ten plants spaced at 0.3mx0.45m were planted in double rows on each sub-plot.

The experiment was conducted 3 times (August 2003 to July 2004, February 2004 to January 2005 and July 2005 to April 2006) to test seasonal stability. Land was ploughed, harrowed and hand-pulverized to a fine tilth. Carbofuran (6kg/ha) was incorporated into the soil to eliminate harmful soil microorganisms. Beds were raised to a height of 0.2m and separated with 0.5m wide paths. Trenches were dug and polyethylene sheet placed underneath to prevent interference of adjacent plots through mobile nutrients.

Farmyard manure and TSP were incorporated into the soil before planting runners. Drip lines (2.5 cm diameter) used for irrigation were laid below black plastic film mulch on top of the soil.

Strawberry stock runners were obtained from the Kenya Agricultural Research Institute at Thika and propagated in plots on Tatton Farm. Before planting dead roots and leaves were pruned. The uprooted runners were kept moist until planting time. The mulch was slit open at intended planting holes where the runners were inserted into the soil. Subsequently, standard cultural practices were applied to all plots.

Soil and manure samples were analyzed at the soil testing laboratory at Egerton University. Mesurements on plants were taken on canopy diameter, runners, leaves, roots, number and weight of fruits. Canopy diameter was determined non-destructively using a metric ruler. Number of runners and leaves was counted. Canopy, runner and leaf data were recorded bi-weekly from 3 to 6 months after planting (MAP). At 3, 6 and 9 MAP, one randomly picked plant per plot was destructively sampled, washed, separated into roots and shoots that were oven-dried and weight. One fully expanded, recently matured leaf without petioles (Anonymous, 2001) was harvested from each plant in each strip plot at 6 MAP for chlorophyll analysis (Ngugi et al., 2006). Red-ripe berries were picked from 6 to 12 MAP at fortnightly intervals. The berries were counted, weight and converted to yield per hectare. Data were subjected to analysis of variance using MSTAT-C.

RESULTS AND DISCUSSION

Pre-plant and Post-plant Nutrient Analysis

Initial soil had: 5.8 pH (H_20) at 1:2.5 (soil: water), 0.24% total N, 0.21% available P, and 4.5% available K. The decomposed manure had: 8.7 pH (H_20) at 1:2.5 (soil: water), 1.33% total N, 0.63% total P, and 1.5% total K. At 6 MAP the soil had: 5.52-6.60 pH, 0.17-0.32% total N, 50-81ppm available P, and 625-1000ppm available K, depending on the treatment. Leaf tissue nutrient content ranged from 0.79-1.79% total N, 0.14-0.32% total P, and 0.14-0.30% total K, depending on the treatment.

George and Albergts (1994) reported that 3% to 3.5% total N, 0.2% to 0.4% total P, and 1.5% to 2.5% total K were sufficient and that >60ppm available P and >125ppm available K were high for strawberry productivity. These amounts could explain why the crops extracted sufficient amounts of P and K from the soil. All post-planting pH values were within a suitable range for growth of strawberry plants (Childers, 1983; Anonymous, 2001).

Effect of FYM and P on Canopy Diameter

There was no significant (*P*>0.05) effect of FYM on canopy diameter. Nevertheless, canopy spread increased over time and was highest in plots receiving 54t/ha FYM, while 0t/ha FYM resulted in the lowest canopy spread (Figure 1). The highest canopy spread was attributed to the N content that the manure supplied. Nitrogen stimulates formation of buds that subsequently develop into leaves and branch-crowns (Anonymous, 2001). Slow mineralisation of nutrients from the soil and manure could have led to the somewhat slow increase of canopy spread over time.

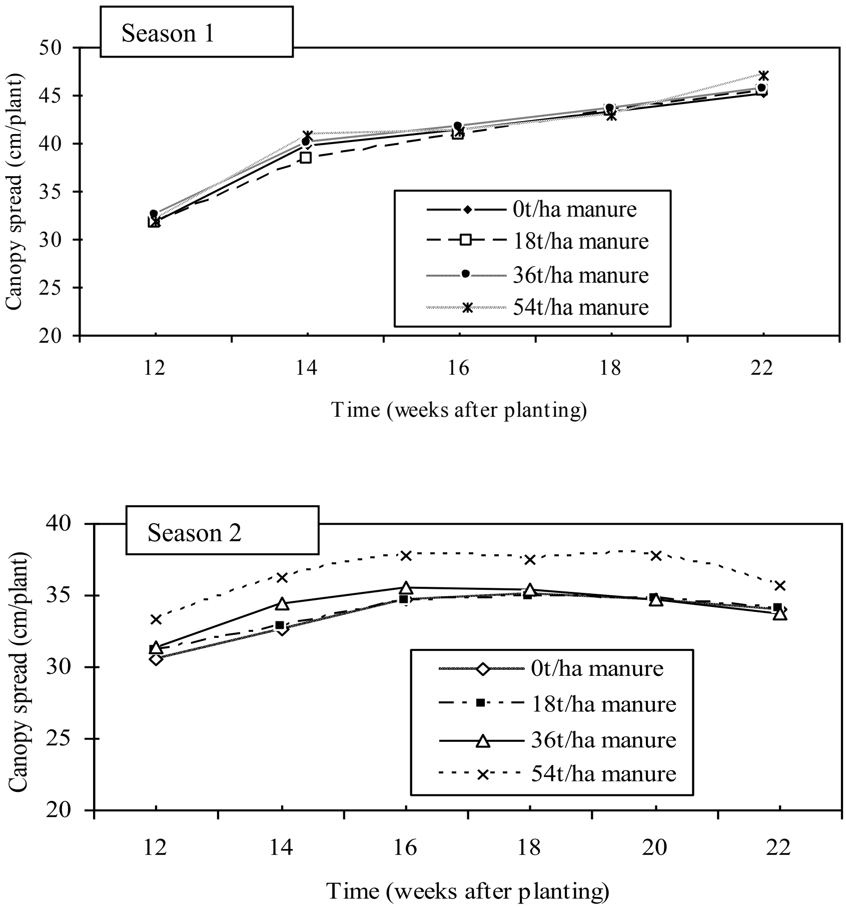
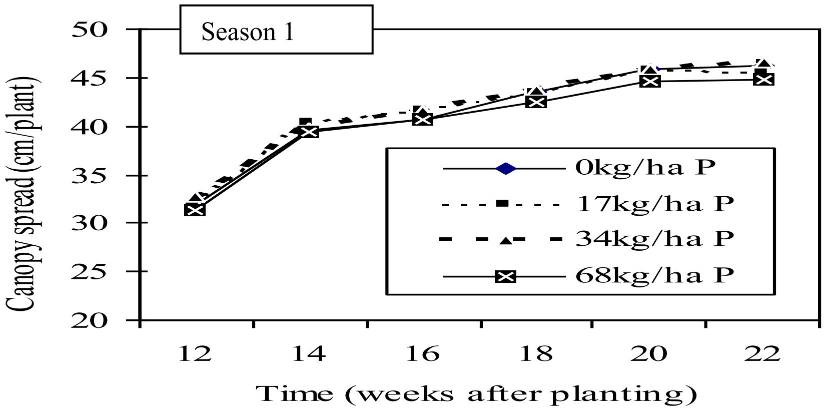


Figure 1. Effect of FYM on canopy spread

The response of canopy spread to P was not significant (*P*>0.05) (Figure 2). This result was attributed to the high P content in the soil (George and Albregts, 1994). Also, the slightly acidic condition at the study site could have led to sorption of the applied P, resulting in no difference between where P was applied and where it was not applied. Nevertheless, 34kg/ha P promoted greater canopy diameter than other doses and 68kg/ha P resulted in the lowest in season 1. In season 2, 17kg/ha P promoted greatest canopy diameter. The decrease in canopy spread in the second season after 20 WAP was attributed to leaf senescence.



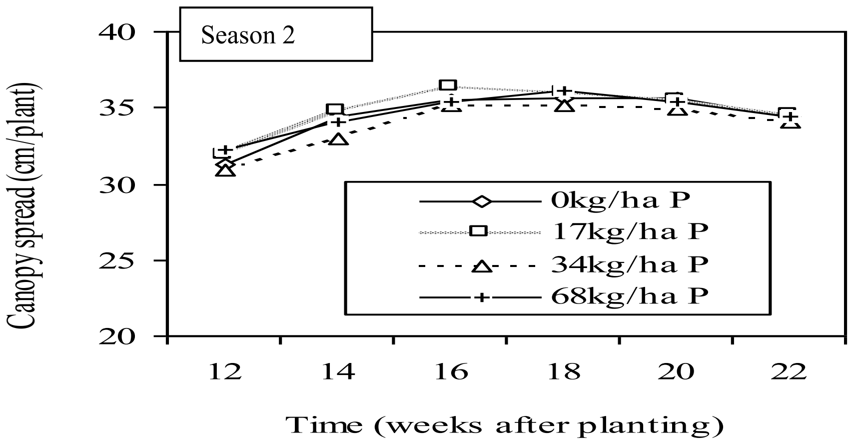


Figure 2. Effect of P on canopy spread

Effect of FYM and P on Number of Runners

The number of runners ranged from 9 to 2 early to late in season 1 (Figure 3). However, the difference among treatments was only significant ($P<0.05$) at 14 WAP in season 1. There was no significant difference among treatments in season 2 (Figure 3). There were more runners in plots receiving manure early in the season compared to later in the season. Thus the effects of manure on runners were not consistent as manure continued to mineralise over the experimental period. As the season progressed and nutrients were utilised by plants and soil fertility probably decreased fewer runners developed. Moreover, the increasing number of stronger sinks such as older leaves, fruits and crowns could have led to translocation of nutrients to them at the expense of runners (Faust, 1989). Shading also could have affected growth negatively, resulting in the control with little shading having a higher number of runners than manured plots.

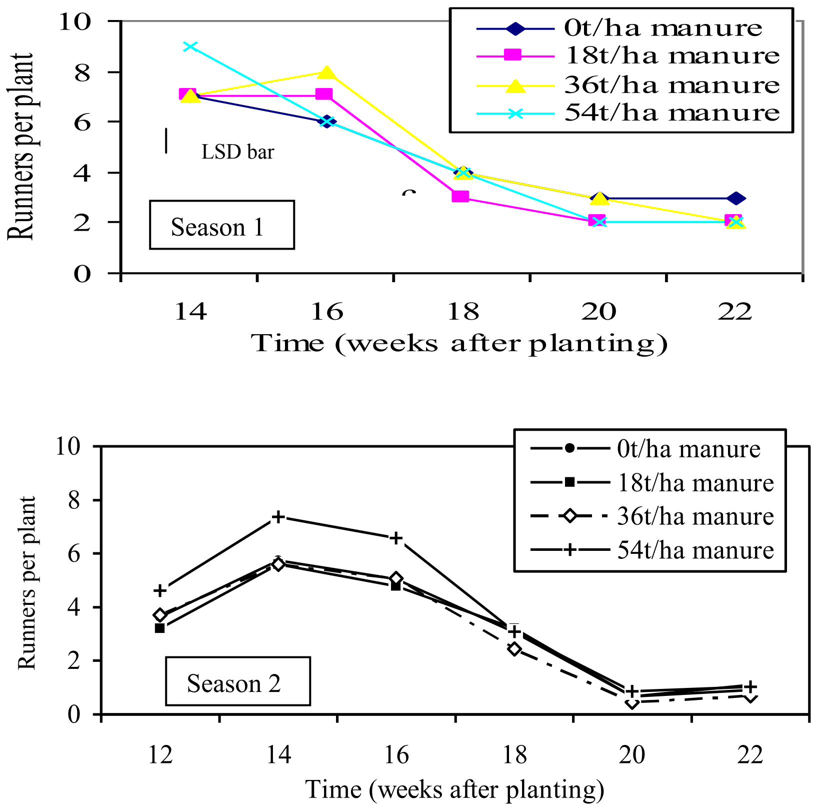


Figure 3. Effect of FYM on number of runners

The influence of P on number of runners was not significant ($P>0.05$) (Figure 4). Despite this result, the trend was that runners decreased in all treatments as the season progressed. The highest number of runners of 8 was for 34kg/ha P at 14 WAP, whereas the lowest of 2 was for 68kg/ha P at 22 WAP in season 1. The readily available P may have led to the increase in runners early in the season. Subsequent reduction could be because of reducing soil fertility, as a result of plant uptake or sorption of the applied P to soil particles. Doses of P greater than 34kg/ha could have led to nutrient imbalances, thus influencing runner growth negatively (Pritts, 1998). A similar trend was observed in season 2 where 68kg/ha P performed well at the beginning but poorly at the end of the season (Figure 4). The probable reason was plant competition at lower doses of nutrient application than at higher doses (Sharma and Ajit, 1994).

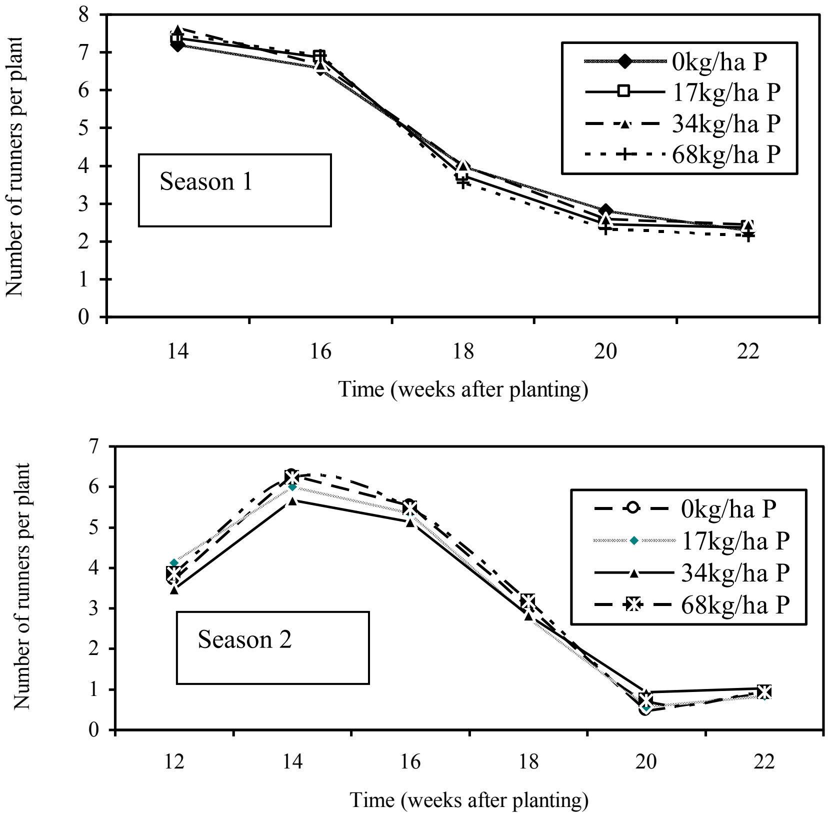


Figure 4 Effect of P on number of runners

Effect of FYM and P on Number of Leaves

The number of leaves increased with time in both seasons, but there were no significant (*P*>0.05) differences. Nevertheless, the 54t/ha FYM resulted in the highest number of leaves of 69, in contrast to the lowest 60 leaves for the 0t/ha FYM at 22 WAP in season 1 (Figure 5). In season 2, still 54t/ha FYM outperformed other FYM rates probably due to high carbon and N loading that overcame any effects of slow mineralization (Nhano et al., 2004).

Although manure adds nutrients, increases water holding capacity, infiltration and pH, and decreases soil bulk density, lack of significant differences among treatments was attributed to similar soil fertility in all the plots. Nitrogen and P are known to promote vegetative growth, but low N and P could have been due to losses during the season, leading to the small differences among treatments (Gikonyo and Simpson, 2004).

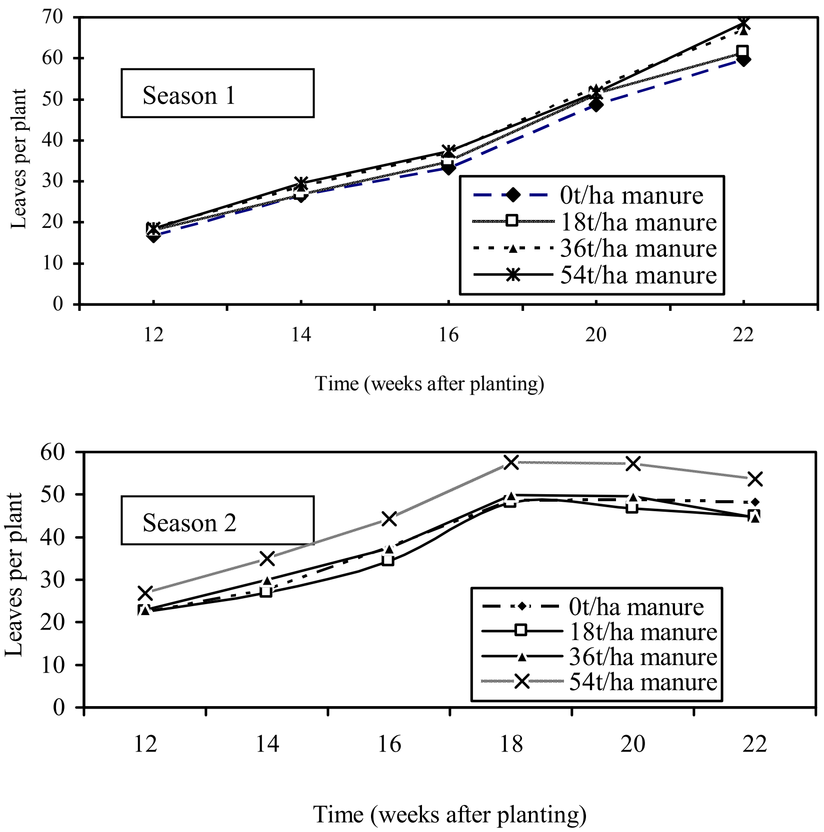
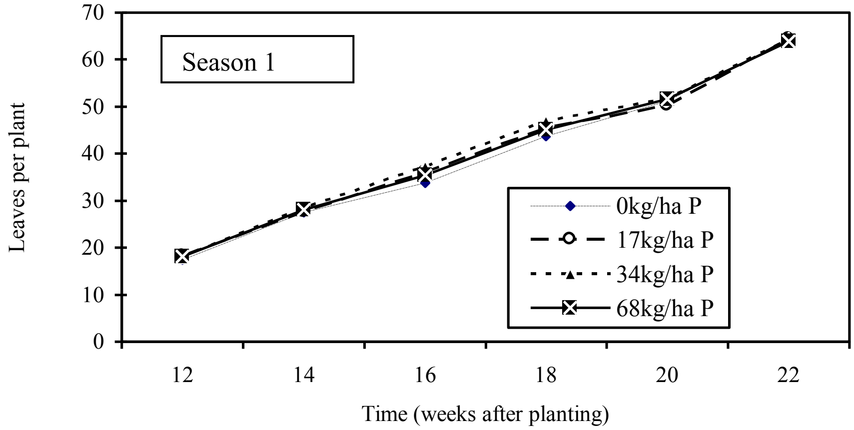


Figure 5. Effect of manure on number of leaves

There was no significant (P>0.05) difference in number of leaves amongst all the P rates throughout the two seasons (Figure 6) probably due to the slow movement of P in the soil. Plant absorption of P depends on desorption of P from the soil (Anonymous, 2001). Roberts and Jonathan (1994) reported that leaf count increased linearly with increasing P content under high N content, explaining why there was no difference in response, as N content in the strawberry soil was low. Also plants could have adapted to low P through proliferation of new roots (Marschner, 1986) that then explored larger volumes of soil to absorb nutrients.



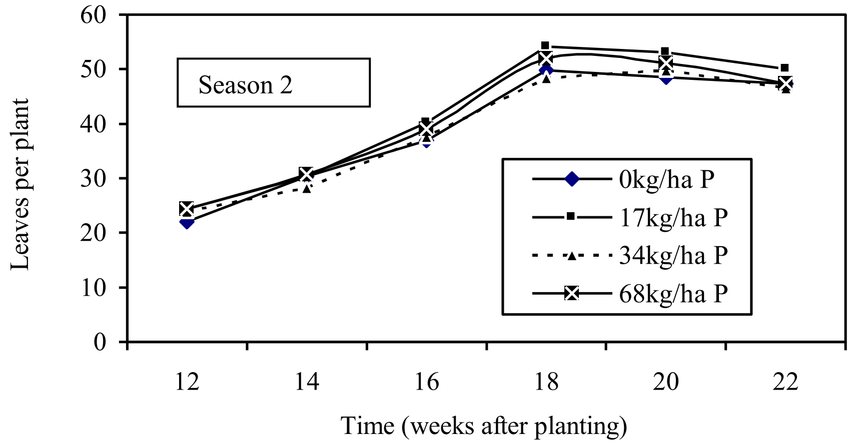


Figure 6. Effect of P on number of leaves

The effect of interaction between FYM and P on number of leaves was significant ($P<0.05$) in both seasons (Table 1) probably due to reduced P sorption capacity and increased P availability in manured soil. In addition, excess nutrients could have been bound by manure, thereby escaping loss through leaching but becoming available to plants (Ojiem et al., 2004). Sharma and Ajit (1994) reported that incorporation of manure increased P use efficiency by 26%.

Table 1. Effect of FYM and P on number of leaves per plant

Season 1					
	Farmyard manure (t/ha)				
P (kg/ha)	0	18	36	54	Mean
0	24[e*]	28[bcde]	26[cde]	33[a]	27
17	25[de]	25[de]	32[ab]	29[abcde]	28
34	29[abcde]	27[bcde]	28[abcde]	31[abc]	29
68	29[abcd]	28[bcde]	30[abcd]	25[cde]	28
Mean	27	27	29	30	
Season 2					
	Farmyard manure (t/ha)				
P (kg/ha)	0	18	36	54	Mean
0	51[bc*]	50[bc]	45[cd]	49[bc]	49
17	54[bc]	46[cd]	54[bc]	59[ab]	47
34	44[cd]	38[d]	50[bc]	67[a]	50
68	47[cd]	54[bc]	50[bc]	54[bc]	57
Mean	49	53	50	51	

*Interaction means followed by the same letter within a season are not significantly different at *P*=0.05, according to the Least Significant Difference (LSD) test.

FYM and P effects on Root & Shoot Biomass & on Root: Shoot Ratio

Phosphorus significantly ($P<0.05$) influenced root and shoot biomass at 20 WAP (Table 2) most likely through the role that phosphorus plays in enhancing cell division that then results in faster accumulation of biomass in plant organs (Marschner, 1986).

Table 2. Effect of P on root and shoot biomasses (g/plant)

P (kg/ha)	Root biomass (g/plant)			Shoot biomass (g/plant)		
	12 WAP	20 WAP*	26 WAP	12 WAP	20 WAP*	26 WAP
0	3.9	9.1[b]	14.3	17.0	32.5[b]	33.5
17	4.9	14.8[a]	17.0	18.2	50.3[a]	33.8
34	3.9	8.5[b]	16.9	16.3	35.4[b]	35.1
68	3.0	10.9[ab]	16.0	15.3	39.8[ab]	33.5

*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. WAP = weeks after planting

The effect of interaction between FYM and P on shoot biomass and on root to shoot ratio was significant (*P*<0.05) (Table 3). The combination of 36t/ha FYM and 34kg/ha P resulted in the highest shoot biomass (Table 3). This effect was attributed to the uptake of other nutrients that are important in the general growth and development of strawberry plants (Sharma and Gupta, 1994). On the other hand, 68kg/ha P in combination with 36t/ha FYM and 18t/ha FYM resulted in the highest root to shoot ratio at 12 WAP and 20 WAP, respectively (Table 3) probably due to the increased P availability and uptake that resulted in proliferation, growth and development of roots. Sharma and Gupta (1994) observed increased P utilization from the soil of 93% to 99% after application of FYM, while liming increased P utilization by 20% to 26%.

Table 3. FYM and P Effects on shoot biomass and on root to shoot ratio

Shoot biomass (g/plant)	Farmyard manure (t/ha)				
P (kg/ha)	0	18	36	54	Mean
0	13.0^{bcd*}	20.0^{abcd}	23.3^{ab}	11.7^{d}	17.0
17	19.7^{abcd}	23.0^{abc}	13.3^{bcd}	16.7^{abcd}	18.2
34	11.7^{d}	15.3^{abcd}	24.3^{a}	14.0^{abcd}	16.3
68	14.3^{abcd}	11.3^{d}	12.3^{cd}	23.0^{abc}	15.3
Mean	14.7	17.4	18.3	16.3	
Root to shoot ratio					
12 WAP	Farmyard manure (t/ha)				
P (kg/ha)	0	18	36	54	Mean
0	0.33^{abc*}	0.20^{c}	0.17^{c}	0.27^{bc}	0.24
17	0.20^{c}	0.23^{c}	0.30^{abc}	0.27^{bc}	0.25
34	0.50^{ab}	0.30^{abc}	0.20^{c}	0.13c	0.28
68	0.27^{bc}	0.53^{a}	0.27^{bc}	0.10c	0.29
Mean	0.33	0.32	0.23	0.19	
20 WAP	Farmyard manure (t/ha)				
P (kg/ha)	0	18	36	54	Mean
0	0.40^{ab*}	0.27^{cd}	0.27^{cd}	0.23^{d}	0.29
17	0.37^{abc}	0.30^{bcd}	0.27^{cd}	0.27^{cd}	0.30
34	0.20^{d}	0.20^{d}	0.37^{abc}	0.20^{d}	0.24
68	0.27^{cd}	0.23^{d}	0.43^{a}	0.23^{d}	0.29
Mean	0.31	0.25	0.33	0.23	

*Interaction means followed by the same letter within each response variable and 12 WAP or 20 WAP are not significantly different at *P*=0.05, according to the LSD test.

Effect of FYM and P on Chlorophyll Content

The response of chlorophyll to FYM was not significant ($P>0.05$), although 18t/ha FYM resulted in the highest chlorophyll content (0.65mg/L), followed by 36t/ha (0.61 mg/L), 54t/ha (0.54 mg/L) and lastly 0t/ha FYM (0.53 mg/L). The higher FYM rates may have led to vigorous growth that diluted nutrients such as iron and manganese, which are vital components of chlorophyll (Jerry and Charles, 1984). On the other hand, 0t/ha manure did not provide enough N and P for chlorophyll synthesis.

The response of chlorophyll to P was also not significant ($P>0.05$), although 17kg/ha P resulted in the highest chlorophyll content (0.61 mg/L), followed by 68kg/ha (0.59mg/L), 34kg/ha (0.58 mg/L) and lastly 0kg/ha P (0.55 mg/L). The production of more chlorophyll where P was applied could be because of the vital role that it plays in biochemical processes (Jerry and Charles, 1984). Moderate phosphorus' positive interaction with magnesium, iron and nitrogen is a plus in chlorophyll formation (Jerry and Charles, 1984). There was no significant ($P>0.05$) effect of interaction between FYM and P on chlorophyll content, although more chlorophyll (up to 0.75mg/L) was formed where moderate P and FYM were applied.

Effect of FYM and P on Fruit Weight

The effects of FYM and P on fruit weight varied over time (Tables 4 and 5). The 36t/ha and 54t/ha FYM were not the best early in the season probably by supporting vigorous vegetative growth at the expense of fruit production and weight. This was corroborated by the significant difference of fruit weight ($P<0.05$) at 46 WAP (Table 4). Later in the season their best performance was attributed to insufficient nutrients at the 0t/ha FYM level and nutrient depletion at the 18t/ha FYM level. Higher FYM rates might have increased shoot growth or total plant growth, resulting in increased flower formation and hence subsequent higher fruit yields (Ngatia et al., 2004).

Phosphorus had no significant ($P>0.05$) effect on fruit weight (Table 5), although 34kg/ha P resulted in the highest fruit weight at 30 WAP and 46 WAP in seasons 1 and 2, respectively (Table 5). The 34 kg/ha P could have led to proper development of roots that produce cytokinins and gibberellins, which are translocated to shoots to break vegetative bud dormancy and promote shoot growth (Waisel et al., 1991). The shoots then increase light interception for photosynthesis and photosynthate production (Ngatia et al., 2004) in plants that then support many fruits (sinks), which translated into higher fruit weight.

Table 4. Effect of FYM on fruit weight (metric tonnes per hectare)

Season 1	Time (weeks after planting)											
Manure (t/ha)	26	28	30	32	34	36	38	40	42	44	46	48	Tota
0	0.095	0.093	0.217	0.161	0.170	0.177	0.052	0.052	0.078	0.137	0.184ab	0.216	1.57
18	0.120	0.115	0.260	0.203	0.145	0.115	0.032	0.037	0.062	0.099	0.138b	0.171	1.49
36	0.094	0.102	0.240	0.231	0.160	0.148	0.046	0.043	0.041	0.068	0.224a	0.210	1.62
54	0.084	0.138	0.231	0.177	0.147	0.099	0.032	0.062	0.061	0.109	0.250a	0.193	1.58
Season 2	26	28	30	32	34	36	38	40	42	44	46	48	Tota
0	0.062	0.162	0.114	0.121	0.108	0.208	0.214	0.376	0.254	0.234	0.255	0.262	2.37
18	0.053	0.245	0.103	0.117	0.100	0.167	0.176	0.337	0.243	0.287	0.243	0.216	2.28
36	0.070	0.187	0.088	0.092	0.092	0.166	0.170	0.314	0.176	0.178	0.206	0.197	1.93
54	0.064	0.181	0.128	0.114	0.111	0.213	0.241	0.404	0.265	0.237	0.257	0.228	2.43

*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.

Table 5. Effect of P on fruit weight (metric tonnes per hectare)

Season 1	Time (weeks after planting)											
P (kg/ha)	26	28	30	32	34	36	38	40	42	44	46	48	Tot
0	0.089	0.105	0.227	0.221	0.137	0.105	0.028	0.056	0.073	0.096	0.198	0.195	1.5
17	0.123	0.128	0.225	0.223	0.147	0.142	0.054	0.046	0.056	0.115	0.222	0.187	1.6
34	0.080	0.118	0.268	0.171	0.237	0.121	0.041	0.042	0.048	0.092	0.167	0.213	1.5
68	0.101	0.098	0.227	0.157	0.160	0.112	0.038	0.050	0.065	0.111	0.210	0.194	1.5
Season 2	26	28	30	32	34	36	38	40	42	44	46	48	To
0	0.057	0.186	0.102	0.107	0.107	0.207	0.216	0.399	0.250	0.231	0.235	0.236	2.3
17	0.055	0.167	0.108	0.098	0.075	0.158	0.167	0.300	0.205	0.237	0.246	0.201	2.0
34	0.077	0.221	0.122	0.127	0.112	0.173	0.195	0.343	0.278	0.273	0.282	0.254	2.4
68	0.058	0.201	0.098	0.111	0.117	0.217	0.223	0.385	0.205	0.194	0.198	0.212	2.2

*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.

The effect of interaction between FYM and P on total fruit weight was not significant (*P*>0.05) in both seasons. This response was probably due to "catching up" performance by all strawberry plants.

CONCLUSIONS AND RECOMMENDATIONS

High rates of FYM slightly increased canopy diameter probably due to the N in the FYM that promotes vegetative growth. Phosphorus significantly increased the number of runners probably due to the vital role of P in cell division and membrane development.

Combined use of inorganic and organic nutrients increased strawberry vegetative and reproductive growth most likely due to increased P uptake, P use efficiency, improved soil physical properties, water holding capacity and root cation exchange capacity under FYM application.

Generally, FYM alone performed better than TSP alone probably due to the diverse nutrients that FYM provides compared to TSP that provides only P. Individually, 36t/ha to 54t/ha FYM and 17kg/ha to 34kg/ha P are recommended where nutrients are deficient. A combination of these rates is also being recommended, since TSP is unaffordable to many resource-poor farmers. Small-scale growers should exploit the synergy and other benefits of combined FYM and TSP application at moderate rates of each.

Further research recommended is testig: (1) other sources of P apart from cattle FYM and TSP; (2) many strawberry varieties, as well as nutrient deficient soils; (3) non-use of polyethylene mulch, or any mulch; (4) strawberry P use efficiency, as well as the P that is derived from fertilizer under different combinations of FYM and TSP; (4) repeated application of these nutrient sources in the same plots; (5) carryover effects through replanting in sites treated with these nutrient materials; (6) these these nutrient materials in other agroecological zones for strawberry.

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