Influence of Organic and Inorganic Sources of Fertilizer on Growth and Leaf Yield of Kale (*Brassica oleraceae* Var. *Acephala* D.C.)

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ABSTRACT

Brassica oleraceae var. *Acephala* D.C. (kale, sukuma wiki) is the most important vegetable in Kenya but its production is hampered by low soil fertility particularly Nitrogen and Phosphorus. Most small holder farmers do not utilize inorganic fertilizers and the use of organic sources alone may have higher labour requirements for its application. The use of two organic sources *Tithonia diversifolia* (Tithonia) leaves and farmyard manure and two inorganic fertilizers Diammonium Phosphate (DAP) and Calcium Ammonium Nitrate (CAN) for improved soil fertility and kale yields was investigated on nitrogen limiting soil in Western Kenya, Maseno University. An experiment was carried out twice between January 1999 and April 2000 to evaluate the effect of *Tithonia diversifolia*, farmyard manure and inorganic sources of fertilizer on growth and leaf yield of kale. The treatments included: T_1 - control, T_2 - Tithonia leaf biomass incorporated 5 tons per hectare (dry matter), T_3 - tithonia leaf biomass incorporated (4.5 tons per hectare (dry matter) in combination with Diammonium phosphate (DAP) T_4 – DAP (200kg per hectare in combination with Calcium Ammonium Nitrate (CAN) 500 kg per hectare), T_5 - Farmyard manure, 15 tons per hectare. Leaf yield was assessed by both cumulative leaf weight per given plant and leaf number, plant height was also taken. Both organic and inorganic sources of fertilizer significantly increased growth and leaf yield of kale. Tithonia leaf biomass on its own or in combination with an inorganic fertilizer gave leaf yields comparable to those applied with exclusively inorganic sources of fertilizer. With the prices of inorganic fertilizers increasing and becoming unaffordable to most farmers in Kenya, organic sources like tithonia leaves that are locally available to the farmers can be alternative sources of fertilizer to increase the yields and production of kale.

KEY WORDS: *Brassica oleraceae, Tithonia diversifolia*, inorganic fertilizers, Leaf yield, manure

1.0 INTRODUCTION

Kale or sukuma wiki (*Brassica oleraceae* var. *acephala* D.C.) belongs to the family Crucifereae, and most likely a native to eastern Mediterranean countries (Nieuwhof 1969). It is a hardy biennial with usually curly and often finely divided leaves and is glaucous green or blue green in colour with an open type of growth. The leaves ascend from the rootstock and plants do not form heads or produce edible flowers. Many types of kale are known and varieties vary in size and height, as well as in form and colour of their leaves (Ware and McCollum 1980). The collard is a form of kale that can be grown in warmer climates. Plants are intermediate in size between the dwarf and tall kales, usually have a thick, stiff main stem which is terminated by a loose head of cabbage-like leaves and the growth is more upright in habit than of dwarfed varieties in kale (Purseglove 1968).

Kales have a wide ecological adaptability and are grown in most countries of the world. In the USA kale is grown in the southern part in fall and early winter for harvest in winter and spring. Kales were first introduced in Kenya as a fodder crop by the Europeans when they settled in the Kenya Highlands, and have become increasingly important as a vegetable in most parts of Kenya. Kales are important leafy vegetables that have a high demand in Kenya (Anonymous 1998). They have become staple vegetable food amongst all categories of income groups in Kenya. Leaves of kales are eaten as green vegetables in making stews of varied kinds, and are used with other foods especially grain products. The leaves of kale and collards rank high among other vegetables within the genus *Brassica* in their nutritive value. They are rich in vitamins and minerals (Chweya 1985). Many factors may affect the growth and leaf yield of kale and collards and these include environmental, genetic and cultural factors.

Leaf yields of kale obtained by farmers in Kenya are still very low averaging 15 tons per hectare (Anonymous 1986). Leaf yields of over 60 tons per hectare have been reported under experimental conditions (Kanampiu 1987). He also reported optimal levels of nitrogen for kale to be 150 kg per hectare. The low leaf yields of kale could be attributed to several factors which include the supply of nutrients (Ahn 1993). Nitrogen (N) and phosphorus (P) have been reported to be deficient in most soils in Western Kenya (ICRAF 1996), and deliberate efforts must be made to improve soil fertility in the region. However, N is a keystone to plant growth and development and is a very important element for leafy vegetables as it has a great influence on leaf expansion through its effect on cell division and expansion (Onyango 1995). It is therefore appropriate to use N as the basis of organic and inorganic fertilizer quantification. The form of fertilizer supplied to plants has a great influence on the growth and yield of kale (Kanampiu 1987), as it affects absorption of nutrients. Ammonium ions are reported to suppress cation absorption and enhance anion absorption (Marschner 1995). Nitrate form gives a better vegetative growth and yield in leafy vegetables than ammonium form (Marschner 1995). Organic sources of fertilizers which can be used to supply N include wild or Mexican sunflower and farmyard manure.

Tithonia diversifolia (Mexican sunflower) which belongs to the family Asteraceae=Compositeae is a shrub that branches alternately and has soft succulent stems and normally grows wild in hedges, along roadsides and on wastelands or as managed hedges along external and internal boundaries of farms (Kendall and Houten 1999), hereafter refered to as tithonia. Research has shown that the shoot of this plant has high nitrogen content and may not be just another tenacious weed that proliferates around farms, but the shoot can be harvested and incorporated into the soil to replenish the soil nutrient content (Buresh and Niang 1997). The fresh leaves of tithonia contain 4%N, 0.3%P and 4%K on dry matter basis (Gachengo *et al.* 1998). This species is abundant in Western Kenya usually in untilled hedgerows around farms (Plate 1). Tithonia is a fast growing plant producing high biomass (2-6 tons dry matter per hectare per year) within a short period which decomposes rapidly. Biomass from tithonia has been used as mulch in maize and has been shown to improve crop yields in terms of size and quality of cobs (ICRAF 1996, Jama *et al.* 2000). Economic analysis carried out on the use of tithonia in maize indicated that it was highly unprofitable and this depended greatly on the maize prices (ICRAF 1996). If the physical response of higher value crops like kale to tithonia is similar to that of maize then the profitability would be higher. Over 70% of farmers studied in Western Kenya were pleased with maize yield responses and many were keen to try tithonia application on other higher value crops such as kale (ICRAF 1996). Preliminary studies in Western Bunyore indicated that, it was more profitable to use tithonia in kale than in maize (ICRAF 1996). This was due to the fact that labour requirement for tithonia collection and application is reduced due to relatively smaller plots for growing vegetables compared to maize fields (ICRAF 1996). Both organic and inorganic sources of fertilizer significantly increased yield of the edible portion of *Gynandropsis gynandra* (spiderplant) through its influence on the number of branches and plant height (Onyango *et al.* 1999). Most organic sources of fertilizer have several advantages that include residual effects, improvement of the soil structure among others. However, their major disadvantage is that they are bulky and have high labour requirement (Ahn 1993 and Marschner 1995). Agronomic and economic evaluation of cattle manure, calliandra leaf biomass and triple super phosphates as sources of P showed grain yields and net benefits were highest for manure (Jama *et al.* 1997).

The demand of kale in Kenyan urban areas is high and continuous supply is required. With increasing prices of conventional fertilizers it is important to venture into affordable and more available sources of organic manures and fertilizers. Limited research reports have shown that organic sources of fertilizer, which are locally available, could be used to increase crop production. There is very little work reported in the use of organic and inorganic sources and their combination in the production of kale. The objective of this study therefore was to evaluate the effect of *Tithonia diversifolia*, farmyard manure, DAP and CAN on growth and leaf yield of kale (*Brassica oleraceae* var *acephala* D.C.)

2.0 Materials and Methods

An experiment was set up twice between January 1999 and April 2000 at Maseno University in Western Kenya to study the effect of organic and inorganic sources of fertilizer on growth and yield of kale. First season experiment was carried out between January and June 1999, and the second season experiment between October 1999 and April 2000.

Maseno University is situated at 0°N, 12°S, 34° 25' E - 34° 47' N and lies at an altitude approximately 1500m above sea level (Jaetzold and Schmidt 1982). The area receives an annual precipitation of 1736 mm, bimodally distributed. The mean maximum temperature is 28°C. The soils are predominantly Ferrasols with a pH range of 4.5-6.5 moderately to strongly acid (Muok *et al.* 1998).

Seedlings of kale variety Georgia collards were first raised in a seedbed of 1m wide and 4m long. DAP at the recommended rate (Anonymous 1986) was uniformly applied to the seedbed and lightly mixed with soil using a rake. Seeds were sown in furrows 10 cm apart and then thinly covered with top soil. The seedbeds were kept weed free by manually uprooting the weeds. Watering was done every evening, however this was reduced two weeks before transplanting to harden the seedlings. The seedlings were transplanted 8 weeks after sowing. The experimental field was ploughed and harrowed into a fine tilth, and seedlings of uniform size were selected and transplanted into the marked fields as per the treatments. Soil sampling for analysis was done in the experimental plots a day before transplanting. The soil samples were then air dried and passed through a 2 mm sieve. The fraction which passed through the sieve was used to analyse for total N, exchangeable cations, organic carbon, available P and pH water using analytical methods according to Ahn (1973 and 1975) and Tanaka (1986) and available N was done on the fresh soils. The analysis showed that these soils were deficient in the major nutrients N and P. Results of the analysis are given in Table 1.

Table 1. Soil Chemical and Physical properties at Maseno University experimental site

Soil variable	Season 1	Season 2
pH (water)	6.30	5.30
Soil organic carbon (%)	1.24	1.24
Available P (mg/kg)	1.60	2.80
Available N(mg/kg)	0.12	0.16
Ex. K (meq/100g)	0.11	0.11
Ex. Mg (meq/100g)	0.55	0.55
Ex. Ca (meq/100g)	2.23	2.23
Ex. Al (meq/100g)	1.08	1.08
%clay	34.30	34.30
%sand	36.50	36.50
%silt	29.30	29.30

The treatments included the control and four fertilizer sources and/or combinations:

Treatments: T_1 – Control - 0 tons ha^{-1}; **T_2 – Tithonia** -5tons ha^{-1} (dry weight); **T_3 -Tithonia+DAP** -4.5 tons ha^{-1} (dry weight) + 150kg DAP ha^{-1}; **T_4 - DAP + CAN** - 200 kg DAP ha^{-1}+500 kg CAN ha^{-1}; **T_5 - Farmyard Manure** - 15 tons ha^{-1}

All the sources and their combinations given in treatments 2 to 5 provided the optimum level of N of 150 kg N per hectare (Kanampiu 1987). The experimental design was a randomized complete block design with 5 treatments and 4 replications. The plot size was 2.5 m by 1.8 m at a spacing of 30 cm by 30 cm giving a plant population of 24 plants per plot. *Tithonia diversifolia* plants growing in untilled land is shown in Plate 1. Young tender leaves were harvested and incorporated into the soil. *Tithonia diversifolia* and farmyard manure (cattle manure) were applied to the marked plots by incorporation two weeks before transplanting. It has been reported that tithonia leaves produce biochemical substances during decomposition that may retard growth of vegetables (Baruah *et al*. 1993) so to minimise this effect the leaves were incorporated in the soil two weeks before transplanting. DAP was applied at transplanting time by applying in transplanting hole and thoroughly mixing with the soil, CAN was applied four weeks after transplanting. Observations were made on plant height, leaf number, this was done every week while leaf fresh biomass was done fortnightly commencing six weeks after transplanting by randomly selecting three plants from each plot. Leaf yields were assessed by both cumulative leaf weight and leaf number per plant.

Computer package PRM3 was used to analyze the data. The means of the variates were separated using the least significant difference ($LSD_{5\%}$). Regression analysis was also done.

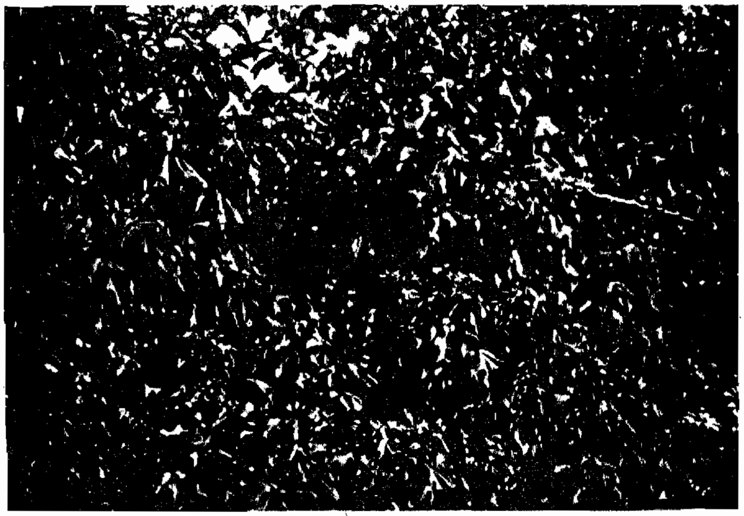


Plate 1. Tithonia plants growing in untilled land at Maseno University

3.0 RESULTS

Organic and inorganic sources of fertilizer had a significant effect on plant height in both season one ($p \leq 0.01$) and two ($p \leq 0.05$) respectively eight weeks after transplanting (Fig. 1).

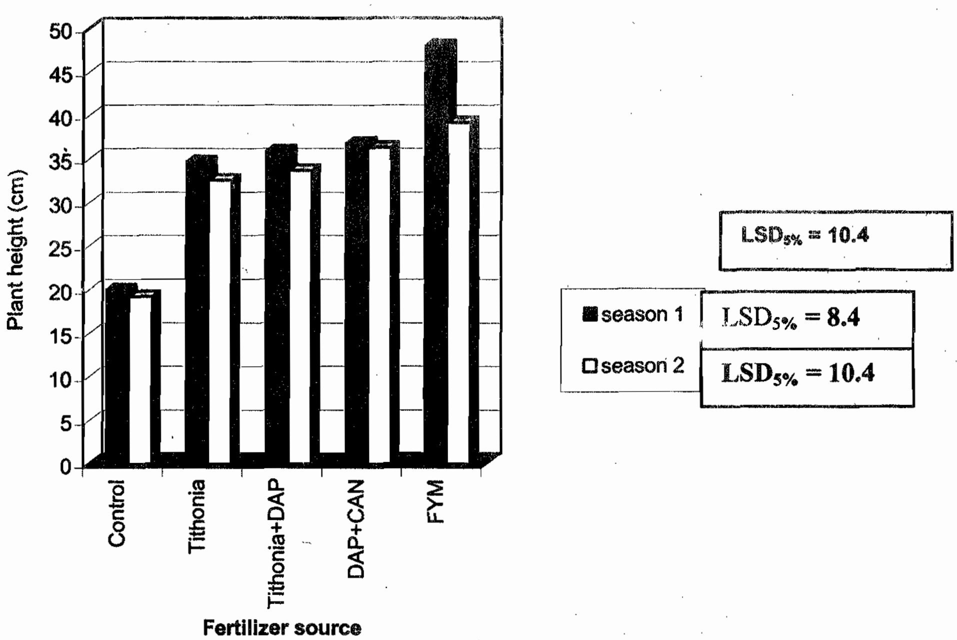
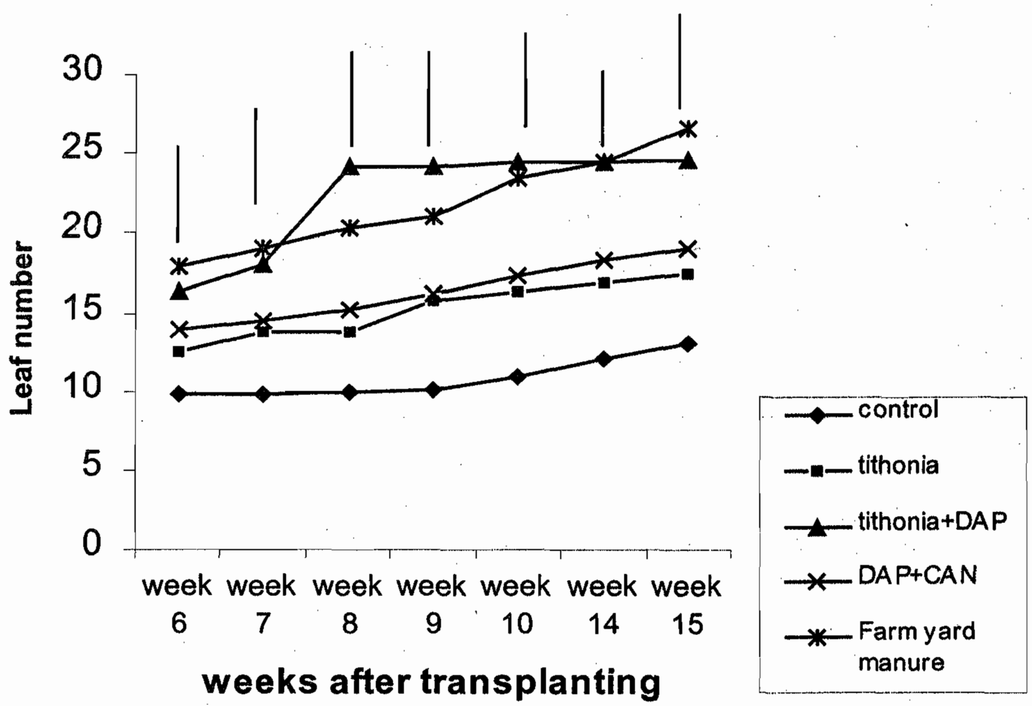


Figure 1. Effect of fertilizer source on plant height of kale 8 weeks after transplanting in season 1 and 2

During season 1, plants supplied with farmyard manure had significantly taller plants than those supplied with tithonia, tithonia + DAP, CAN + DAP (Fig. 1). In the second season plants treated with tithonia, tithonia + DAP, CAN + DAP and farmyard manure were significantly taller than the control plants (Fig. 1).

There was a gradual increase in the number of leaves per plant with time in all the treatments (Fig. 2). The effect of inorganic and organic sources of fertilizer was significant ($p \leq 0.05$) by the 6th week after transplanting (Fig. 2) when measurements commenced. Table 2 shows that the rate of leaf production as indicated by coefficients in the regression equations were lower for the control plants compared with the treated plants during season 1. The rate of leaf production for control plants was 0.3 leaves per week while that of tithonia + DAP and farmyard manure were 0.8 and 0.9 leaves per week respectively based on fully expanded leaves (Table 2).



Vertical bars represent LSD 5%

Figure 2. Effect of fertilizer source on kale leaf number

Table 2. Correlation between leaf number and weeks after sowing season 1

Nitrogen source	Regression equation	R^2
Control	y=0.35x+7.6	0.956*
Tithonia	y=0.50x+10	0.850*
Tithonia+DAP	y=0.85x+12	0.990*
DAP+CAN	y=0.55x+11	0.950*
Farmyard Manure	y=0.88x+13	0.935*

At 8 weeks after transplanting the effect of fertilizer source on leaf number in both seasons was also significant ($p \leq 0.05$). Plants treated with tithonia + DAP (season 1) and farmyard manure (season 2) had the highest leaf number at 8 weeks after transplanting (Fig. 3). There was a significant ($p \leq 0.01$) effect of organic and inorganic sources and their combination on leaf fresh weight 8 weeks after transplanting (Fig. 4).

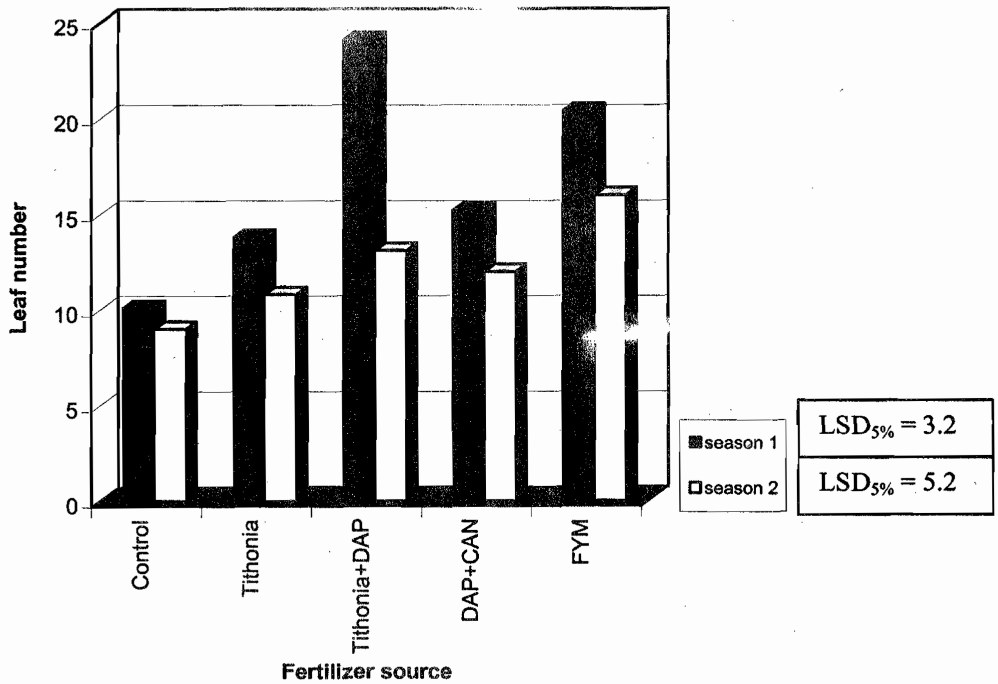


Figure 3. Effect of fertilizer source on kale leaf number per plant at 8 weeks after transplanting in season 1 and 2

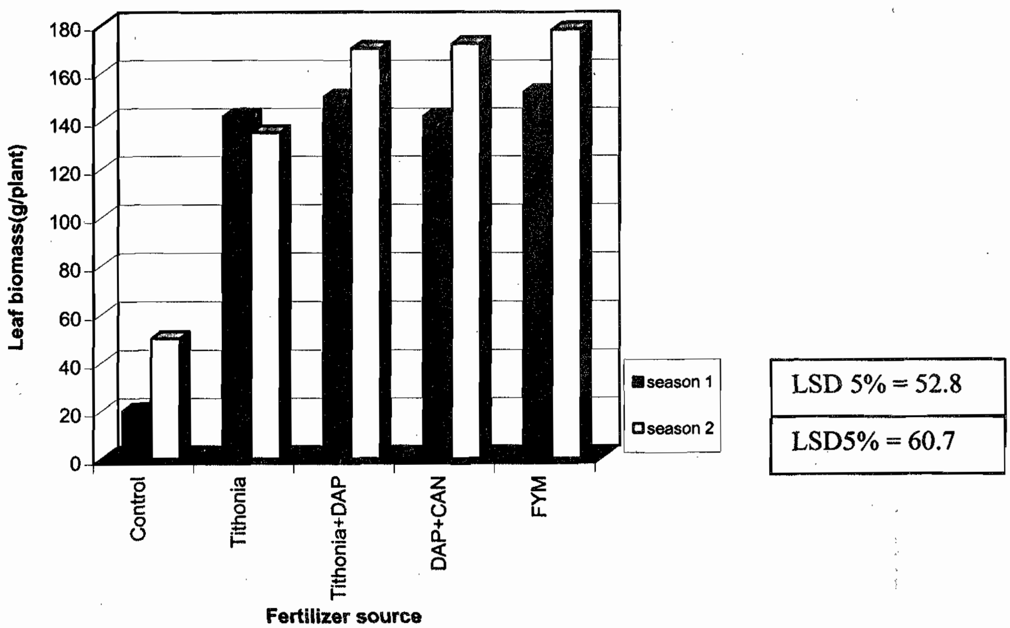


Figure 4. Effect of fertilizer source on kale leaf biomass (g/plant) at 8 weeks after transplanting in season 1 and 2

Plants applied with fertilizer had a significantly ($p \leq 0.01$) higher cumulative leaf weight than the control in both experiments tithonia leaf biomass incorporated in the soil either on its own or in combination with DAP gave leaf yields not significantly different from those applied with exclusively inorganic sources of fertilizer.

4.0 Discussion

Both organic and inorganic sources of fertilizer significantly increased leaf yield through their influence on plant height and number of leaves produced. Both the number of leaves per plant and plant height contributed to leaf yield, although leaf size may have a greater influence than leaf number. Regression analysis showed that in seasons 1 and 2, 50% ($y=6.7x+3.4$, $r^2=0.54$) and 70% ($y=16x-68$, $r^2=0.72$) of the variations in leaf fresh biomass respectively could account for changes in the number of leaves. On the other hand about 80%($y=4.8x-32$, $r^2=0.82$) and 90%($y=6.6x-78$, $r^2=0.94$) of the changes in leaf fresh biomass for seasons 1 and 2 respectively could be accounted for by changes in plant height. Leaves play a crucial role in the accumulation of assimilates by the important part they play in trapping light energy for the process of photosynthesis. The plant height may have an indirect effect on leaf growth in terms of nutrient translocation and providing adequate room for leaf expansion.

Although both organic and inorganic sources of fertilizer and their combination were used, the quantities of N provided were kept at the same level of 150 kg per hectare. Nitrogen and P are the two major macronutrients normally supplied to the plant in form of fertilizers and have been found limiting in Western Kenya (ICRAF 1996). Nitrogen was used as a reference element because it is central to the growth and development of all crop plants especially leafy vegetables (Hewitt 1966, Marschner 1995, Novoa and Loomis 1981). Nitrogen has an important role in substances like proteins and nucleic acids and is normally required in large amounts especially for vegetables, although it interacts with other essential elements (Novoa and Loomis 1981). Organic sources have the capacity to supply other nutrients to the plants in addition to the organic matter added to the soil which helps to improve soil physical and chemical properties. Nitrogen is an important element in the growth and development of plants (Hewitt 1966). The major effect of the N nutrient is the promotion of leaf growth (Marschner 1995) as observed in leaf numbers and leaf yields of the plants supplied with both organic and inorganic sources of fertilizer. Nitrogen does this through its effect on cell division and expansion (Onyango 1995). Phosphorus on the other hand is a component of certain enzymes and proteins (Jones 1998).

Organic sources of fertilizer provided more than the nutrients N and P. Most organic manures normally contain complex mineral compounds, which when broken down by soil microorganisms, provide not only a variety of nutrients but also add to the most important constituent of the soil, humus (Ahn 1993). Humus provides excellent substrate for plant growth. The kale plants applied with organic sources of manure especially farmyard manure were exceptionally healthy, taller, with more and larger leaves and hence higher leaf yields. This could be attributed to the fact that the nutrients in organic manures are released gradually through the process of mineralisation (Jones 1998) maintaining optimal soil levels over prolonged periods of time. Some of the organic substances released during mineralisation may act as chelates that help in the absorption of iron and other micro-nutrients (Salisbury and Ross 1987). The organic matter increases both the water holding capacity of the soil and soils aeration, and may even greatly increase cation exchange capacity of the soil (Ahn 1993). The improved soil properties enables the roots to grow deeper ensuring strong and thicker stems, taller plants and hence high leaf yields in plants applied with farmyard manure (ICRAF 1996). The fast rate of decomposition of tithonia leaves (Kendall and Houten 1999) providing large N and P in adequate quantities may explain the observed higher yields in tithonia treated plants.

The use of inorganic sources of fertilizers in increasing food production has been overemphasised at the expense of the organic sources of fertilizer. Although this has resulted in great increases in agricultural production it has been realised that most of these artificial fertilizers are environmentally harmful coupled with the fact that these materials are very expensive and most of our farmers cannot afford them. There are large quantities of tithonia that could be utilised as organic sources of fertilizer. Although the use of organic fertilizers is recommended it is important to note that there are problems associated with their use. Animal manures are bulky in relation to their nutrient content, and labour and expenses of transporting them often discourages their use (Ahn 1993). The wide-scale use of tithonia is likely to be limited by both supply and high labour for application to cropped fields (Jama *et* *al.* 1999). Tithonia is not a legume that can fix atmospheric N biologically, so there are concerns about its ability to provide N on a sustainable basis. These concerns and problems notwithstanding the use of tithonia and farmyard manure in kale has a potential that needs to be exploited due to their availability. The comparison made in this study between the organic and inorganic sources of fertilizer and their combination indicates that the organic sources are able to increase yields to an extent comparable to the conventional inorganic sources.

In conclusion the results of this study showed that the organic and inorganic sources of fertilizer and their combination had a significant effect on leaf yield through their effect on plant height and leaf number. There was no significant differences in leaf yield of plants applied with tithonia, tithonia + DAP, CAN + DAP and farmyard manure although their effects were significantly higher than in the controls. However, farmyard manure and tithonia on its own or in combination with DAP could be used in increasing leaf yields of kale which are comparable with the yields obtained from inorganic sources.

ACKNOWLEDGEMENT.

We acknowledge the financial support from the Institute of Research and Post Graduate Studies (IRPS), the department of Botany, Maseno University for availing the research facilities (experimental plots and laboratory) and ICRAF- Maseno Centre for doing soil analysis.

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