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GROWTH, YIELD AND QUALITY RESPONSE OF WATERMELON (C*itrullus lanatus* [THUNB] MANSF. & NAKAI) CV. CRIMSON SWEET) SUBJECTED TO DIFFERENT LEVELS OF TITHONIA MANURE

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ABSTRACT
Low soil fertility in the small-hold farms due to depletion of nitrogen and organic matter is one of the major factors contributing to the declining yield of watermelon in Kenya. A focused study was therefore carried out at the Kenya Agricultural Research Institute regional research center in the semi-arid area of Marigat in Kenya. The main objective was to investigate the effect of different rates of *Tithonia diversifolia* manure on the performance of watermelon *(Citrullus lanatus*.Thunb. (Mansf. & Nakai) cultivar 'Crimson Sweet'. *Tithonia diversifolia* manure was applied at the rates of 0 kg (0 ton ha^{-1}) 1.5 kg (1.8 ton ha^{-1}), 3.0 kg (3.6 ton ha^{-1}) and 4.5 kg (5.4 ton ha^{-1}). The treatments were arranged in a randomized complete block design. The study was conducted for two seasons in (Aug–Dec 2007 and Feb-April 2008). Application of *T. diversifolia* manure in all cases resulted in significant increase in total and marketable yield, fruit numbers, and average fruit weight, compared to the control. Total yield was increased by between 25% and 31% when tithonia was applied at 5.4 t/ha compared to the yields obtained from the untreated plots. The sweetness of watermelon fruits, as well as leaf area index and number of leaves were also enhanced under high levels of tithonia application.

Keywords: Watermelon. *Tithonia diversifolia,* manure, Brix, yield, vine length

INTRODUCTION

Watermelon (*Citrullus lanatus* [Thunb] Mansf. & Nakai) is grown in the Marigat region of Kenya as a cash crop. The area has warm temperatures of 17 to 32 ºC, friable and strongly calcerous deep clay loam soils with a pH of 6.0 to 7.5. The average annual rainfall in the area is 590 to 652 mm with 60 % reliability, distributed over two seasons. Apart from its many uses as a fruit vegetable, watermelon is an important crop with world production being 98,600,915 metric tons (2006), while the average amount of watermelon from Africa stood at 4,412,042 metric tons (FAO, 2007). Watermelon production level in Kenya has been constrained by the low soil fertility, especially low soil N and organic matter. This has led to the low total production of 6070 metric tons. The average yield of the crop under proper management is 28.4 tons ha^{-1} (FAO, 2007).

To address the declining yields, farmers have been applying inorganic fertilizers; mainly urea (46% N), but at low rates of about 28 kg N ha^{-1}, against the recommended rate of 70 kg N ha$^{-1)}$. The use of mineral fertilizers by many smallholder farmers in Kenya remains low because of socio-economic constraints such as limited availability or high costs of fertilizers and other inputs (Poudel *et al*., 1999), poor infrastructure, and poor distribution mechanisms (Huntley, *et al*., 1997).

Manures and composts can provide significant quantity of nutrients when properly used and have a persistent effect on the soil for many years. It has been documented by Addiscot et al. (1991) that annual application of manure may lead to improvement of soil fertility and reduce the risk of serious nitrate losses in drainage water. The movement towards agricultural sustainability and farming systems has revived farmer's interest in using compost and other organic sources of nutrients (Roe, 1998). Organic supplements that traditionally include green manure and farmyard manure (Biswas, *et al*., 2000), improve soil moisture in the top and sub-soil layers (Venugopalan and Tarhalkar, 2003), increase soil organic carbon (Thomsen and Christensen, 2004; Venugopalan and Tarhalkar, 2003), and soil phosphorus and/or nitrogen (Venugopalan and Tarhalkar, 2003; Alsup *et al*., 2002).

Ozores-Hampton *et al*. (2005) reported that soil organic matter; pH and P, K, Ca, and Mg concentrations in 1998 and 1999, and Zn, Mn, Fe and Cu in 1999 were higher in plots with organic amendments than in control plots. Soil organic matter was 3-fold higher in bio-solid treated plots than in non-amended plots, indicating the effects of long-term annual organic amendments application. The authors also reported that plant biomass was higher in plots with organic amendments for both pepper and watermelon in all seasons despite the fact that the amended plots received 50% less synthetic N and K application than non-amended plots. In this instance organic amendments appeared to be viable substitutes for synthetic fertilizers and provided long-term benefits to soil quality as well. Chang *et al*. (1990) showed that the rates of response to annual applications of manure were dependent on the rate of manure applied and precipitation,

but the specific rates of accumulation were similar among manure treatments with the same irrigation regime. However, inevitably large quantities of manures need to be used to provide all the macro- and micronutrients required for optimum growth and yield of crops. Apart from quantities required, manures are bulky; require high labor for collection, transportation and incorporation (Addiscot, *et al*., 1991; Sparks, 2005; Takahiro, 1991). Biswas *et al*. (2000) reported that despite the availability of traditional sources of organic nitrogen such as farmyard manure and green manure, farmers are reluctant to use these organic sources because of their associated management problems and higher costs, compared with mineral nitrogen fertilizers. In addition, incorporation of organic matter with high C/N ration may temporarily lead to N deficiency through nitrogen competition between roots and soil microbes (Takahiro, 1991).

Tithonia diversifolia commonly known as Mexican sunflower is a non nitrogen-fixing shrub of the Asteraceae family (Jama, *et al*., 2000; Buresh and Niang, 1997). The shrub is a plant common in some parts of Kenya (Savala, *et al*., 2003). Green biomass of *Tithonia* has been recognized as an effective source of nutrients for lowland rice in Asia (Jama, *et al*., 2000; Buresh and Niang, 1997), for maize in eastern and southern Africa (Jama, *et al*., 2000), and for vegetables (ICRAF, 1997; Jama, *et al*., 2000). Green leaf biomass of *Tithonia* is high in nutrients, averaging about 3.5 % N, 0.37 % P and 4.1 % K on a dry matter basis (Jama, *et al*., 2000; Buresh and Niang, 1997). Although it is not a legume, *Tithonia* accumulates large amounts of nitrogen and phosphorus from the soil and when cut and incorporated into the soil, it realises nearly all its nitrogen to the soil very quickly. *Tithonia* also acts as a natural pesticide. Application of about 5 t ha^{-1} dry matter, which supplies about 18 kg ha^{-1} P, can overcome moderate P deficiencies, but does not overcome severe P deficiency, and therefore additional P must be supplied through commercial P sources (Jama, *et al*., 2000). The use of *Tithonia* biomass is economically more attractive with high-value crops such as vegetables (Jama, *et al*., 2000).

Ayuke *et al*. (2004) and Nziguheba *et al*. (2004) reported that some of the advantages of *T. diversifolia* use are the rapid release of nutrients and the possibility of its extracts being pests repellant. Field observations suggest that application of *Tithonia* to beans can reduce yield loss caused by bean fungal root rot and on maize reduced yield loss caused by *Striga hermontheca* (Del.) (Buresh and Niang, 1997).

MATERIALS AND METHODS

Study Site

The study was conducted at Kenya Agricultural Research Institute Perkerra, located at latitude 35^{o}30'E and 0^{o}28'N and at altitude of 1065 m above sea level. The site received precipitation of 121.2 mm during the growing season (August – Dec 2007) and 430.7 mm (Feb to April 2008) with mean daily temperatures of 30.7ºC and 29.3^{o}C respectively. The soils are predominantly friable, strongly calcerous, moderately deep clay loam, dark reddish brown lithosols and cambisols with calcic xerosols. The soil at the site had a pH of 6.95, with a very low total N of 0.039 – 0.05%, and organic carbon of 0.73 – 0.97%.

Planting Material and Cultural Practices

The experimental plots were ploughed to 45 cm depth using disc ploughs, harrowed to a fine tilth before being ridged. All weeds were removed during the plots layout. At planting, Triple Super Phosphate (48% P_2O_5) and Potassium Nitrate (13%N, 46% K_2O) were applied into each plot and thoroughly mixed with the top 30 cm soil before 3 seeds per hole were placed at about 2.5 cm depth on the ridges spaced at 4 m between the ridges and 1 m between plants, giving each plant an area of 2 m^2. Each plot consisted of a single row of 5 plants spaced at 1 m between plants. Soon after planting, the first irrigation water was applied. Weeding and water application were done once every week until flowering stage when weeding frequency reduced. Spraying was done every 3 days to contain the highly destructive melon fly (*Bactrocera cucurbitae* Coquillett). To reduce sun scotching and to ensure uniform appealing skin color at harvesting the fruits were turned/rotated regularly and were also covered with dry grass during the last 3 weeks.

Experimental Material, Design and Treatments

Tithonia manure was composted from young tender stems that were harvested, chopped into small pieces, enriched with ash, and composted in polythene-aligned pits for three weeks. Chemical composition of the manure was considered and P and K were added accordingly in order to obtain similar nutrient conditions in the soil in plots receiving different treatments. To achieve this, Triple Super Phosphate and Potassium Nitrate were applied to the plots which were 4 m-wide. The plots were laid in randomized complete block experimental design replicated three times. *Tithonia diversifolia* manure was applied at the rates of 0 kg (0 ton ha^{-1}) 1.5 kg (1.8 ton ha^{-1}), 3.0 kg (3.6 ton ha^{-1}) and 4.5 kg (5.4 ton ha^{-1}).three replications.

Data Collection and Analysis

To get the total number of leaves per plant gotten by counting and averaging fully expanded leaves from three out of five plants per plot at 25, 35 and 45 days after emergence (DAE). To get the leaf area, leaf length and leaf width measurements were taken from a randomly selected 5th- leaf from the shoot tip, at 25, 35 and 45 DAE. Leaf length was measured beginning at the leaf blade-petiole intercept to the leaf tip. The width was measured at the widest leaf lobes. Individual leaf area (LA) was then calculated from leaf length and leaf width, using the equation of Young *et al.* (2007):

$$LA = -210.61 + 13.358W + 0.5356LW$$

Where; L is the leaf length
W is the leaf width.

From the LA, Leaf Area Index (LAI) was calculated as:

$$LAI = {Leaf \ldots area}/{Land \ldots area}$$

Length of main vine was measured from the soil-level to the growing tip at 15, 25, 35 and 45 DAE, while fruit number involved counting the number of fruits from three plants at 60 DAE. The first harvest was done 72 days from planting. Out of the harvested fruits, three fruits from each plot were then weighed using an electronic weighing scale (Model: Tanita KD 200-510, 5000g x 5g) to give an average fruit weight for each treatment.

Among the quality parameters measured were the total soluble solids (ºBrix). This parameter was measured using a hand-held refractometer (0-30 ºBrix) on three mature fruits from each plot from the first harvest. The average values were then used as the representative values per treatment. Fruit thickness was measured from the same fruits that the total soluble solids were measured.

The data obtained was subjected to Analysis of Variance (ANOVA) at $P \leq 0.05$ using PROC GLM (SAS version 8, 1999). Significantly different means were separated using Duncan's Multiple Range Test at 5% level of significance. The univariate procedure of SAS was used to check that the data were normally distributed before analysis.

RESULTS

Response of the various parameters measured was depended on the amount of tithonia manure applied as well as the season. The mean leaf area index of the crops grown in season one was 30% higher in the plots subjected to 3.6 t/ha of tithonia manure compared to the control. However, in season two increasing the level of tithonia did not result in observable differences in the leaf area index, except at the highest application level of 5.4 t/ha that gave reduced leaf area index compared to the treatments (Fig. 1).

Among the other growth parameters measured, vine length was not affected by tithonia application in both seasons. However, tithonia application had a significant but inconsistent effect on the number of branches per plant. While in season one the highest number of branches was observed at 3.6 t/ha, in the second season the highest number of branches of 4.0 and 4.5 were observed in the plants subjected to tithonia application rate equivalent to between 1.8 and 3.6 t/ha respectively. The largest increase of 31% in the number of branches was observed in the second season when tithonia was applied at an equivalent rate of 3.6 t/ha (Table 1). Tithonia effect on the number of leaves mirrors those observed on the number of branches. Tithonia application rate of 3.6 t/ha resulted in the highest number of leaves in both seasons compared to the control (Table 1).

Application of *T. diversifolia* at 5.4 t/ha resulted in a significant (($p \leq 0.05$)) increase of 600 fruits/ha compared to the control in both seasons. On the other hand, fruit weight was not affected in season one by tithonia application while in season two the fruits from the plots subjected to 5.4t/ha of tithonia were 21% heavier than those harvested from the control plots (Table 3).

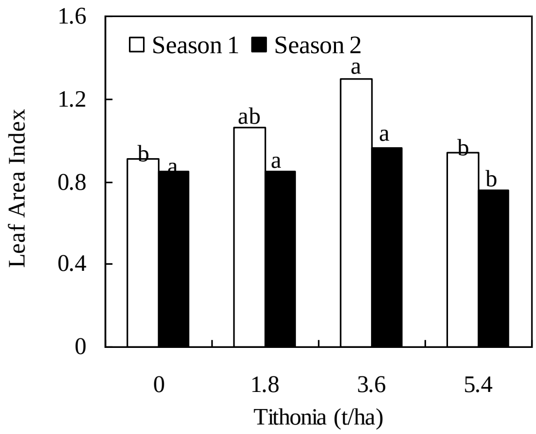

Fig.1. Changes in the leaf area index of watermelon "Crimson sweet" as affected by the application of different rates of *Tithonia diversifolia*

Table 1. Influence of *Tithonia diversifolia* manure on selected growth parameters of watermelon

	Season 1[x]			Season 2		
Tithonia (t/ha)	Number of branches	Leaf number	Vine length	Number of branches	Leaf number	Vine length
0.00	3.6b[z]	144.4b	211.5a	3.41c	163.3b	386.8a
1.80	3.9ba	153.1b	219.0a	4.16ab	170.2a	398.4a
3.60	4.1a	183.8a	217.6a	4.52a	188.2a	381.9a
5.40	3.72ba	170.0ab	214.7a	3.90bc	164.9b	369.6a

[z]Values within columns followed by the same letter are not significantly different at $P \leq 0.05$ according to Least Significant Difference (LSD). [x]Season 1 trial (August – Dec 2007), Season 2 trial (Feb to April 2008).

Table 2: Effect of tithonia manure on total and marketable yield (t/ha) of watermelon 'Crimson Sweet' Application

	Yield (t/ha)			
Tithonia manure	Season 1[x]		Season 2	
(t/ha)	Total	Marketable	Total	Marketable
0.00	19.70b[z]	17.92a	21.09b	19.11b
1.80	21.53ab	18.58a	23.43ab	21.09b
3.60	24.97ab	19.01a	24.12ab	22.14b
5.40	28.63a	22.36a	28.02a	26.35a

[z]Values within columns followed by the same letter are not significantly different at $P \leq 0.05$ according to Least Significant Difference (LSD). [x]Season 1 trial (August – Dec 2007), Season 2 trial (Feb to April 2008).

Table 3: Effect of tithonia manure on fruit number and weight of watermelon 'Crimson Sweet'

Yield (t/ha)				
Tithonia manure	Season 1[x]		Season 2	
(t/ha)	Total	Marketable	Total	Marketable
0.00	19.70b[z]	17.92a	21.09b	19.11b
1.80	21.53ab	18.58a	23.43ab	21.09b
3.60	24.97ab	19.01a	24.12ab	22.14b
5.40	28.63a	22.36a	28.02a	26.35a

[z]Values within columns followed by the same letter are not significantly different at P≤ 0.05 according to Least Significant Difference (LSD). [x]Season 1 trial (August – Dec 2007), Season 2 trial (Feb to April 2008).

Rind thickness, fruit shape as well as skin colour was not influenced by tithonia application in both years. However, the use of tithonia manure showed strongest correlation with total soluble solids ($y = 7.14 + 0.36x$, $R^2 = 0.65$). Tithonia manure applied at the rates above 3.6 tha^{-1} resulted in increased watermelon sweetness as quantified by the amount of soluble solids. The highest total soluble solids of 8.74 and 8.09 observed in fruits subjected to tithonia application rate of 5.4 tha^{-1} in season one and two respectively were significantly different from the control at P≤ 0.05 (Fig. 2). No other significant differences were observed in total soluble solids that could be attributed to the manure.

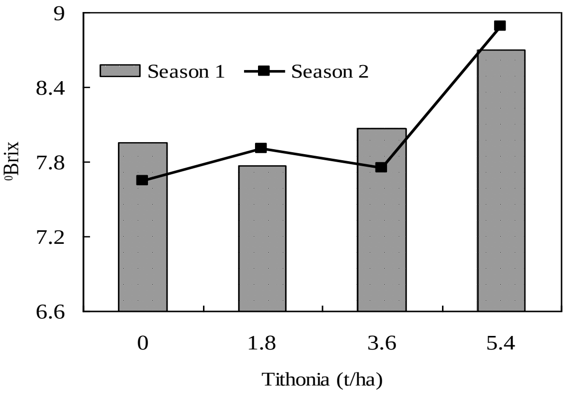

Fig 2. Effect *Tithonia diversifolia* on soluble solids (ºBrix) of watermelon "crimson sweet"

DISCUSSION

The largest increase in LAI of 30% was observed in watermelon plants subjected to 3.6t/ha in season 1 (Fig. 1). Roberts, et al. (1997) reported similar results on the relationship between watermelon foliage and fruit yield. However, the significant reduction in the leaf area index of watermelon observed when tithonia rate was applied at 5.4t/ha might be attributed to the possible slow decomposition of tithonia at high application rates and less nitrogen release to the plants by the soil microorganisms.

Besides, the key photosynthetic role, canopy cover is also important in watermelon production as foliage is necessary for shading of the fruits and reduction of sunburn. Vine cover is normally proportional to N-nutrition and this could explain the initial increase observed in LAI with increase in N supply from tithonia. The positive correlation ($R^2 = 0.92$ and 0.97) in season 1 and 2 respectively between LAI and watermelon fruit yield could be due to a possible increase in leaf area and weight, carboxylases and chlorophyll content, all of which determine the photosynthetic activity of the leaf and ultimately dry matter production and allocation to the various organs of plants. Besides, the key photosynthetic role, canopy cover is also important in watermelon production as foliage is necessary for shad.

In general, there was varied response of plant growth components to the application of *T. diversifolia* manure compared to the control. The leaf numbers and number of branches depended on the tithonia application rates. These results are in agreement with other studies (Jama, et al. 2000; ICRAF, 1997) that showed significant responses by rice, maize and vegetable crops to *T. diversifolia* manure application. The use of soil amendments such as *T. diversifolia* manure improved soil conditions particularly through replenishment of soil N and could therefore be associated with increased growth. Similar findings on effect of increasing N supply to plant growth parameters have been reported by Roberts, et al. (1997) on watermelon crop, Pholsen and Suksri, (2004) on maize and Gungula, et al. (2005) on sorghum.

Tithonia diversifolia used as green manure has been shown to increase yield of other crops such as maize in eastern and southern Africa, rice as well as vetables in Asia (Jama et al., 2000; Gachengo et al., 1998. Rashidi and Keshavarzpour (2007) reported maximum number of fruits per plant as 1.56 and a minimum value of 1.40. The low mean fruit numbers (1.22 in season 1 and 1.43 in season 2) we observed per plant was probably due to low fruit set, high incidences of melon fly attack, and the high rate of abortion noticed possibly because of limited nutrients supply. Moreover, in season 1, the pollinator bees attended less to the watermelon flowers due to the flowering sorghum, and foxtail millet in the adjacent plot.

The enhanced sweetness of watermelon fruits attributed to high levels of *Tithonia diversifolia* manure in this study was probably due to its high content of potassium (2.34 mg/kg) which is key in fruiting and fruit quality. The findings were similar to those reported by Jama, *et al.*, (2000) who found 4.1%k (on dry weight basis) in tithonia.

The research confirms the importance of tithonia in the production of watermelon in semi arid areas. Tithonia manure applied at the rates above 3.6 t/ha resulted in enhanced growth, yield and sweetness of watermelon plants. *Tithonia diversifoli* can therefore be recommended as an alternative source of nutrients for the production of watermelon.

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