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Use of cattle manure, calcium ammonium nitrate and diammonium phosphate in watermelon (*Citrullus lanatus* (Thunb.) Matsum. & Nakai) production increases fruit quality and maximize small holder farmers net returns and profits

Abstract

Watermelon (*Citrullus lanatus* (Thunb.) Matsum. & Nakai) is a high value vegetable crop that has gained importance in Kenya. Its production is constrained by low soil fertility and improper use of inorganic fertilizers leading to low yield and poor quality fruit and low incomes amongst watermelon small farmer holders. To address this problem, a study was conducted for two seasons at Kwale prison's farm, Matuga Sub-county in Kwale County to determine the effects of organic (cattle manure) and inorganic fertilizers (Calcium ammonium nitrate (CAN) and diammonium phosphate (DAP) on quality of watermelon. The study was carried out in 2014 for two seasons. The experimental design was a 4x3 factorial arrangement of treatments embedded in randomized complete block design, with three replications. The two factors were:

1) Cattle manure (0, 2.5, 5.0 and 7.5 tha^{-1}),
2) Inorganic fertilizers (three combinations of CAN and DAP) were 0, 50 and 100kgN/ P_2O_5 ha^{-1}.

The parameters studied were fruit firmness, fruit rind thickness and total soluble solids. Benefit cost ratio analysis was conducted to assess the profitability of using both organic and inorganic fertilizers. Data was collected and subjected to analysis of variance (ANOVA) and means separated by Tukey's honestly significant difference (HSD) at $p \leq 0.05$ using SAS version.[1] The results of this study showed that fruit quality was enhanced with increasing organic (cattle manure) (7.5 to 10%) and increasing level of inorganic (CAN and DAP) (1 to 3.4%) fertilizers dosage. Fruity quality and benefit cost ratio responses of watermelon to manure application were dependent on the level of supplementation with CAN and DAP. Generally, the quality of watermelon fruits and the benefit cost ratio improved with increasing level of supplementation of cattle manure with nitrogen and phosphorus. The findings suggest that cattle manure and inorganic fertilizers improve the quality of watermelon fruits and enable watermelon small holder farmers to maximize their net returns and profits.

Keywords: watermelon, organic fertilizer, inorganic fertilizer, quality, benefit cost ratio

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Introduction

Watermelon is a vegetable crop grown by small-holder farmers for both subsistence and commercial purposes in Kenya.[2] Watermelon consumption is higher than that of the other cucurbit family members.[3] Watermelon accounts for 7% of the world area devoted to vegetable production.[4,5] Several of these cultivars have been recommended for the Kenyan climate and they include Sugarbaby, Crimson Sweet, Charleston Gray, Chilean Black, Congo, Fairfax and Tom Watson.[6] However, among these cultivars, only the first three are available in Kenyan market, with Sugarbaby being the most popular because of its sugary taste, small size, earlier maturity and higher yields.[7] The average world production of watermelon is 98.6 million metric tonnes, while Africa produces 4.4 million metric tonnes.[3] It can also be used for making jams and jelly, and flavoring drinks and smoothies. The demand for watermelon in Kenya is higher than its production, resulting in the fruit being very expensive[6,7] and only affordable to the rich class. With local demand for watermelon unsatisfied, its potential for export cannot be realized even though the export market is available.[8] To meet the local demand and have some surplus for export, production of watermelon in Kenya needs to be increased.[9] One of the major challenges currently facing watermelon farmers in Kenya is poor growth and low yields due to either nutrient deficiency or excessive application of nutrients especially with nitrogen and phosphorus.[7] The current recommended fertilizers are calcium ammonium nitrate (CAN) at the rate of 80kgNha^{-1} and triple super phosphate (TSP) at the rate of 100kg $P_2O_5ha^{-1}$[8] Many farmers have however complained of excessive vegetative growth, low yield and poor quality of fruit upon use of the recommended fertilizer rates.[10] The average yield and quality of watermelon upon use of the national recommended rates in Kenya are lower compared with other countries. Most of Kenyan soils, especially in the coastal areas, are known to contain adequate amounts of potassium.[11,12] Warncke[13] reported that effective and economic nutrient management begins with an understanding of the nutrient requirements of the crops being grown and the nutrient status of the soil. The nutrient requirements of watermelon may vary with management practices and with type or cultivar.[9] Simonne et al.[14] demonstrated to the need for selecting a single target rate based on research that avoids excessive fertilizer applications that often reduce the nutrient use efficiency of a crop and increase the potential for environmental degradation. Timely and appropriate application rate of nitrogen fertilizer can make a significant difference in the quality and quantity of watermelon.[8] The fruit responds well to farmyard manure and to side-dressings of slurry.[7]

A review of soil fertility research in Kenya shows that early on thousand field trials were conducted between 1966-1986 primarily on mineral fertilizers, from which blanket recommendations were formulated. Although there is evidence that such recommendations can increase crop yields in the short-term, recent studies suggest that recommendations based on the limiting nutrients result in much higher nutrient use efficiencies than those of the blanket fertilizer recommendations.[12] Plant nutrients are usually removed from the soil through crop harvest.[15] Such nutrients will therefore require replenishment to ensure optimal plant growth. Use of organic blended with inorganic fertilizers is one of the ways of increasing nutrient status of soil and crops.[16] The fertilizers are intended to supply plant needs directly rather than indirectly through modification of such properties as soil pH and structure.[8]Use of appropriate fertilizers in the production of watermelon improves the yields and quality of fruits.[7] Although inorganic fertilizers are important sources of nutrients such as nitrogen, their use is limited by their high cost and unavailability when needed.[9] Adequate supply of nitrogen is associated with high photosynthetic rate, vigorous vegetative growth and a dark green colour of the leaves.[8] Nitrogen also increases leaf and shoot growth, number of leaves and plant weight over time.[7] Thus the processes such as protein synthesis, nucleic acid and chlorophyll synthesis are dependent on nitrogen supply.[14] Phosphorus is important in energy transfer in the plant. It also plays a role in the improvement of crop quality. Improper application of chemical fertilizers has negatively affected tropical soils.[17] On the other hand use or organic fertilizers such as cattle manure have been shown to improve growth and development of watermelon plants. Indeed, Audi et al.[18] reported that application of cattle manure and CAN either singly or in combinations resulted in significant increase in total and marketable yield, fruit numbers, and fruit weight of watermelon compared to the control (zero application). Soil tests and crop yields depict the status of the soil while nutrient balances are used as sustainability indicators. However, there has been little quantitative analysis of the potential impact of the farmers' existing soil fertility management strategies for the sustainability of farming systems over time. The study, therefore, seeks to determine the effects of rates of organic and inorganic fertilizer application on the growth and yields component of watermelon.

Materials and methods

Experimental site

The study was conducted at the Kenya prison's farm, in Matuga Sub-county in Kwale County, for two seasons (May to August, 2014- long rainy season (season one) and September to December, short rainy season (season two)). The site lies at latitude 4.16˚ South and longitudes 39.57˚East, with an altitude of approximately 420 meters above sea level. The average minimum and maximum temperatures range from 20.5˚C and 31.5˚C, respectively. The site receives an annual rainfall of 1200 mm. The soils are predominantly sandy loam (15% clay, 52% sand and 33% loam) with a pH 5.2-6.5.[19] The soil nutrients were 26.7gkg^{-1} 2.1gkg^{-1}, 0.07mgkg^{-1}, and 0.05mgkg^{-1} for C, N, P and K contents, respectively.

Planting materials

The test material used in the study was watermelon seeds cultivar 'Sugarbaby.' The seeds were dressed with a combination of fungicides (Thiram 75% WP) and insecticides (Azadirachtin) to prevent soil-borne diseases and insects attack. This cultivar was chosen because it has a good taste/flavour and it is popular in the coast region as its mature fruits have a good shelf life and is more preferred in the local markets and in the hotel industry.[5]

Experimental design and treatment application

The experimental design was a split plot factorial arrangement of treatments embedded in a randomized complete block design (RCBD) with three replications. The factors studied included: (1) organic fertilizer in the form of cattle manure at the rates of 0 (M_0), 2.5 (M_1), 5 (M_2) and 7.5 (M_3)tha^{-1}, as the main plots and (2) inorganic fertilizer in the form of DAP (at planting) and CAN (as a top dress) at the rates of 0 (NP_0), 50 (NP_1) and 100 (NP_2) kgN/ P_2O_5 ha^{-1}) as the sub plot (Figure 1). DAP and CAN are common inorganic fertilizers used during planting and top dressing, respectively. Nitrogen was applied in two equal splits as calcium ammonium nitrate (CAN, 26% N) while phosphorus was applied as diamonium phosphate (DAP, 46% P_2O_5). Phosphorus was applied at planting, by placing the fertilizer in the planting holes and thoroughly mixing with top soil. Similarly, manure was applied at planting in the planting holes. Manure tested had nutrient content of 17.3gkg^{-1}N, 52mgkg^{-1}P, 0.21mgkg^{-1}K and a pH of 5.2. The first application of CAN was done four weeks after planting, and a second one, three weeks later.

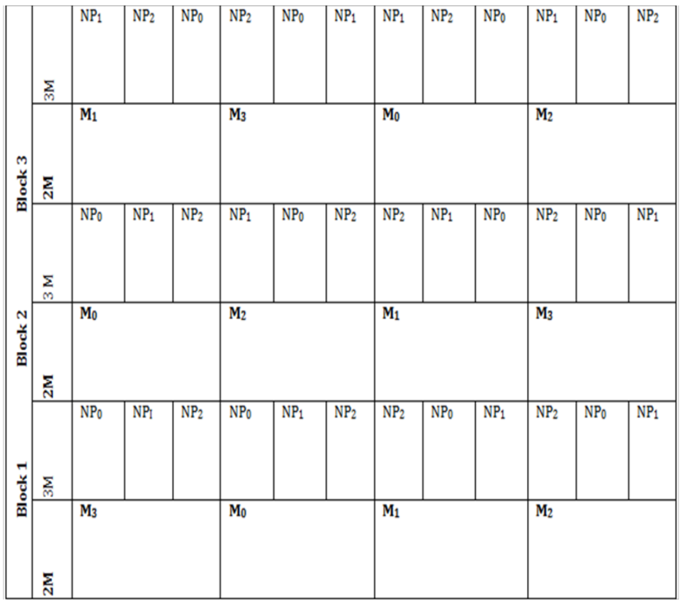

Figure 1 Experimental layout.

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Agronomic practices

Primary land preparation was done using a tractor. The land was further prepared with hand hoe to a reasonable depth and harrowed once before sowing in May 2014 and September 2014. The experimental field was then subdivided into three blocks (replications) each of which was further subdivided into 12 plots, measuring 4.5m by 4.2m each. Organic (cattle manure) and inorganic fertilizer (CAN and DAP) rates were measured using an electronic weighing balance. The amount of cattle manure applied per plant hole was 0.225kg, 0.45kg and 0.675 kg representing the rates of 2.5, 5.0 and 7.5tha^{-1}, respectively. The amount of fertilizer DAP applied per planting hole was 0, 9.78g and 19.57g translating to 0, 50 and 100kg P_2O_5ha^{-1}, while 0, 17.3g and 34.6g CAN translating to 0, 50, 100 kgN ha^{-1}, respectively. Two seeds were placed at a depth of 2.5cm per hill. A spacing of 1.5m x 0.6m was used giving a plant population of 21 plants per plot. This translated to 11,112 plants per hectare. The seedlings were thinned to one plant per hill two weeks after germination. A single row consisted of seven (7) plants spaced at 0.6m between plants. The crop was mainly rain fed but supplemental irrigation was done twice per week (in the morning and evening) during dry spells to maintain the crop. Weeding was carried out manually using hand hoe whenever it was deemed necessary, until the time the crop reached the flowering stage, after which the frequency was reduced to once per fortnight until the end of cropping season. Four weeks after sowing, the crops were sprayed three times with lamda cyahalothrin 'Karate' (insecticide) and benomyl (benlate) fungicide at the rates of 2 litres and 1.5kgha^{-1} respectively at 4, 6 and 8 weeks after planting (WAP) to contain the highly destructive melon fly (*Bactrocera cucurbitae* Conquillent). To reduce sun scotching and to ensure uniform appealing skin colour at harvesting the fruits were turned regularly and were also covered with dry grass during the last three (3) weeks.

Data collection

Rind thickness (cm)

Watermelon fruits were harvested from each of the three central watermelon plants of each treatment. Then one fruit from each of the central plant was cut cross-sectionally and a ruler was used to measure the rind thickness in centimeters. The measurements were taken from outside to inside the rind up to where the flesh begins. The three rind thickness were summed up and divided by three.

Total soluble solids (TSS)

Harvested watermelon fruits were used to determine total soluble solids (dissolved sugars) using a hand-held refractometer (0-30º brix) on three mature fruits from each treatment. A refractometer (RHB; Shangai Precision and Scientific Instrument Co., Shangai, China). The total soluble solids (dissolved sugars) were determined from the same watermelon fruits used for measuring fruit firmness. The homogenous juice was extracted by a blender and the same used for three titrations to measure total soluble solids (dissolved sugars), which were averaged to get the mean.

Fruit firmness

Watermelon fruits was harvested from each treatment then used to determine fruit firmness using hand held penetrometer (model 62/DR, UK). Fruit firmness was determined from the same watermelon fruits used for measuring fruit thickness and total soluble solids. The results were recorded in kg Force.

Economic analysis

Cost-benefit ratio was done to assess the profitability of using fertilizer as computed by Upton (1987) as shown below;

$$\text{BenefitCostRatio} = \frac{\text{Grossincome - Variablecosts}}{\text{Variablecosts}}$$

Data analysis

Data collected were subjected to analysis of variance (ANOVA) using statistical analysis software (SAS, ver. 10) and means were separated by the Turkey's honestly significant difference (HSD) at $p \leq 0.05$.

Results

Rind thickness

The results showed significant ($P \leq 0.05$) interaction effect of cattle manure and inorganic fertilizers (NP) on the watermelon fruit rind thickness in the two seasons (Table 1). While increasing manure rate from 0 to 2.5tha^{-1} **(**M0 to M1) reduced fruit rind thickness by 8.3% and 10.3% in the first and second season respectively, when no inorganic fertilizers were applied (0kgNha^{-1} and 0 kg P_2O_5ha^{-1}), the same increase in manure rate significantly ($P \leq 0.05$) reduced fruit rind thickness by 30% and 30.3% in the first and second season respectively, when inorganic fertilizers were applied at the rates of 50kgNha^{-1} and 50 kg P_2O_5ha^{-1} (N1P1). At higher inorganic fertilizer application rates (100kgNha^{-1} and 100 kg P_2O_5ha^{-1}), an increase in manure rate from 0 to 2.5tha^{-1} **(**M0 to M1) reduced fruit rind thickness by 17.3% and 16% in the first and second season respectively. Means followed by the same letter within interaction and the main effects treatments are not significantly different according to THSD at 5% level of significance. M_0, M_1 M_2 and M_3 represent organic fertilzer applied in the form of cattle manure at the rates of 0, 2.5, 5.0 and 7.5tha^{-1}, respectively. NP_0, NP_1, NP_2 represent inorganic fertilizer ai the form of DAP (applied at planting) and CAN (applied as a top dress) at the rates 0, 50 and 100 N/P_2O_5kgha^{-1}, respectively.

Table 1 Effect of manure and inorganic fertilizer (NP) on rind thickness of watermelon fruit in seasons one and two

Cattle manure	Season one				Season two			
	Inorganic fertilizer (NP)				Inorganic fertilizer (NP)			
	N0P0	N1P1	N2P2	Mean	N0P0	N1P1	N2P2	Mean
	-------------------- rind thickness (cm)-------------------------------							
M0	1.08a	1.10a	1.04a	1.07a	0.97a	0.99a	0.92a	0.96a
M1	0.99b	0.81c	0.88d	0.89b	0.87b	0.69c	0.76d	0.77b

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Table Contined

Cattle manure	Season one				Season two			
	Inorganic fertilizer (NP)				Inorganic fertilizer (NP)			
	N0P0	N1P1	N2P2	Mean	N0P0	N1P1	N2P2	Mean
	------------------- rind thickness (cm)-------------------------------							
LSD value - M		0.4				0.47		
LSD Value - NP		0.43				0.33		
LSD MxNP		0.41				0.49		
Probabilities of the test for ANVA for organic cattle manure and inorganic fertilizers								
Manure		0.0001				0.0001		
Inorganic NP		0.0001				0.0001		
M×NP		<0.0001				<0.0001		
P value		<0.0001				<.0001		
% CV		8.6				4.3		

An increase in manure rate from 2.5 to 5tha^{-1} (M1 to M2) reduced fruit rind thickness by 13% and 14.9% in the first and second season respectively, when no inorganic fertilizers were applied (0 kgNha^{-1} and 0kg P_2O_5), while the same increase in manure rate reduced fruit rind thickness by 6.1% and 7.2% in the first and second season respectively, when inorganic fertilizers were applied at the rates of 50kgNha^{-1} and 50kg P_2O_5ha^{-1} (N1P1). At higher inorganic fertilizer application rates (100kgNha^{-1} and 100kg P_2O_5ha^{-1}), an increase in manure rate from 2.5 to 5.0tha^{-1} (M1 to M2) reduced fruit rind thickness by 26% and 28.9% in the first and second season respectively.

Whereas an increase in manure rates from 5.0 to 7.5tha^{-1} (M2 to M3) reduced fruit rind thickness by 27.9% and 31% in the first and second season respectively, when no inorganic fertilizers were applied (0kgNha^{-1} and 0kg P_2O_5 ha^{-1}), the same increase in manure rate reduced fruit rind thickness by 18.4% and 20.3% in the first and second season respectively, when inorganic fertilizers were applied at the rates of 50kgNha^{-1} and 50kg P_2O_5ha^{-1} (N1P1). At higher inorganic fertilizer application rates (100kgNha^{-1} and 100kg P_2O_5ha^{-1}), an increase in manure rate from 5.0 to 7.5tha^{-1} (M1 to M2) reduced fruit rind thickness by 21.5% and 25.9% in the first and second season respectively.

Fruit firmness

The results showed significant ($P \leq 0.05$) interaction effect of cattle manure and inorganic fertilizers (NP) on the fruit firmness in the two seasons (Table 2). In both seasons, increasing manure levels from 0 to 2.5 t ha^{-1} (M0 to M1) had no effect on fruit firmness at the three inorganic fertilizer application rates of 0kgNha^{-1} and 0kg P_2O_5ha^{-1} (N0P0), 50kgNha^{-1} and 50kg P_2O_5ha^{-1} (N1P1), and 100kgNha^{-1} and 100kg P_2O_5ha^{-1} (N2P2). While increasing manure rate from 2.5 to 5.0tha^{-1} (M1 to M2) increased the fruit firmness by 25% and 26 % in the first and second seasons, respectively, when no inorganic fertilizers were applied (0kgNha^{-1} and 0kg P_2O_5ha^{-1}), the same increase in manure rate significantly ($P \leq 0.05$) increased fruit firmness by 28.6% and 26.4% in the first and second seasons, respectively, when inorganic fertilizers were applied at the rates of 50kgN ha^{-1} and 50kg P_2O_5ha^{-1} (N1P1).At higher inorganic fertilizer application rates (100kgN ha^{-1} and 100kg P_2O_5ha^{-1}), an increase in manure rate from 2.5 to 5.0tha^{-1} (M1 to M2) increased the fruit firmness by 25.4% and 31.4% in the first and second season respectively.

Table 2 Effect of manure and inorganic fertilizer (NP) on watermelon fruit firmness in the first and second season

Cattle manure	Season one				Season two			
	Inorganic fertilizer (NP)				Inorganic fertilizer (NP)			
	N0P0	N1P1	N2P2	Mean	N0P0	N1P1	N2P2	Mean
	------------------- Fruit firmness (kg f)------------------------------							
M0	7.3c	7.3c	7.3c	7.3c	7.4c	7.5c	7.4c	7.4c
M1	7.2c	7.0c	7.1c	7.1c	7.3c	7.2c	7.2c	7.2c
M2	9.0b	9.0b	8.9b	8.9ab	9.2b	9.1b	9.4a	9.1ab
M3	9.0b	9.0b	9.6a	9.4a	9.4a	9.5a	9.7a	9.6a
Means	8.3a	8.2a	8.1a		8.4a	8.3a	8.3a	
LSD value - M		0.24				0.52		
LSD Value - NP		0.26				0.37		
LSD Value - M×NP		0.47				0.53		

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Table Contined

Cattle manure	Season one				Season two			
	Inorganic fertilizer (NP)				Inorganic fertilizer (NP)			
	N0P0	N1P1	N2P2	Mean	N0P0	N1P1	N2P2	Mean
	------------------- Fruit firmness (kg f)------------------------------							
M×NP		0.0001				0.0001		
P value		<0.0001				<0.0001		
% CV		11.1				13.4		

When no inorganic fertilizers were applied (0kgNha^{-1} and 0kg P_2O_5ha^{-1}), an increase in manure rates from 5 to 7.5tha^{-1} (M2 to M3) did not affect fruit firmness in the first season, while the same increase in manure rate increased fruit firmness by 2.2% in the second season. While an increase in manure rates from 5 to 7.5tha^{-1} (M2 to M3) had no effect on fruit firmness in the first season when inorganic fertilizers were applied at rates of 50kgNha^{-1} and 50kg P_2O_5ha^{-1}(N1P1), the same increase in manure rate, under the same rates of inorganic fertilizers, increased fruit firmness by 4.4% in the second season. At higher inorganic fertilizer application rates (100kgNha^{-1} and 100 kg P_2O_5 ha^{-1}), an increase in manure rate from 5.0 to 7.5tha^{-1} (M2 to M3) increased fruit firmness by 7.9% in the first season, while the same increase in manure rate in the second season did not affect fruit firmness at inorganic fertilizer application rates of 100kgNha^{-1} and 100kg P_2O_5ha^{-1}. Means followed by the same letter within interaction and the main effects treatments are not significantly different according to THSD at 5% level of significance. M_0, M_1 M_2 and M_3 represent organic fertilzer applied in the form of cattle manure at the rates of 0, 2.5, 5.0 and 7.5tha^{-1}, respectively. NP_0, NP_1, NP_2 represent inorganic fertilizer ai the form of DAP (applied at planting) and CAN (applied as a top dress) at the rates 0, 50 and 100N/P_2O_5kgha^{-1}, respectively.

Total soluble solids

The results showed significant ($P \leq 0.05$) interaction effect of cattle manure and inorganic fertilizer (NP) on the total soluble solids (TSS) in watermelon fruits (Table 3). In the two seasons, increasing manure levels from 0 to 2.5tha^{-1} (M0 to M1) had no effect on total soluble solids at the three inorganic fertilizer application rates of 0kgN ha^{-1} and 0 kg P_2O_5ha^{-1} (N0P0), 50kgNha^{-1} and 50kg P_2O_5ha^{-1} (N1P1), and 100kgNha^{-1} and 100kg P_2O_5ha^{-1} (N2P2). Means followed by the same letter within interaction and the main effects treatments are not significantly different according to THSD at 5% level of significance. M_0, M_1 M_2 and M_3 represent organic fertilzer applied in the form of cattle manure at the rates of 0, 2.5, 5.0 and 7.5 t ha^{-1}, respectively. NP_0, NP_1, NP_2 represent inorganic fertilizer ai the form of DAP (applied at planting) and CAN (applied as a top dress) at the rates 0, 50 and 100N/P_2O_5kgha^{-1}, respectively.

While increasing manure rate from 2.5 to 5.0tha^{-1} (M1 to M2) increased total soluble solids by 25.3% and 23.2% in the first and second season, respectively, when no inorganic fertilizers were applied (0 kgNha^{-1} and 0kg P_2O_5 ha^{-1}), the same increase in manure rate increased total soluble solids by 27.4% and 23.5% in the first and second seasons, respectively, when inorganic fertilizers were applied at the rates of 50 kgNha^{-1} and 50kg P_2O_5ha^{-1} (N1P1). At higher inorganic fertilizer application rates (100kgNha^{-1} and 100kg P_2O_5ha^{-1}), an increase in manure rate from 2.5 to 5.0tha^{-1} (M1 to M2) increased total soluble solids by 24.3% and 27.2% in the first and second season respectively.

An increase in manure rates from 5.0 to 7.5tha^{-1} (M2 to M3) had no effect on the total soluble solids at the three inorganic fertilizer application levels of 0kgNha^{-1} and 0kg P_2O_5ha^{-1} (N0P0), 50kgNha^{-1} and 50kg P_2O_5ha^{-1} (N1P1), and 100kgNha^{-1} and 100kg P_2O_5ha^{-1} (N2P2) in both seasons.

Effect of manure and inorganic fertilizer (NP) on cost benefit analysis ratio for watermelon production enterprise

Results of the cost benefit analysis showed that application of cattle manure and inorganic fertilizers (NP) significantly ($P \leq 0.05$) increased cost benefit ratio in both seasons (Table 4). In the first season, the highest cost benefit ratio (6.8) was realized when either 5t manure (M2), 100kgN and 100 kg P_2O_5ha^{-1} (N2P2) or 7.5t manure (M3),50kgN and 50 kg P_2O_5ha^{-1} (N1P1) were applied. The lowest cost benefit ratio of 2.4was realized when no organic or inorganic fertilizers were applied.

In the second season, the highest cost benefit ratio (7.2) was realized when either 5.0 t manure (M2), 100 kgN and 80kg P_2O_5ha^{-1} (N2P2) or 7.5 t manure (M3),50kgN and 50kg P_2O_5ha^{-1}(N1P1) were applied (Table 5). The lowest cost benefit ratio of 2.8 was realized when no organic or inorganic fertilizers were applied.

Table 3 Effect of manure and inorganic fertilizer (NP) on Total soluble solids in watermelon production in seasons one and two

Cattle manure	Season one				Season two			
	Inorganic fertilizer (NP)				Inorganic fertilizer (NP)			
	N0P0	N1P1	N2P2	Mean	N0P0	N1P1	N2P2	Mean
	------------------- Total soluble solids (%) -------------------------							
M0	7.6b	7.6b	7.6b	7.6c	8.3b	8.4b	8.3b	8.3c
M1	7.5b	7.3b	7.4b	7.4c	8.2b	8.1b	8.1b	8.1c
M2	9.4a	9.3a	9.2a	9.3ab	10.1a	10.0a	10.3a	10.1b

Table Contined

Cattle manure	Season one				Season two			
	Inorganic fertilizer (NP)				Inorganic fertilizer (NP)			
	N0P0	N1P1	N2P2	Mean	N0P0	N1P1	N2P2	Mean
	------------------- Total soluble solids (%) -------------------------							
LSD Value - NP		0.21				0.31		
LSD Value - M×NP		0.4				0.33		
Probabilities of the test for ANOVA for organic cattle manure and inorganic fertilizers								
Manure		0.0001				0.0001		
Inorganic NP		0.0001				0.0001		
M×NP		0.0001				0.0001		
P value		<0.0001				<0.0001		
% CV		15.2				9.4		

Table 4 Effect of manure and inorganic fertilizer (NP) on cost benefit ratio for watermelon production in the first season

Manure-NP combination*	Yield (kg/ha)	Gross income (KES)**	Variable cost (KES)***	Profit (KES)	Cost benefit ratio
M0-N0P0	75000	1500000	434443	1065557	2.5
M0-N1P1	95000	1900000	453733	1446267	3.2
M0-N2P2	105000	2100000	471306	1628694	3.5
M1-N0P0	97500	1950000	442909	1507091	3.4
M1-N1P1	130000	2600000	464069	2135931	4.6
M1-N2P2	120000	2400000	478856	1921144	4
M2-N0P0	140000	2800000	454282	2345718	5.1
M2-N1P1	145000	2900000	471319	2428681	5.2
M2-N2P2	175000	3500000	450431	3049569	6.8
M3-N0P0	165000	3300000	463303	2836697	6.1
M3-N1P1	175000	3500000	450853	3049147	6.8
M3-N2P2	165000	3300000	495606	2804394	5.7

*Manure: M0 = 0tha-1, M1= 2.5tha-1, M2 = 5.0tha-1 and M3 = 7.5tha-1

N:N0 = 0kg N ha-1, N1 =50 kg N ha-1 and N2 = 100kgNha-1

P:P0 = 0kg P2O5ha-1, P1 = 50kg P2O5ha-1 and P2 = 100kg P2O5ha-1

**Unit price KES 20 per kg

***Includes cost of farm inputs

Table 5 Effect of manure and inorganic fertilizer (NP) on cost benefit ratio for watermelon production in the second season

Manure-NP combination*	Yield (kg/ha)	Gross income (KES)**	Variable cost (KES)***	Profit (KES)	Cost benefit ratio
M0-N0P0	85000	1700000	435943	1264057	2.9
M0-N1P1	105000	2100000	455053	1644947	3.6
M0-N2P2	115000	2300000	472720	1827280	3.9
M1-N0P0	107500	2150000	444243	1705757	3.8
M1-N1P1	140000	2800000	465480	2334520	5
M1-N2P2	130000	2600000	480267	2119733	4.4
M2-N0P0	150000	3000000	455693	2544307	5.6
M2-N1P1	155000	3100000	472730	2627270	5.6
M2-N2P2	185000	3700000	450433	3249567	7.2
M3-N0P0	175000	3500000	464443	3035557	6.4

Table Contined

Manure-NP combination*	Yield (kg/ha)	Gross income (KES)**	Variable cost (KES)***	Profit (KES)	Cost benefit ratio
M3-N1P1	185000	3700000	450855	3249145	7.2
M3-N2P2	175000	3500000	497017	3002983	6

Discussion

The results of the study showed that quality parameters of watermelon fruits (rind thickness, fruit firmness and total soluble solids) improved significantly ($P \leq 0.05$) with the application of cattle manure and inorganic fertilizers (NP). Application of cattle manure and inorganic fertilizers at the rates of 7.5t manure ha^{-1},100kgNha^{-1} and 100kg $P_20_5ha^{-1}$ reduced the rind thickness, increased fruit firmness and total soluble solids (dissolved sugars), compared with the control treatment. These results are in agreement with those by Aguyoh et a.[20] who observed that fertilizer application enhanced the quality of watermelon fruits due to the role played by nitrogen in the formation of starch, which is converted to sugar at the time of ripening. Gichimu et al.[21] made similar observations in Kenya following the application of compound fertilizer at different rates. Use of NPK fertilizer led to the production of sweet and firm watermelon fruits with thin rinds. Magnesium and nitrogen are integral part of the chlorophyll molecule. High level of these nutrients support the intake of potassium, and this contributes to the enhanced sweetness of watermelon fruits.[20] Nitrogen plays a great role in photosynthesis and contributes to enhanced potassium and calcium uptake that are responsible for transporting photosynthesis from source (leaves) to the sinks (fruits).[20] This enhanced transport could have led to high quality fruits which are more firm with relatively thin rinds, as observed in the current study.

Farmers invest in farming in order to realize more income and maximize their profits. The results of the study indicated that application of cattle manure and inorganic fertilizers (NP) in watermelon influenced the net returns of watermelon. The net returns increased with increased rate of supplementation of organic (cattle manure) with inorganic fertilizers (nitrogen and phosphorus). Application of nutrients to crops increases the growth rate that translates into improved yields and quality. The improved yield and quality as a result of organic and inorganic fertilizer applications led to higher profits. The results of this study concur with those observed by Gichimu et al.[21] who reported higher economic returns when compound fertilizer (NPK) was applied to watermelon than when no soil amendment was applied. The cost benefit analysis showed that application of organic (cattle manure) and inorganic fertilizers (N and P) increased cost benefit ratio in both seasons (Table 4) (Table 5). The highest cost benefit ratio (6.8 and 7.2) were realized in the first and second season, respectively, when 5.0t manure ha^{-1} was supplemented with 100kgN and 100kg $P_2O_5ha^{-1}$ (N2P2) or when 7.5t manure ha^{-1} was supplemented with 50kgN and 50kg $P_2O_5ha^{-1}$ (N1P1). This indicates that every shilling invested by a farmer in the watermelon production will yield KSh. 6.8 or 7.2 in return. These results also indicate that resource poor farmers may apply the high rate of cattle manure (7.5tha^{-1}) and supplement it with the low rates of inorganic fertilizers (50kgN and 50kg $P_2O_5ha^{-1}$). Where cattle manure is scarce, it is advisable that farmers apply the low rate of cattle manure (5tha^{-1}) and supplement it with the high rates of inorganic fertilizers (100kgN and 100kg $P_2O_5ha^{-1}$).

Conclusion and recommendations

The quality of watermelon fruits in response to manure application was dependent on the level of supplementation with inorganic fertilizers (CAN and DAP). Use of cattle manure, CAN and DAP significantly ($p \leq 0.05$) increased fruit firmness, total soluble solids (sugars) and greatly decreased fruits rids thickness. Similarly, the returns to investment in the watermelon enterprise depended on the level of combination of organic and inorganic fertilizers. Application of cattle manure and inorganic fertilizers (N and P) significantly ($P \leq 0.05$) influenced the cost-benefit ratio and net returns of watermelon. Use of cattle manure and inorganic fertilizers (NP) resulted to higher net returns on watermelon and subsequently higher profits. From the results of this study, it can be recommended that smallholder farmers in coastal Kenya apply either the high rate of manure (7.5tha^{-1}), supplemented with the low rates of inorganic fertilizers (50kgNha^{-1} and 50kg $P_2O_5ha^{-1}$) or the low rate of manure (5tha^{-1}), supplemented with the high rates of inorganic fertilizers (100kgN$ha^{-1}$and 100kg $P_2O_5ha^{-1}$).

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Conflict of interest

Authors declare that there is no conflict of interest.

References

1. SAS. SAS Users Guide: SAS/STAT. NC: SAS Inst. Inc; 2005.
2. Huh YC, Solmaz I, Sari N. Morphological characterization of Korean and Turkish watermelon germplasm. Korean Journal of Agricultural Science. 2014;41(4):309−314.
3. FAO. Crop Water management-Watermelon. *Land and Water Management Division*. 2007; 145 p.
4. Guner N, Wehner TC. The Genes of Watermelon. *Am J Hort Sci*. 2004;39(6):175–1182.
5. Goreta S, Perica S, Dumicic G, et al. Growth and yield of watermelon on polyethylene mulch with different spacings and nitrogen rates. *Am J Hort Sci*. 2005;40(2):366–369.
6. Tindall HD. Vegetables in the tropics. London: The Macmillan press Ltd; 1983:150–152.
7. HCDA. Fruits and vegetables: Horticultural Crops Development Authority Technical bulletin. 2006.
8. MOA. Fruits and vegetables. Kenya: Agricultural Resource Center; 2003. 120 p.
9. Maluki M, Ogweno J, Gesimba RM. Evaluation of nitrogen effects on yield and quality of watermelon {*Citrullus lanatus* (Thunb.) Matsumara & Nakai} grown in the coastal regions of Kenya. *Int J Plant Soil Sci*. 2016;9:1–8.
10. HCD. Horticulture validated report 2015-2016. Kenya: KNBS; 2017. 60 p.
11. Kanyanjua SM, Keter JK, Okalebo RJ, et al. Identifying potassium-deficit soils in kenya by mapping and analysis of selected Sites. *Soil Science*. 2006;171(8):610–625.
12. FURP. The fertilizer Use Recommendation Project (Phase 1). Main Report, Methodology and inventory of existing Information. Fertilizer

Trial Documentation (FERDOC). *Min of Agri.* 1988.

13. Warncke DD. Nutrient Management for Cucurbits: Melons, Pumpkin, Cucumber, and Squash. Indiana CCA: Michigan State University; 2007.

14. Simonne E, Dukes M, Hochmuth R, et al. Long-term effects of fertilization and irrigation recommendations on watermelon yield and soil-water nitrate levels in Florida's sandy soils. *Acta Hort.* 2002;627:181–186.

15. Hossain MF. Nutrients removed in harvested portion of crop by continuous corn receiving organic and inorganic fertilizers. *J Plant Sci.* 2006;1:264–272.

16. Girma T, Beyene S, Biazin B. Effect of organic and inorganic fertilizer application on soil phosphorous balance and phosphorous uptake and use efficiency of potato in Arbegona District, Southern Ethiopia. *J Fertilizers & Pesticides*. 2017;8:1–6.

17. Elmstrom GW, Fiskell JGA, Martin FG. Nutrient distribution in soil and watermelon plant uptake: effect of fertilizer timing, rate, and placement. *Soil Crop Sci Fla Proc.* 1973;32:154–158.

18. Audi W, Aguyoh JN, Gao Qiong L. Yield and quality of watermelon as affected by organic and inorganic nitrogen sources. *Asian J Agri Food Sci.* 2013;1:180–189.

19. Jaetzold R, Schmidt H, Hornetz, et al. Production Handbook of Kenya. Agricultural Information Resource Centre, Nairobi, Kenya. 2012; 250 p.

20. Aguyoh JN, Audi W, Saidi M, et al. Growth, yield and quality response of watermelon (*Citrulluslanatus [Thunb] Mansf*. &*Nakai*) Cv. crimson sweet) subjected to different levels of tithonia manure. *Int J Sci Nat.* 2010;1(1):7–11.

21. Gichimu BM, Owuor BO, Dida MM. Agronomic Performance of Three Most Popular Commercial Watermelon Cultivars in Kenya as Compared to One Newly Introduced Cultivar and One Local Landrace Grown on DystricNitisols under Sub-Humid Tropical Conditions. *ARPN J Agri Biol Sci.* 2008;3:65–71.

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