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Evaluation of Nitrogen Effects on Yield and Quality of Watermelon {*Citrullus lanatus* (Thunb.) Matsumara & Nakai} Grown in the Coastal Regions of Kenya

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Authors' contributions

This work was carried out in collaboration between all authors. Author MM designed the study, wrote the protocol and wrote the first draft of the manuscript. Author JO managed the literature searches. Author RMG managed the experimental process. All authors read and approved the final manuscript.

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ABSTRACT

Field experiment was conducted in KARI, Matuga, Kwale District in the coastal region of Kenya for two seasons to test the response of 'sugar baby' watermelon [*Citrullus lanatus* [Thumb]. Mansf.] to four levels of nitrogen (0,40,80 and 120 kgN/ha). The treatments were laid out in a randomized complete block design with three replications. Nitrogen had positive significant effect on days to flowering, sex expression ratio, number of fruits/plant, fruit weights, firmness, rind thickness, total soluble solids. Application of 80 and 120 kgN/ha increased the fruit sugar content by 23% and 28% compared with zero application. The total fruit yield was highest at 120 kgN/ha and lowest at zero application. For improved growth yield and quality of water melons in the coastal region of Kenya 120 kgN/ha was recommended.

Keywords: Watermelon; 'sugar baby'; nitrogen; growth; yield, quality.

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1. INTRODUCTION

Watermelon (*Citrullus lanatus*) is one of the most widely cultivated crops in the world [1]. Its global consumption is greater than that of any of the cucurbit family member [2]. It accounts for 6.8% of the world area devoted to vegetable production [3,4]. China is reportedly the leading country in production of watermelon followed by Turkey, United States, Iran and Republic of Korea [1]. There are over 1,200 varieties of watermelon worldwide [5] and a wide variety of watermelons have been cultivated in Africa. Several of these varieties have been recommended for Kenyan range of climate. These 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 markets with 'Sugarbaby' being the most popular because of its sugary taste, smaller size, earlier maturity and higher yields [7]. Watermelons are a good source of water in the diets of human beings, but can also be used for making jams and other preservatives including jell preparation. They are also useful in flavoring drinks and smoothies.

The demand for watermelon in Kenya is higher than production resulting in the fruit being very expensive. With local demand unsatisfied, its potential for export cannot be realized. To meet the local demand and create surplus for export, production of watermelon in Kenya needs to be increased [7]. One of the major challenges currently facing watermelon farmers in Kenya is low yields and poor quality due to heavy or low fertilization especially of nitrogen [7]. Nitrogen fertilization when applied at correct rates increases vegetative growth and hence high yields and quality [8]. The current recommended fertilizers are calcium ammonium nitrate (CAN) at the rate of 80 Kg N/ha and triple super phosphate (TSP) at the rate of 100 Kg P_2O_5/ha and 0 Kg/ha of K_2O [9]. Many farmers have, however, complained of heavy vegetative growth, low fruit yield and poor quality upon use of fertilizer rates. On the other hand, Potassium, has been tested on most Kenyan soils especially in the coastal areas, and found to be enough, thus no need for additional K fertilization [10,11]. Warncke [8] reported that effective and economic crop fertilizer management begins with an understanding its nutrient requirements and the nutrient status of the soil. Crop nutrient requirements vary and in many occasions depend on management practices and variety [12]. Because farmers have complained of low yield and quality of water melons, this research was carried out with the objective of establishing the effect of nitrogen nutrition at different levels on growth, yield and quality of watermelons in the Kenyan coastal region.

2. MATERIALS AND METHODS

2.1 Site and Materials

Field experiments were conducted at KARI, Matuga, Kwale District in the coastal regions for two seasons April to August 2012, February to June 2013. Watermelon variety 'sugar baby' was tested under four levels of nitrogen (0, 40, 80 and 120 kgN/ha). The treatments were laid out in a randomized complete block design replicated three times.

2.2 Soil Testing

Before land preparation, pre-plant soil samples were obtained from the upper soil surface layer (0 - 20 cm), after-planting soil sample were collected on each individual plot treatment bulked together to make a representative sample as per treatment using a 5 cm diameter soil auger. The soil samples were air dried for analysis to establish the initial soil N and P. About 5 gram of the air-dry soil was taken in a glass beaker and 10 ml of distilled water was added. The contents were mixed thoroughly with a glass rod and allowed to stand for 30 minutes. The soil pH was measured using EQUIP-TRONICS Digital pH meter model EQ-610. The soil samples were digested on a labcon digester at 300℃ in a mixture of hydrogen peroxide, sulphuric acid, selenium and salicylic acid [13]. The digests were analyzed for total N and P. The total N content in the digests were determined by Kjeldahl method, 10 ml of the digest solution was taken in the distillation flask, 20 ml of 40% NaOH was added and the NH_3 evolved was collected in a flask containing 4% H_3BO_3. Finally, the distillate was titrated against 0.1N H_2SO. Total phosphorous was determined using the ascorbic acid blue color procedure and the absorbance measured at 880 nm wavelength UV-spectrophotometer [13].

2.3 Plant Tissue Analysis

At 6 weeks after planting (WAP), leaf samples were collected by cutting using a sharp sterilized knife from the three central watermelon plants, oven-dried at 80ºC for 48 hours and grounded.

The mineral constituents of the plant were determined by digesting the samples on a labcon digester at 300℃ in a mixture of hydrogen peroxide, sulphuric acid, selenium and salicyclic acid [13]. The digests were analysed for total N and P. The total N content in the digests were determined by Kjeltec method using FOSS instrument as described in the ASN3201 as total Kjeldahl nitrogen (TKN). Total phosphorous was determined using the ascorbic acid blue colour procedure and the absorbance measured at 880 nm wavelength UV-spectrophotometer [13].

2.4 Culural Practices

The field was ploughed and harrowed once before planting on the flats in April 2012 and February 2013. Two seeds were planted per hill with a spacing of 1.5×0.6m. The seedlings were later thinned to one per hill two weeks after sowing to give 21 plants per sub-plot. There were three blocks each with 12 sub-plots per block. Each sub-plot measured 4×3m, and each block measured 55m x 3m separated by 3m path, 0.5m and 1m within sub-plots and main plots respectively. Nitrogen fertilizers in the form of calcium ammonium nitrates (26%N) was applied at the rates of (0.40,80 and 120 kgN/ha) was randomly applied in each of the 12 sub-plots comprising the 3 blocks as a top dress in split, first four weeks after planting then three weeks later. Two weeding were carried out manually using hand hoe at 4 and 8 week after planting respectively. Four weeks after sowing the crop was sprayed three times with lamdacyahalothrin 'Karate' (insecticide) and benomyl (benlate) fungicide at the rates of 2 liters and 1.5 kg/ha respectively at 4, 6 and 8 WAP to protect the plants against insect pests and fungal.

2.5 Data Collection and Analysis

Records for each of the 3 central watermelon plants per each sub-plot treatment were taken on the plant attributes include: days to flowering, sex-expression ratio. Ten weeks after planting (WAP) records were also taken on the following plant attributes: fruit number / plant, fruit weight [kg] / plant using a weighing balance, rind thickness [cm] using a ruler, total soluble solids by use of a refractometer using the fruits flesh near the center of the 3 central watermelon in each sub-plot and firmness using a penotrometer. Petiole analysis for N and P was done at early fruit set, fruit ½ sizes and at first harvest. The data collected for each season were subjected to Analysis of Variance (ANOVA) and mean separated using the THSD at (P = .05).

3. RESULTS

3.1 Effect of Nitrogen Levels on Yield Components and Yield of Watermelon

3.1.1 Days to flowering

Use of N fertilizer application had significant effect on the days to flowering of watermelon plants (Table 1). In both seasons, the watermelon plants with N levels applied at the rate of 120 kg N/ha had the earliest flowers to appear followed by 80 Kg N/ha and 40 Kg N/.

3.1.2 Sex expression ratio

Significant effects of N levels were observed on sex ratio of watermelon flowers (Table 1). During the first season, N applied at 120 Kg N/ha had the lowest ratio of male to female flowers an indication of more female flowers while those at 80, 40, and 0 (control) Kg N/ha had the highest sex ratios.

3.1.3 Fruit number per plant

Nitrogen had significant effect on watermelon fruit (Table 1). In both seasons, plants with N applied at the rate of 120 Kg N/ha had more fruit followed by 80 Kg N/ha, while N applied at 40 and 0 (control) Kg N/ha had the lowest number of fruit.

3.1.4 Unit fruit weight

Application of N fertilizer had significant effect on watermelon unit fruit weight (Table 1). In both seasons N applied at the rate of 120 Kg N/ha had the heaviest individual fruit followed by 80 Kg N/ha, 40 Kg N/ha while the lowest unit fruit weight was recorded under the control (0 Kg N/ha).

3.1.5 Yield (t/ha)

Application of N fertilizer had significant effect on watermelon yield (Table 2). In both seasons N applied at the rate of 120 Kg N/ha yielded more followed by 80 Kg N/ha, 40 Kg N/ha while the lowest yield was recorded under the control (0 Kg N/ha).

Table 1. Effect of nitrogen levels on yield components and yield of watermelon plants during production in season 1 (April to Aug. 2012) and 2 (Feb. to Jun. 2013)

Nitrogen levels (Kg N/ha)	Days to flowering (days)	Sex expression ratio	Fruit number (no./plant)	Unit weight (Kg)	Fruit weight (Kg/plant)
		a. Season one			
0	33.8 a*	7.52 a*	1.00 c*	1.44 d*	15.95 d*
40	31.8 b	6.41 a	1.07 c	2.06 c	22.93 c
80	29.6 c	6.48 a	1.59 b	2.45 b	27.19 b
120	28.4 d	4.07 b	4.17 a	2.82 a	31.31 a
		b. Season two			
0	33.0 a	9.91	1.78 c	1.61 d	17.89 d
40	31.1 b	10.10	2.11 c	2.17 c	24.06 c
80	29.2 c	8.47	2.85 b	2.64 b	29.42 b
120	27.9 d	4.65	4.92 a	3.01 a	33.41 a

**Means with no letter or followed by the same letter within a column and a season are not significantly different (P = .05) according to the Tukey's honestly significance difference*

3.2 Effect of Nitrogen Levels on Fruit Quality at Harvest of Watermelon

3.2.1 Rind thickness

Application of N fertilizer had significant effect on watermelon rind thickness (Table 2). In both seasons, watermelon plants with N applied at the rate of 120 Kg N/ha had fruits with thin rinds followed by 80 Kg N/ha, 40 Kg N/ha while fruit with the thickest rind was recorded under the control (0 Kg N/ha).

3.2.2 Total soluble solids

Use of N fertilizer had significant effect on total soluble solids (TSS) of watermelon fruits (Table 2). In both seasons, watermelon fruits with N applied at the rate of 120 Kg N/ha had the highest TSS followed by 80 Kg N/ha, 40 Kg N/ha while fruits under the control the lowest TSS (0 Kg N/ha).

3.2.3 Fruit firmness

Applying N and P fertilizer had significant effect on watermelon fruit firmness (Table 2). In both seasons, watermelon fruits with N applied at the rate of 120 Kg N/ha were more firm followed by 80 Kg N/ha, 40 Kg N/ha while fruits under the control were the least firm (0 Kg N/ha).

3.3 Soil Nutrition Status and Tissue Phosphorous Content

The soil and tissue phosphorous content was lower (Tables 3 and 4) than what is considered as ideal (Table 5). The Soil was slightly acidic (Table 3).

3.4 Effect of Nitrogen Levels on Tissue Analysis of Watermelon

The results from watermelon leaf petiole analysis on total nitrogen indicated that higher nitrogen was observed at 40 Kg N/ha and lowest at 0 Kg N/ha in both seasons (Table 6). In general, nitrogen content on watermelon leaves increased with the increasing levels of nitrogen.

4. DISCUSSION

Since it was apparent that the soil was nitrogen deficient and nitrogen application significantly improved watermelon yield components and yield. Nitrogen is known to promote vegetative growth [14]. More leaves translate to better chlorophyll development and higher stomatal conductance hence enhanced photosynthesis. This therefore leads to more photosynthates being manufactured. It is therefore possible that more photosynthates were translocated to the sinks leading to earlier maturity of watermelon fruits, more and heavier fruits subsequently leading to higher yield. The watermelon sex ratio significantly increased with increase in nitrogen up to a point (more than 80 Kgs N/Ha) when further increase led to a reduction. This is in agreement to the findings from Emilson et al. [15] who found out that cucumber grown in increasing levels of nitrogen fertilizers lead to a significant decrease in their sex ratio signifying an increase in female flowers. The decreasing sex ratio leads to a greater potential fruit yield because of the increase in the number of female flowers per plant which develops into fruits.

Furthermore these results are corroborated by the findings of Agba and Enya [16] who recorded higher cucumber yield when nitrogen was applied at the rate of 180 Kg N/ha compared to the control, and with those of Waseem et al. [17] who reported that high dose of nitrogen (100 kg Nha^{-1}) fertilizer significantly maximizes cucumber fruit length, and vine length. In addition, Ahmed et al. [18] and Jiilani et al. [19] reported that an increase in nitrogen application resulted in maximum cucumber and brinjal fruit length and width respectively. The least yield from the control could be attributed to possible depletion of nitrogen from the soil. Whereas the higher yields results can be attributed to the role of nitrogen in creating plant fresh, dry matter and energy-rich compounds which regulates photosynthesis [20].

Table 2. Effect of Nitrogen Levels on fruit quality during Watermelon Production in Season 1 (April to Aug. 2012) and 2 (Feb. to Jun. 2013)

Nitrogen levels (Kg N/ha)	Rind thickness (cm)	TSS (%)	Firmness (KgF)
	a. Season one		
0	0.95 a*	8.9 d*	3.5 d*
40	0.84 b	10.6 c	5.1 c
80	0.65 c	11.4 b	6.8 b
120	0.45 d	12.4 a	8.4 a
	b. Season two		
0	1.05 a	9.1 d	3.7 d
40	0.93 b	10.8 c	5.3 c
80	0.75 c	11.7 b	6.9 b
120	0.57 d	12.6 a	8.8 a

**Means with no letter or followed by the same letter within a column and a season are not significantly different (P = .05) according to the Tukey's honestly significance difference*

Table 3. Soil results for experimental site production in season 1 (April to Aug. 2012) and 2 (Feb. to Jun. 2013)

	Carbon:Nitrogen	Phosphorous	pH (Cacl2)
	a. Season one		
Before planting	22:0.10	9.3 ppm	5.3
After planting	20:0.9	10.4 ppm	4.8
	b. Season two		
Before planting	23:0.09	9.8 ppm	4.9
After planting	24:0.8	10.5 ppm	4.7

Table 4. Plant tissue analysis for water melons grown in Matuga research station in Season 1 (April to Aug. 2012) and 2 (Feb. to Jun. 2013)

	Carbon:Nitrogen	Phosphorous	pH (Cacl2)
	a. Season one		
Before planting	0.5	9.3 ppm	4.7
After planting	1.3	8.4 ppm	4.8
	b. Season two		
Before planting	0.9	9.8 ppm	4.9
After planting	1.3	8.5 ppm	4.7

Table 5. Soil and plant tissue sufficiency ranges

	Carbon:Nitrogen	Phosphorous	pH (Cacl2)
Soil analysis	20:1	20-30 ppm	
Plant tissue analysis	2.5-4.0	0.25-0.7	5.0-6.8

Table 6. Analysis of Leaf Petiole during production in Season 1 (April to Aug. 2012) and 2 (Feb. to Jun. 2013)

Nitrogen levels (Kg N/ha)	Total Nitrogen (%)	Available Phosphorus (%)
	a. Season one	
0	0.92	0.22
40	1.37	0.25
80	1.23	0.24
120	1.35	0.22
	b. Season two	
0	1.00	0.23
40	1.41	0.25
80	1.41	0.25
120	1.40	0.24

In the present experiment there were no nitrogen levels that lead to a decline in yield. According to Hochmuth and Hochmuth [21] excess nitrogen application causes osmotic stress, which can cause oxidative damage injuring many important cellular components, such as lipids, protein, DNA and RNA leading to reduced growth and eventual yield of plants. The decline in yield at very high high N rates could be explained by the fact that a high concentration of soluble N increases the osmotic potential of the soil solution, causing reduction in water uptake by the plant roots [22]. However, Waseem et al. [17] reported that in deficient soils initial application of N increases yield but further increases in N may result in reduction of yield but this is not in all cases. He explains that in some cases excess N may not lead to reduced yield because some plants have the ability to take up N that is not necessarily transformed into dry matter and hence growth. Nitrates absorbed by the plants are normally assimilated in the roots into nitrites then to ammonium and amino acids through the action of nitrate and nitrite reductase enzymes [19] and not all absorbed nitrate ions are reduced and converted into amino acids but are stored in the plant cells as nitrates as influenced by plant nitrogen use efficiency and the amount applied [22]. Using nitrogen fertilizers significantly influenced quality of watermelon fruits at harvest. Quality of the fruit was enhanced with the increase in nitrogen levels. Quantitative analysis revealed the influence of Nitrogen in determining the watermelon quality. This was confirmed through the fruits which were more firm, thinner rind, with significantly increased total soluble solids (TSS) and low acidity as compared to control treatments. These results are in agreement with Aguyoh et al. [23] who reported that increased nutrient application enhances the quality of watermelon fruits. Furthermore Nitrogen helps in starch formation which during ripening is converted to sugar. Nitrogen and Magnesium are integral part of chlorophyll molecule and at higher level they supported the intake of K, hence resulted in the enhanced sweetness of watermelon fruits. Chloroplast contains protein rich in sulphur, manganese maintain chloroplast structure of stroma and grana and at high level of N and its uptake was supported along with water uptake. This resulted to stable chloroplast hence increased chlorophyll content thus higher net photosynthesis leading to increased TSS in the fruits. Nitrogen and phosphorus plays a role in photosynthesis and at higher levels activated potassium and calcium uptake which are responsible for transporting photosynthates from source (leaves) to the sinks (fruits).This enhanced transport led to a good quality fruits with higher TSS, thinner rind thickness and firmer. Water helps in cell wall and membrane development. It is therefore possible that application of nitrogen would have led to higher total soluble solids and firmer fruits respectively. This may therefore be attributed to higher TSS, and firmer fruits due to nitrogen application which are important qualities on watermelon. The application of N at high level improved sugar content compared to zero application. The improved crop growth in response to N application led to higher rate of photosynthesis and therefore higher amount of sugar in the fruit. Application of N at high levels resulted to optimal stomatal conductance. This lead to efficient carbon dioxide assimilation and water use efficiency hence higher photosynthesis and therefore higher sugars in the fruits.

Nitogen at high levels supports manganese uptake leading to enhanced electron transport system hence higher net photosynthesis thus increased TSS in the fruits. Similar results were observed when compound fertilizer applied at different Similar results were observed when compound fertilizer applied at different levels was used in Kenya {NPK (16:16:8)}. Use of compound fertilizer resulted to watermelon fruits with higher total soluble solids and more firm fruits compared with the control [24].

Application of nitrogen influenced availability of nitrogen and phosphorus on both soil and watermelon tissue. Nitrogen and phosphorus availability increased with increasing levels of nitrogen. Calcium ammonium nitrate fertilizers contain calcium ions, this in turn displaces Hydrogen ions in soil solution to adsorption sites resulting into a pH range that favors both N and P availability in the soil, hence increase in nitrogen rates resulted in increase in P and N availability both in soil and leaves (petioles). Agba and Enya [16] found sufficient ranges of recently matured watermelon leaf petiole when nutrient was applied as compound fertilizer (NPK). Therefore, the nutrient uptake of nitrogen was sufficient.

5. CONCLUSION AND RECOMMENDATION

Kwale soils are Nitrogen deficient. Nitrogen fertilizers levels influenced yield and quality of watermelon. Use of N significantly led to more fruits, more female flowers and subsequently higher yield. Quality of watermelon fruits was also significantly improved with thinner rind thickness, and higher TSS. Therefore, this provides coastal farmers with the best nitrogen fertilizer rates that maybe applied in integrated nutrient management for watermelon production.

Based on this finding, further research may be done using more levels and different sources of Nitrogen fertilizers at different areas since ecological conditions may affect the result.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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