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# The effect of different Phosphorous levels on Yield and Quality of Watermelon {*Citrullus lanatus* (Thunb.) Matsumara & Nakai} grown in the Kenyan Coastal region

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**ABSTRACT**

*The response of watermelon variety 'sugar baby' to three levels of phosphorous (0,50 and100 Kg $P_2O_5$/ha) was tested in a field experiments in KARI, Matuga, Kwale District in the coastal region of Kenya. A randomized complete block design with three replications was used. Phosphorous had a positive significant effect on the sex expression ratio, number of fruits/plant, fruit weights, firmness, rind thickness, total soluble solids. Application of 50 and 100 Kg $P_2O_5$/ha increased the fruit sugar content by 10% and 4% compared with zero application. The total fruit yield was highest at 50 and 100 Kg $P_2O_5$/ha,with increasing fruit yield of 16% and16.4% respectively compared with zero application. Rind thickness, fruit firmness decreased and increased with increasing levels of P respectively. The watermelon sex ratio significantly increased with increase in phosphorous up to a point (more than 50 Kg $P_2O_5$/ha) when further increase led to a reduction signifying an increase in female flowers. For improved growth, yield, total soluble solids and firmness of water melons in the coastal region of Kenya 50 Kg $P_2O_5$/ha was recommended.*

**Keywords:** Water melon, 'Sugar baby', phosphorous, growth, yield, quality

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## INTRODUCTION

Global consumption of Watermelon (*Citrullus lanatus*) is greater than that of any of the cucurbit family member. It accounts for 6.8% of the world area devoted to vegetable production [7]. There are over 1,200 varieties of watermelon worldwide [12] several of these varieties have been recommended for different climatic ranges in Kenya. These include 'Sugarbaby', 'Crimson Sweet', 'Charleston Gray', 'Chilean Black', 'Congo', 'Fairfax' and 'Tom Watson' [15]. Among these cultivars, the 'Sugarbaby' is the most popular because of its sugary taste, smaller size, and earlier maturity and higher yields [9]. Despite popular belief that watermelon is made up of only water and sugar, watermelon is actually considered a nutrient dense food, a food that provides a high amount of vitamins, minerals and antioxidants for a low amount of calories.

Watermelon is a potential export crop for Kenya since there is demand regionally and internationally. However the present state is that demand is higher than production. To meet the local demand will result in for export; therefore, production of watermelon in Kenya needs to be increased [5]. Low yields eating and storage qualities are among the major challenges currently facing watermelon farmers in Kenya. This has been attributed to heavy or low fertilization especially of nitrogen [5]. National 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 $K_2O$ [13].

Average yields and quality upon use of the national recommended rates in Kenya are lower than what is achieved in other countries. Potassium, has been tested on in the coastal areas of Kenya, and found to be enough, thus no need for additional K fertilization [11]. This study was initiated with the objective of establishing the optimum phosphorous requirement for optimum yields of watermelons 'sugar baby variety' in the coastal regions of Kenya.

## MATERIALS AND METHODS

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, 50 and 100 Kg $P_2O_5$/ha). The treatments were laid out in a randomized complete block design replicated three times. Before land preparation, pre-plant soil samples were obtained from the upper soil using the transverse method, one month after-planting soil samples were collected randomly from four locations in each a plot between plants within a row. The samples were bulked together to get one composite sample. the composite sample soil was then air dried, sieved through a 2mm mesh screen and analyzed for available P according to standard procedures [14].

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 $80^oC$ for 48 hours and grounded. The mineral constituents of the plant were determined by digesting the samples on a labcon digester at 300°C in a mixture of hydrogen peroxide, sulphuric acid, selenium and salicyclic acid [14]. The digests were analyzed 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 color procedure and the absorbance measured at 880 nm wavelength UV-spectrophotometer.

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 1.5x 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 4x3m, and each block measured 55m x 3m separated by 3m path, 0.5m and 1m within sub-plots and main plots respect1vely. Phosphorus fertilizers in the form of triple superphosphate (46% $P_2O_5$/ha) was applied at the rates of (0.50 and100 Kg $P_2O_5$/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 weedings were carried out manually using hand hoe at 4&8 week after planting respectively.4weeks after sowing The crops were sprayed three times with lamdacyahalothrin 'Karate' (insecticide) and benomyl (benlate) fungicide at the rates of 2 liters and 1.5kg/ha respectively at 4, 6 and 8 WAP to protect the plants against insect pests and fungal. Records for each of the 3 central watermelons 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 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 means separated using the THSD at P=0.05.

## RESULTS

### *Effect of Phosphorous Levels on Watermelon*

#### *a) Days to Flowering*

Use of P fertilizer application had significant effect on the days to flowering of watermelon plants (Table 1). In both seasons, watermelon plants with P levels applied at the rate of 50 and 100 Kg $P_2O_5$/ha had had the earliest flowers to appear while 0 Kg $P_2O_5$/ha had the latest.

#### *b) Sex Expression Ratio*

Phosphorus levels had significant effect on sex expression in the second season (Table 1). Phosphorus applied at 50 and 100 Kg $P_2O_5$/ha had the lowest sex ratio while the control had the highest.

#### *c) Fruit Number per Plant*

Phosphorus had significant effect on watermelon fruit per plant (Table 1). In both seasons, plants with P applied at the rate of 50 and 100 Kg $P_2O_5$/ha had more fruit followed by 0 Kg $P_2O_5$/ha.

**Table 1. Effect of phosphorous Levels on Yield Components and Yield of Watermelon Plants during Production in Season 1 (April to Aug. 2012) and 2 (Feb. to Jun. 2013)**

| Phosphorous levels (Kg $P_2O_5$/ha) | Days to flowering (Days) | Sex expression ratio | Fruit number (no./plant) | Unit Weight (Kg) | Fruit weight (Kg/plant) |
|---|---|---|---|---|---|
| | | a. Season one | | | |
| 0 | 31.4 a* | 6.29** | 1.66 b* | 1.96 c* | 21.75 c* |
| 50 | 30.6 b | 6.22 | 2.05 a | 2.30 b | 25.54 b |
| 100 | 30.6 b | 5.85 | 2.18 a | 2.32 a | 25.75 a |
| | | b. Season two | | | |
| 0 | 30.9 g* | 7.66 b* | 2.59 g* | 2.15 h* | 23.89 h* |
| 50 | 30.1 h | 7.96 ab | 3.08 f | 2.46 g | 27.35 g |
| 100 | 30.1 h | 9.24 a | 3.08 f | 2.47 g | 27.34 g |

**Means with no letter or followed by the same letter within a column and a season are not significantly different (P=0.05) according to the Tukey's honestly significance difference.*

***d) Unit Fruit Weight***

Application of P fertilizer had significant effect on watermelon unit fruit weight (Table 1). In both seasons P applied at the rate of 50 and 100 Kg $P_2O_5$/ha had the heaviest individual fruit while the lowest was observed under the control (0 Kg $P_2O_5$/ha).

***e) Yield (t/ha)***

Application of P fertilizer had significant effect on watermelon yield (Table 1). In both seasons P applied at the rate of 50 and 100 Kg $P_2O_5$/ha yielded more while the lowest was recorded under the control (0 Kg $P_2O_5$/ha).

***Effect of phosphorous Levels on Fruit quality at harvest of Watermelon***

***a) Rind Thickness***

Application of P fertilizer had significant effect on watermelon rind thickness (Table 2). In both seasons, watermelon plants with P applied at the rate of 50 and 100 Kg $P_2O_5$/ha had fruits thinner rind while fruit with the thickest rind was recorded under the control (0 Kg $P_2O_5$/ha).

***b) Total Soluble Solids***

Use of P fertilizer had significant effect on total soluble solids (TSS) of watermelon fruits (Table 2). In both seasons, watermelon fruits with P applied at the rate of 50 and 100 Kg $P_2O_5$/ha had the highest TSS while fruits under the control (0 Kg $P_2O_5$/ha) had the lowest TSS.

***c) Fruit Firmness***

Applying P fertilizer had significant effect on watermelon fruit firmness (Table 2). In both seasons, watermelon fruits with P applied at the rate of 50 Kg $P_2O_5$/ha had the most firm fruits followed by 100 Kg $P_2O_5$/ha while the control (0 Kg $P_2O_5$/ha) had the least firm fruits.

**Table 2. Effect of phosphorous 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 | 0.80 a* | 10.2 b* | 5.2 c* |
| 50 | 0.69 b | 11.2 a | 6.4 a |
| 100 | 0.69 b | 11.1 a | 6.3 b |
| | b. Season two | | |
| 0 | 0.89 a* | 10.3 b* | 5.4 c* |
| 50 | 0.79 b | 11.4 a | 6.6 a |
| 100 | 0.79 b | 11.3 a | 6.5 b |

**Means with no letter or followed by the same letter within a column and a season are not significantly different (P=0.05) according to the Tukey's honestly significance difference.*

***Soil nutrition status and tissue phosphorous content***

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

**Table 3. Soil results for 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 | 9.8ppm | 4.9 |
| After planting | 24:0.8 | 10.5ppm | 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 | 9.8ppm | 4.9 |
| After planting | 1.3 | 8.5ppm | 4.7 |

**Table 5: Soil and Plant tissue Sufficiency ranges**

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

***Effect of phosphorous Levels on Tissue Analysis of Watermelon***

The results from watermelon leaf petiole analysis on total phosphorous indicated that higher phosphorous was observed at 50 Kg $P_2O_5$/ha followed by at100 Kg $P_2O_5$/ha and lowest at 0 Kg $P_2O_5$/ha in season 1.In season 2, higher phosphorous was observed at100 Kg $P_2O_5$/ha followed by 50 Kg $P_2O_5$/ha and lowest at 0 Kg $P_2O_5$/ha (Table 3). In general, phosphorous content on watermelon leaves increased with the increasing levels of phosphorous.

**Table 3. Analysis of Leaf Petiole during Production in Season 1 (April to Aug. 2012) and 2 (Feb. to Jun. 2013)**

| Phosphorous levels (Kg $P_2O_5$/ha | Available Phosphorus (%) | Total Nitrogen (%) |
|---|---|---|
| | a. Season one | |
| 0 | 0.23 | 1.12 |
| 50 | 0.24 | 1.26 |
| 100 | 0.23 | 1.27 |
| | b. Season two | |
| 0 | 0.24 | 1.29 |
| 50 | 0.24 | 1.31 |
| 100 | 0.25 | 1.33 |

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## DISCUSSION

Phosphorous application had significant effect on watermelon yield components and yield. Increase in phosphorous levels resulted in reduction in days to flowering, lower sex expression ratio, more fruits, heavier fruits and subsequently higher fruit yield. Phosphorus is known to stimulate root development leading to better root establishment. Phosphorus promotes vegetative growth [10]. More leaves translate to better chlorophyll development and higher stomatal conductance hence enhanced photosynthesis. This therefore leads to more photosynthates being manufactured. In the present study, it is 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 findings are in agreement with Eifediyi and Remison [3] findings who found out that cucumber grown in increasing levels of inorganic fertilizer (N.P.K.20:10:10) application revealed significant increase in growth and yield attributes including the vine length, number of leaves per plant, number of branches, leaf area, number of fruits per plant, fruit length, fruit girth, fruit weight per plant, fruit number per plant signifying an increase in total yield per hectare.

Furthermore, these findings are collaborated by the finding of Akanbi *et al.* [2] who found out that *Solanum melongena var.'* long purple', grown in increasing levels of NPK (15:15:15) application revealed significant increase in growth parameters and fruit traits of brinjols including fruit and seed attributes such as length, girth, number of fruits /plant, number of seeds/fruits, seed weight and fruit yield. In both cases (brinjols & cucumber) increasing rates of NPK resulted to simultaneous increase in P uptake.

The watermelon sex ratio significantly increased with increase in phosphorous up to a point (more than 50 Kg $P_2O_5$/ha) when further increase led to a reduction. This is in agreement to the findings from Aguyoh *et.al*. [1] who found out that cucumber grown in increasing levels of phosphorous 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. Guner and Wehner [8] reported complimentary action of the two elements P & N hence as phosphorous was increasing soil available nitrogen uptake was increasing leading to a reduction in sex ratio.

Using phosphorous fertilizers significantly influenced quality of watermelon fruits at harvest. Quality of the fruit was enhanced with the increase in phosphorous levels. Quantitative analysis revealed the influence of phosphorous 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*. [1] who reported that increased nutrient application enhances the quality of watermelon fruits. Furthermore phosphorous is involved in enzyme regulation that are necessary in starch synthesis which during ripening is converted to sugar. Application of P at higher levels supported uptake of Nitrogen and Magnesium which are integral part of chlorophyll molecule. In turn 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 P sulphur, and manganese uptake was supported along with water uptake. This resulted to stabilized chloroplast hence increased chlorophyll content thus higher net photosynthesis leading to increased TSS in the fruits. Phosphorus plays a role in photosynthesis and at higher levels activated potassium and calcium uptakes 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 phosphorous would have led to higher total soluble solids and firmer fruits respectively. Phosphorous enhances calcium uptake Aguyoh *et.al*. [1] and it is known that water and calcium have been reported to play a major role in cell wall development. Calcium plays an important role in maintaining the quality of fruits and vegetables [6]. Calcium may have two opposite effects on texture. Calcium makes tissues firm via complex formation with pectic substances; in addition, it enhances tissue softening by β -elimination. However, the net result of calcium addition has invariably been to firm the tissue of fruits [4]. This may therefore be attributed to higher TSS, and firmer fruits due to phosphorous application which are important qualities on watermelon. The application of P at high level improved sugar content compared to zero application. The improved crop growth in response to P application led to higher rate of photosynthesis and therefore higher amount of sugar in the fruit. Application of P at high levels resulted to optimal stomatal conductance. This lead to efficient carbondioxide assimilation and water use efficiency hence higher photosynthesis and therefore higher sugars in the fruits. Manganese activates several enzymes and is involved in the processes of electron transport system in photosynthesis. Phoshorous at high levels supported 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 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 [6].

Application of phosphorous influenced availability of phosphorus and nitrogen on both soil and watermelon tissue. Phosphorus and Nitrogen availability increased with increasing levels of phosphorus. Sufficient concentrations of calcium ions in the soil liquid phase, in turn displaced Hydrogen ions in soil solution to adsorption sites resulting into a pH range that favours both N and P availability in the soil, hence increase in P rates resulted in increase in P and N availability both in soil and leaves (petioles). This is in agreement with Elmstrom *et al*. [4] who found that watermelon tissue P concentrations increased 10 to 15% with banded P215 Kg/ha $P_2O_5$ only when all of the N and K, instead of half, were broadcast and incorporated preplant at 211 Kg/ha N and $K_2O$. Therefore, the nutrient uptake of phosphorous was sufficient.

## CONCLUSION

Phosphorous fertilizers levels influenced yield and quality of watermelon. Use of P 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 Phosphorous fertilizer rates that may be applied in integrated nutrient management for watermelon production. Based on these findings, 50 Kg $P_2O_5$/ha for improved growth, yield, total soluble solids and firmness of water melons in the coastal region of Kenya was recommended.

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