Effect of NPK Fertilizer Rates on Growth and Yield of Field and Greenhouse Grown Pepino Melon (*Solanum muricatum* Aiton)

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Abstract. Pepino melon (*Solanum muricatum* Ait.) is an exotic vegetable whose consumption is on the increase in Kenya due to its health and nutritional benefits. A study was conducted at Egerton University, Kenya in 2018-2019 to investigate the effect of NPK fertilizer rates (0, 100, 200, 300 and 400 kg ha⁻¹) on growth and yield of field and greenhouse grown pepino melons. The experiment was laid in a randomized complete block design with three replications. Data was recorded on plant height, stem diameter, number of leaves per bush, number of branches, days to 50% flowering, fruit weight and total yield. Data were analyzed using analysis of variance with the SAS statistical package. Significant means were separated using Tukey's Honestly Significant Difference at $p \leq 0.05$. Results indicated that NPK fertilizer rates and growing environment influenced growth and yield of pepino melon. At 100 DAP plants grown in the greenhouse and supplied with 200 kg NPK ha⁻¹ had a stem diameter of 14.01 mm which was significantly bigger $p \leq 0.05$ compared to those grown in the field and supplied with 300 kg NPK ha⁻¹ with a stem diameter of 11.71 mm in trial two. Application of 300 kg NPK ha⁻¹ for field grown pepino melons gave the highest yield of 1102.48 kg ha⁻¹ and 1060.55 kg ha⁻¹ in trial one and two respectively. In conclusion, application of 300 kg ha⁻¹ of NPK fertilizer for field grown pepino melon is recommended.

Introduction

Pepino melon (*Solanum muricatum* Ait.) is an exotic vegetable which belongs to the family solanaceae [1]. The fruit was initially grown in South America but its cultivation has extended to Australia, New Zealand, USA [2] Central America, Morocco, Spain, Israel and the highlands of Kenya [3]. The vegetable was introduced in Kenya in 2013 and its consumption in Kenya is increasing due to its health, nutritional and economic value [4]. The edible part is the fruit which is aromatic and juicy [5]. The fruit can be eaten when mature green as a vegetable in stews [1] and the ripe fruit is eaten as a dessert fruit, in salads and ice creams [5].

Pepino is low in calories but very rich in minerals such as calcium, phosphorous and potassium and vitamins A, B1, B2, B3 and C [6]. The fruit varies in size and shape depending on the cultivar and the colour ranges from completely purple, solid green or green with purple stripes, or cream colored with or without purple stripes [7]. The main challenge in vegetable production is nutrient deficiency due to improper use of fertilizers [8]. Proper vegetable growth requires ideal nutrient supply [9]. In the tropics, soil fertility is declining due to excessive rainfall and continuous cultivation has led to lack of essential nutrients in the soil [10]. NPK fertilizer has the ability to release nutrients very fast into the soil and thus help sustain soil fertility and crop production [11]. The present study aimed at investigating the effects of different rates of NPK fertilizer on growth and yield of field and greenhouse grown pepino melons.

Materials and Methods

Site Description

The experiment was conducted at the Horticulture Research and Teaching Field, Egerton University, Njoro. The field lies at a latitude of 0° 23' South, longitudes 35° 35' East in the Lower Highland III Agro Ecological Zone (LH3) at an altitude of approximately 2,238 m above sea level [12]. Average maximum and minimum temperatures range from 19 °C to 22 °C and 5 °C to 8 °C, respectively, with a total annual rainfall ranging from 1200 to 1400 mm. The soils are predominantly mollic andosols [12].

Experimental design and treatment application

The experimental design was Randomized Complete Block Design (RCBD) with five treatments and three replications. The five treatments include (0, 100, 200, 300 and 400 NPK (17:17:17) kg ha⁻¹). Pepino seedlings (Ecuadorian Gold variety) were obtained from Garlic and Pepino Farm, Nakuru, Kenya. For the field experiment, each experimental plot was 3.2m × 3.2m and the seedlings were planted in rows 80 cm apart and 50 cm within the plants to give a total of 24 plants per plot [13]. In the greenhouse experiment, each experimental plot was 2m × 5 m at the same spacing as in the field experiment to give a total of 25 plants per plot. Soil samples were collected from the experimental plots in the field and greenhouse and analyzed for total N, P, K and pH before the experiment using the method described by [14]. NPK fertilizer was applied and thoroughly mixed with the soil before placing the seedlings in the transplanting holes. Weeding was done uniformly to all experimental units. Field capacity was determined as described by Cong [15] thereafter tensiometers were placed in two experimental units in each block. Irrigation was done when the field capacity fell below 60% because pepino requires a field capacity of 60-65% [16]. Drip irrigation was used in the greenhouse and it supplied about 180 liters to the 375 plants in the greenhouse.

Data collection

Data was collected and recorded on the following parameters from a total of 8 plants from the two middle rows of each plot. The outer rows in each plot served as guard rows.

i) Plant height: This was determined from the ground to the tip of the plant by means of a tape measure. This was done at an interval of 14 days starting 30 days after planting up to 100 days after planting.

ii) Stem diameter: The same pepino plants used to measure plant height were used to measure stem thickness at the ground level using vanier calipers (in mm) once after every 14 days starting from 30 days after planting up to 100 days after planting.

iii) Number of leaves per bush before flowering: Number of leaves were counted from the selected plants just before flowering. A mean number of branches was computed for each experimental plot.

iv) Number of branches: The number of primary branches was determined by counting from the selected plants from each plot and replicate at the peak of vegetative phase, just before flowering. A mean number of branches was computed for each plot from the 8 selected plants.

v) Days to 50% flowering: The number of days taken by the selected plants in each experimental plot to attain 50% flowering was determined. Thereafter, the mean number of days taken to attain 50% flowering in each experimental plot was computed.

vi) Fruit Weight: Mature fruits were harvested and then weighed on electronic weighing machine (JA10003) to determine fruit weight (g) per plant in each treatment.

vii) Total yield: Mature fruits were harvested and weighed on an electronic weighing machine (JA10003) to determine total yield (kg ha⁻¹) in each treatment.

Data analysis

Data collected was subjected to Analysis of Variance (ANOVA) and significant means separated using Tukey's honestly significant difference (Tukey's HSD) test at $p \leq 0.05$. The SAS statistical package [17] was used for data analysis.

Results

Pre-planting soil analysis

The result of the pre-planting soil analysis (to affirm the soil conditions) are presented in Table 1.

Table 1: Pre-planting soil analytical results

Soil properties	Field		Greenhouse	
	Trial 1	Trial 2	Trial 1	Trial 2
Total Nitrogen (%)	0.28-0.45	0.21-0.40	0.21-0.78	0.20-0.72
Potassium (mg/kg)	12.6-22.13	10.2-20.45	19.4-48.6	17.5-38.7
Available P (mg/kg)	1.31-1.72	1.23-1.63	1.96-3.06	1.88-2.99
pH(water)	4.8-5.7	4.6-5.2	4.38-6.03	4.25-6.00

Temperature data

The results of average monthly temperature in the field and greenhouse are presented in Table 2.

Table 2: Average monthly field and greenhouse temperature (°C) in trial one and two

		Environment		2018		2019		
Trial one		Nov	Dec	Jan	Feb	Mar	Apr	May
	Field	20.9	19.7	20.9	21.7	22.8	22.6	21.2
	Greenhouse	30.3	21.0	33.4	30.2	29.4	34.0	35.8
		2019						2020
Trial two		July	Aug	Sept	Oct	Nov	Dec	Jan
	Field	19.1	19.2	20.5	19.3	19.3	18.9	19.1
	Greenhouse	18.5	29.4	30.0	28.0	32.0	28.0	35.3

Plant height: NPK fertilization and growing environment had a significant effect on plant height in both trials. Plants which were supplied with 200kg NPK ha⁻¹ and grown in the greenhouse were significantly taller at $p \leq 0.05$ than the other NPK rates though not significantly different at $p \leq 0.05$ from those supplied with 300 kg NPK ha⁻¹ grown in the field in both trial one and two. The same trend was observed from 30 to 100 DAP. In trial two, 44 DAP plants supplied with 200 kg ha⁻¹ were significantly different from those supplied with 300 kg ha⁻¹ in the field (Table 3). Generally, it was noted that plant height increased from 30 DAP to 100 DAP. Plants which were planted in the greenhouse were generally taller than those grown in the field in both trials (Table 4).

Table 3: Effect of NPK fertilizer rates and growing environment on plant height (cm) of pepino melon in trial one

Environment	Fertilizer (kg ha ⁻¹)	30 DAP	44 DAP	58 DAP	72 DAP	86 DAP	100 DAP
Greenhouse	0 kg	16.79e	26.13c	36.38c	44.54d	52.66cd	56.50bcd
	100 kg	23.92bcd	39.34b	50.63b	55.34c	62.00b	52.63cd
	200 kg	35.79a	55.58a	62.88a	69.34a	76.67a	77.00a
	300 kg	25.08bc	38.50b	48.00b	56.92bc	60.09bc	63.67b
	400 kg	26.54b	38.83b	46.55b	55.25c	61.25bc	60.38bc
Field	0 kg	18.46de	21.54c	25.25d	31.87e	41.83e	48.58d
	100 kg	21.08bcde	23.96c	28.13d	36.92de	47.58de	52.92cd
	200 kg	21.79bcde	23.87c	28.83cd	36.25de	46.38de	52.84cd
	300 kg	35.35a	52.50a	61.44a	66.29ab	72.63a	74.83a
	400 kg	20.92cde	22.29c	29.25cd	38.25de	48.63de	51.50d

*Means followed by the same letter (s) within a column are not significantly different according to Tukey's HSD at $p \leq 0.05$.

Table 4: Effect of NPK fertilizer rates and growing environment on plant height (cm) of pepino melon in trial two

Environment	Fertilizer (kg ha ⁻¹)	30 DAP	44 DAP	58 DAP	72 DAP	86 DAP	100 DAP
Greenhouse	0 kg	13.28d	16.61f	19.93e	23.05e	28.49e	33.00e
	100 kg	22.99bc	28.50cd	33.22c	36.16c	40.39c	57.22bc
	200 kg	38.78a	44.83a	48.34a	62.00a	70.06a	81.33a
	300 kg	25.16bc	29.56c	33.11c	37.22c	43.82bc	48.94bc
	400 kg	25.67b	29.44c	32.17c	35.67c	43.05c	50.34bc
Field	0 kg	18.88cd	20.88ef	23.71de	25.38e	29.59de	30.92e
	100 kg	21.67bc	23.59de	27.75cd	31.84cd	36.17cde	37.21de
	200 kg	23.56bc	24.84cde	29.09cd	31.29cd	40.46c	44.04cde
	300 kg	32.82a	38.92b	41.06b	51.29b	51.58b	62.00b
	400 kg	22.38bc	24.63cde	25.11de	33.75c	37.46cd	42.17de

*Means followed by the same letter (s) within a column are not significantly different according to Tukey's HSD at $p \leq 0.05$.

Stem diameter: NPK fertilizer rates and growing environment had a significant effect on stem diameter of pepino melon plants. Plants which were grown in the field and supplied with 300 kg NPK ha⁻¹ had a significantly high stem diameter at 30 DAP but not significantly different at $p \leq 0.05$ from those grown in the greenhouse and supplied with 200 kg NPK ha⁻¹ in trial one. From 44 DAP to 100 DAP plants grown in the greenhouse and supplied with 200 kg NPK ha⁻¹ had a significantly high stem diameter at $p \leq 0.05$ though not different from those grown in the field and supplied with 300 kg NPK ha⁻¹ in trial one (Table 5). In trial two, plants which were grown in the greenhouse and supplied with 200 kg NPK ha⁻¹ had a significantly higher stem diameter at $p \leq 0.05$ though not significantly different from those grown in the field and supplied with 300 kg NPK ha⁻¹ from 30 DAP to 86 DAP. At 100 DAP plants grown in the greenhouse and supplied with 200 kg NPK ha⁻¹ had a stem diameter of 14.01 mm which was significantly different $p \leq 0.05$ at from those grown in the field and supplied with 300 kg NPK ha⁻¹ with a stem diameter of 11.71 mm (Table 6).

Table 5: Effect of NPK fertilizer rates and growing environment on stem diameter(mm) of pepino melon in trial one

Environment	Fertilizer (kg ha ⁻¹)	30 DAP	44 DAP	58 DAP	72 DAP	86 DAP	100 DAP
Greenhouse	0 kg	4.91c	5.91de	7.33d	4.84d	5.51c	6.92d
	100 kg	5.72bc	8.37bc	9.35c	8.02bcd	9.03bc	9.83c
	200 kg	8.56ab	9.96a	12.55a	14.30a	15.63a	13.11ab
	300 kg	4.89c	8.21bc	9.64bc	6.09cd	6.99bc	9.75c
	400kg	4.31c	7.08cd	9.91bc	5.82cd	6.49bc	9.37cd
Field	0 kg	4.52c	4.08f	5.21e	7.93bcd	5.51c	10.40c
	100 kg	3.94c	4.79ef	5.85de	8.78bc	8.62bc	9.99c
	200kg	4.88c	4.51ef	5.64de	8.29bcd	9.87b	10.70bc
	300 kg	9.05a	9.41ab	11.34ab	11.09ab	14.32a	15.32a
	400 kg	4.41c	4.69ef	6.32de	8.59bcd	9.30b	10.64bc

*Means followed by the same letter (s) within a column are not significantly different according to Tukey's HSD at $p \leq 0.05$.

Table 6: Effect of NPK fertilizer rates and growing environment on stem diameter (mm) of pepino melon in trial two

Environment	Fertilizer (kg ha ⁻¹)	30 DAP	44 DAP	58 DAP	72 DAP	86 DAP	100 DAP
Greenhouse	0 kg	3.38d	4.11c	5.30c	6.64c	8.25b	8.94c
	100 kg	4.29cd	4.97bc	6.66bc	7.73c	8.58b	9.50c
	200 kg	5.91a	7.61a	9.05a	10.85a	11.93a	14.01a
	300 kg	4.49bc	5.30bc	6.51bc	7.33c	8.31b	8.99c
	400kg	4.57bc	5.19bc	6.74bc	7.86bc	8.25b	9.12c
Field	0 kg	1.32e	1.77d	2.23d	2.83d	3.43d	3.21f
	100 kg	1.72e	2.07d	2.36d	3.04d	4.26cd	4.48ef
	200kg	2.28e	2.02d	2.76d	3.15d	4.79cd	5.76de
	300 kg	5.37ab	6.20b	7.81ab	9.45ab	11.00a	11.71b
	400 kg	1.71e	2.37d	2.98d	3.47d	5.45c	6.06d

*Means followed by the same letter (s) within a column are not significantly different according to Tukey's HSD at $p \leq 0.05$.

Number of leaves per bush before flowering: NPK fertilizer rates and growing environment had a significant effect $p \leq 0.05$ at on number of leaves. In both trials plants which were supplied with 400 kg NPK ha⁻¹ whether grown in the field or greenhouse had the highest number of leaves per bush just before flowering compared to the control in both environments. In trial one, plants supplied with 400 kg NPK ha⁻¹ had 128.79 and 126.67 leaves per bush in the greenhouse and field environments respectively (Fig. 1). Plants which were not supplied with fertilizer had the lowest number of leaves in both environments and trials. It was observed that as the fertilizer rate increased the number of leaves also increased in both environments and trials.

Figure 1: Effect of NPK fertilizer rates and growing environment on number of leaves of pepino melon in trial 1 and 2

Number of branches: NPK fertilizer rates and growing environment had a significant effect at $p \leq 0.05$ on the number of primary branches. In trial one plants supplied with 200kg NPK ha⁻¹ and grown in the greenhouse had 23.05 branches while those supplied with 300 kg NPK ha⁻¹ and grown in the field had 19.35 branches and were not significantly different at $p \leq 0.05$. Control recorded the lowest number of branches with 8.99 and 7.13 branches for greenhouse and field grown pepino melons respectively. However, plants supplied with 300 kg NPK and grown in the field were not significantly different from greenhouse plants supplied with 400 and 300 kg NPK ha⁻¹. In trial two, field grown plants supplied with 300 kg NPK ha⁻¹ had 18.46 branches while greenhouse grown plants supplied with 200 kg NPK ha⁻¹ had 15.03 branches and they were not significantly different at $p \leq 0.05$.

Greenhouse grown plants that received 200 kg NPK ha⁻¹ were not significantly different at $p \leq 0.05$ from field grown plants that received 400, 100 and 200 kg NPK ha⁻¹ and greenhouse grown plants that received 100, 300 and 400 kg NPK ha⁻¹ (Fig. 2). The control plants had the lowest number of branches with 9.13 and 7.06 branches for field and greenhouse grown pepino plants respectively. Generally, it was observed that plants had higher number of branches in trial one compared to trial two.

Figure 2: Effect of NPK fertilizer rates and growing environment on number of branches of pepino melon in trial 1 and 2

Days to 50% flowering: NPK fertilizer rates and growing environment had a significant effect at $p \leq 0.05$ on days to 50% flowering. Plants which were supplied with NPK fertilizer took longer to flower compared to the control which took the shortest time to flower in both environments and trials. In trial one, control plants grown in the field took an average of 33 days to flower while those grown in the greenhouse took an average of 31 days to flower. In trial one plants which were supplied with 400 kg NPK ha⁻¹ took 63 and 60 days to flower in the field and greenhouse respectively. In trial two, plants supplied with 400 kg NPK ha⁻¹ took 65 and 60 days in the field and greenhouse respectively (Fig. 3). Plants supplied with the other fertilizer rates took between 35 to 45 days to flower. Generally, plants in the greenhouse took a shorter time to flower compared to those grown in the field.

Figure 3: Effect of NPK fertilizer rates and growing environment on number of days to 50% flowering of pepino melon in trial 1 and 2

Fruit weight: NPK fertilizer rates and growing environment had a significant effect at $p \leq 0.05$ on fruit weight of pepino melon. Field grown plants supplied with 300 kg NPK ha⁻¹ had the highest fruit weight of 380.23 g and 361.46 g in trials one and two respectively. In trial one, pepino plants which received 0 kg NPK ha⁻¹ had a fruit weight of 137.04 g and 68.53 g in the field and greenhouse respectively (Fig. 4). Generally, field grown pepino melons had a higher fruit weight compared to greenhouse grown pepino plants. It was also observed that as the NPK fertilizer rates increased the fruit weight also increased up to 300 kg NPK ha⁻¹ for field grown plants and 200 kg NPK ha⁻¹ for greenhouse grown pepino melons. Increasing NPK fertilizer rates above 300 kg NPK ha⁻¹ for field grown plants and 200 kg NPK ha⁻¹ for greenhouse grown did not lead to a significant increase in fruit weight.

Figure 4: Effect of NPK fertilizer rates and growing environment on fruit weight of pepino melon in trial 1 and 2

Total yield: NPK fertilizer rates and growing environment had a significant effect at $p \leq 0.05$ on total yield of pepino melon. Increasing rates of NPK fertilizer led to an increase in the total yield of pepino melon in both growing environments (Fig. 5). However, it was noted that increasing the rate above 300 kg NPK ha⁻¹ for field grown plants and 200 kg NPK ha⁻¹ for the greenhouse grown pepino plants led to an insignificant increase or decrease in yield. The control (no fertilizer) recorded the lowest total yield in both environments and trials. Field grown pepino melons that were supplied with 300 kg NPK ha⁻¹ had the highest yield of 1102.48 kg ha⁻¹ and 1060.55 kg ha⁻¹ in trial one and two respectively (Fig. 5). Greenhouse grown plants supplied with 200 kg NPK ha⁻¹ had a total yield of 782.64 kg ha⁻¹ and 648.8 kg ha⁻¹ in trial one and two respectively. In trial one, plants not supplied with fertilizer (control) had a total yield of 411.22 kg ha⁻¹ and 211.36 kg ha⁻¹ in the field and greenhouse respectively. In trial two, the control recorded 209.4 kg ha⁻¹ and 212.7 kg ha⁻¹ in the field and greenhouse respectively. Generally, it was observed that the yield was higher in the field grown compared to the greenhouse grown pepino melons. It was also observed that the total yield was higher in trial one compared to trial two.

Figure 5: Effect of NPK fertilizer rates and growing environment on total yield of pepino melon in trial 1 and 2

Discussion

NPK fertilizer rates and growing environment has a significant effect on height of pepino melon plants. Similar results were reported by [18] in which capsicum plants that received NPK 150:120:60 kg ha⁻¹ fertilizer resulted to increased plant height of 60.10 cm compared to other NPK fertilizer rates and the control. Similarly, [19] reported that bell pepper plants that were grown in the polyhouse were taller than those grown in the open field. There was a significant increase in plant height in the plots that were supplied with 200 kg NPK ha⁻¹ in the greenhouse and 300 kg NPK ha⁻¹ in the field compared to the control. The higher response in pepino melon growth in the greenhouse might be due to availability of essential elements from the NPK fertilizer. Plant height is very important for determining growth of crops [20]. The increase in plant height of pepino melon plants supplied with NPK fertilizer could be due to the release of nutrients from the fertilizer and this led to an increase in photosynthesis [21]. Increased rates of NPK fertilizer resulted in higher growth including plant height in both growing environments. Optimum plant height is positively correlated with plant productivity [22]. On the other hand, the low plant height recorded in the control in both environments was due to lack of nutrients which led to reduced growth. Increasing NPK fertilizer rates above 200 kg NPK ha⁻¹ in the greenhouse and 300 kg NPK ha⁻¹ in the field did not result into an increase of plant height. This could be due to luxurious consumption of nutrients by the crops leading to no increase in growth.

NPK fertilizer rates and growing environment had a significant effect on stem diameter of pepino melon plants. The average stem diameter of 4.08cm in capsicum plants which were supplied with NPK 150:120:60 kg ha⁻¹ compared to the other NPK fertilizer rates and the control [18]. Stem diameter is one of the most important sites for the storage of food materials from photosynthesis and can be influenced by the nutrients present in the soil [23]. Plants which were grown in the greenhouse had a larger stem diameter compared to those grown in the open field. This may be due to increased photosynthesis and respiration due to the favorable micro climatic conditions in the greenhouse [24].

NPK fertilizer treatments significantly influenced the vegetative performance of pepino melon plants. Plants which were supplied with 400 kg NPK ha⁻¹ had the highest number of leaves in both environments and this could be due to the high amount of nitrogen in the fertilizer. Nitrogen is a component of the chlorophyll molecule and promotes vegetative growth which in turn helps in flowering and fruit set. Similar results were reported by Babatunde et al., [25] where application of NPK fertilizer (15:15:15) had a significant effect on number of leaves of tomato plants. Nafiu et al., [26] also reported that application of 300 kg NPK ha⁻¹ on okra led to increased number of leaves compared to the control and the other treatments, in this experiment 300 kg NPK ha⁻¹ was the highest

fertilizer treatment. Furthermore, Okonwu and Monsah [27] reported that application of 350 kg NPK ha⁻¹ led to increased number of leaves of pumpkin. On the contrary, Gloria et al., [28] reported that application of NPK fertilizer rates did not have a significant effect on the number of leaves of okra. The increase in number of leaves in our study can be attributed to nitrogen supply in the fertilizer applied and the fact that nutrient availability especially nitrogen influenced plant vegetative development which is in agreement with Babatunde et al., [25]. The low number of leaves in the control treatments could be due to low levels of nitrogen.

Number of branches was greatly influenced by the growing environment and NPK fertilizer application. Naik et al., [24] also reported increased number of branches of tomato plants grown in the greenhouse. Similarly, Lego et al., [18] reported that application of NPK 150:120:60 kg ha⁻¹ led to an increase in the number of branches of capsicum (*Capsicum annum* L.) cv Asha. The significant difference observed in the number of branches can be due to the fact that the NPK fertilizer applied to the soil was readily available in a form that is readily absorbed by plant roots and thereby resulting to a significant increase in the morphological growth of the plants [29]. The number of branches is positively correlated to yield. On the contrary, Nafiu et al., [26] reported that an increase in the number of branches did not lead to increased okra fruit production as expected. This might be due to the fact that other shoot characteristics were favored in growth at the expense of fruit production. Nafiu et al., [26] reported that okra plants that received an application of 300 kg NPK ha⁻¹ had the highest number of primary branches.

Statistically significant results were observed for days taken to flowering. Plants which were not supplied with any fertilizer (control) took the shortest time to flower while those supplied with the highest fertilizer rate 400 kg NPK ha⁻¹ took the longest time to flower. Kumar et al., [30] reported that increasing levels of NPK delayed flowering of tomato plants. On the contrary, Imran et al., [31] reported that cucumber plants which were not supplied with any fertilizer took the longest time (38 days) to flower compared to application of 1000 g fertigation⁻¹. In this study it was observed that greenhouse plants flowered earlier compared to field grown plants. Similarly, Nkansah et al., [32] reported that sweet pepper plants grown in the greenhouse flowered earlier than those grown in the open field. This could be due to the micro climate in the greenhouse. Pepino plants supplied with 400 kg NPK ha⁻¹ took the longest time to flower in the field and greenhouse. This was attributed to excessive nitrogen which favored vegetative growth at the expense of flower development. The short time taken by pepino plants which were not supplied with NPK fertilizer (control) to attain 50% flowering in both environments could be due to lack of essential nutrients which are needed by plants for growth.

There was a significant effect of NPK fertilizer rates and growing environment on fruit weight of pepino melon. Field grown plants supplied with 300 kg NPK ha⁻¹ had the highest fruit weight in both trials. However, it was noted that application of NPK fertilizer beyond 300 kg NPK ha⁻¹ did not significantly increase fruit weight of pepino plants grown in the field. Results of this study for both greenhouse and field grown pepino melons are in agreement with those of Oloyede et al., [33] who found that increasing NPK fertilizer rate led to an increase in fruit weight of pumpkin up to a point beyond which there was no significant increase pumpkin fruit weight. Temperature plays a very important role in growth and development of fruits in most fruit vegetables [34]. High air temperature encourages early fruit production compared to vegetative growth and this might eventually lead to less fruit production [35]. Low air temperatures lead to increased number of flowers, late ripening and large fruits [36]. This might be the reason why field grown fruits had a higher fruit weight compared to greenhouse grown fruits. Papadopoulos and Hao [37] reported that day temperatures of 19°C led to early yields, total yield and the best fruit weight for greenhouse grown tomatoes. Therefore, if the temperature is above 19°C fruit size will be reduced and this is due to decreased pollination and fertilization at high temperatures [38]. The temperature in the greenhouse were above 19°C most of the months and this may be the cause for low fruit weight of greenhouse grown pepino melons. Increase in temperature leads to a decrease in fruit weight and this could be due to reduced translocation of sugars [39]. Results of this study are in agreement with those of Ahumada and Cantwell [40] who reported that the fruit weight of pepino melon ranged from 100 to 500 g. On the

contrary, lower fruit weight of 268 g, 80-250g and 181-330 g of pepino melon have been reported [41-43]. Similarly, Martinetti and Paganini [44] reported that increased fertilizer rates led to an increase in fruit weight up to a point beyond which there was no significant increase in fruit weight. The low fruit weight obtained following application of 400 kg NPK ha⁻¹ could be attributed to excess nitrogen which leads to reduced plant growth, small leaves, stunted root systems and in severe cases death [45].

NPK fertilizer rates and growing environment had a significant effect on total yield of pepino melon. Field grown pepino melon plants had the highest yield compared to greenhouse grown plants. Application of 300 kg NPK ha⁻¹ for field grown pepino melons gave the highest total yield in both trials. Similar trend of results was obtained by Gloria et al., [28] who reported that application of NPK fertilizer increased the yield of okra plants. In the study, okra plants which were supplied with 13g of NPK had the highest yield and control had the lowest yield. The results of our study are in harmony with the findings of Omotoso and Shitu [46] who concluded that increasing NPK fertilizer rates led to an increase in the yield of okra plants. In this study field grown pepino plants had a high total yield compared to greenhouse grown plants. On the contrary, Nkansah et al., [32] reported high yield for greenhouse grown sweet pepper compared to open field grown sweet pepper plants. In a study by Cavusoglu et al., [41] the yield of pepino melon was found to be 3.68 t ha⁻¹ to 14.03 t ha⁻¹. This was higher than the yield recorded in this study, however, Cavusoglu et al., [41] reported that the yield of pepino melon depends on climatic conditions. In this study, the low yield recorded in the greenhouse might be due to increased flower abortion as compared to field where flower abortion was minimal. Flower abortion occurred in the greenhouse because of high temperatures. In trial one the average temperature in the greenhouse ranged from 21°C to 35.8°C, whereas in trial two it ranged from 18.5°C to 35.3°C (Table 2). It was noted that flower abortion occurred when the temperature in the greenhouse was above 30°C. When the temperatures are above 30°C, this contributed to poor conditions for pepino melon fruit formation [47]. Temperature is vital for fruit set in most solanaceous vegetables [48]. In tomato, a mean daily temperature of 29°C leads to a decrease in fruit number and fruit weight [49]. This could be due to the fact that the reproductive organs of most solanaceous vegetables are highly sensitive to high temperature compared to the vegetative organs [50]. Furthermore, temperatures above 23°C affects one or more processes involved in successful fertilization [51]. Metabolic processes in tomato are favored by temperatures of between 25-30°C while fruit set requires a mean daily temperature of 21-24°C [52]. The reduced yield in the greenhouse grown pepino fruits could be due to high temperatures which could have led to impaired pollen germination, pollen tube growth and fertilization resulting to flower abortion and hence reduced fruit set [53]. High temperature in tomato plants led to a decrease in sucrose uptake to the developing flower buds and this causes flower abortion and this may also have been the case in greenhouse grown pepino melons [54]. Additionally, high day time temperatures in pepper lead to a decrease in the activity of acid invertase in the developing flower buds and this explains the inability of reproductive organs to take up assimilates [55]. Apart from reducing up take of carbohydrates in the developing flower buds, high temperature also leads to increased production of ethylene by the flowers and this will also lead to flower abortion but this will depend on the cultivar [56]. Under high temperatures conditions low fruit set is caused by reduced pollen viability [57]. Decrease in pollen viability may be due to changes which occur during the development of the anthers [52]. During the tetrads stage, high temperature affects the structure and function of the tapetum which plays a vital role of providing nutrients to the pollen mother cells and regulating the release of pollen grains [52]. Fruit set in tomato was reduced under high temperatures due to reduced release of pollen grains [58]. The malfunctioning of the tapetum causes pollen sterility and this have led to the low fruit set leading to low yields for greenhouse grown plants. High temperature during the tetrads stage in tomatoes causes enlargement of the tapetal cells and this leads to pollen sterility [59]. In summary the results of this study are in agreement with the findings of [49], [57-59] and also with another study which was carried out in a glasshouse in Turkey, where it was observed that when the temperature was above 25°C flower formation and fruit set of pepino melon was negatively affected [41]. The field temperature during this study ranged from 19.7°C to 22.8°C in trial one and 18.9°C to 20.5°C in trial two (Table 2), thus

reduced flower abortion and hence the high yield recorded in the field grown pepino melons in the two trials. The low temperature recorded in the field might have led to an increase in the number of floral organs possibly due to the initiation of a high number of flower primordia [60]. This might explain the high total yield recorded for the field grown pepino melons because high yield depends on profusion of flowering, successful pollination and fertilization.

Conclusions

Growth parameters were favored by growing pepino melon in the greenhouse. However, yield in the greenhouse was not as high as it was in the field. Application of 300 kg NPK ha⁻¹ and growing of pepino melons in the field gave the highest fruit weight and yield. Application of NPK fertilizer beyond 300 kg ha⁻¹ for field grown pepino melons is uneconomical as it does not result to a significant increase in yield. On the other hand, control recorded the lowest growth, fruit weight and yield in both field and greenhouse.

It is therefore recommended that field grown pepino melons should be supplied with 300 kg NPK ha⁻¹ for optimum fruit weight and yield at the location where this experiment was conducted. Yield may vary depending on climatic conditions, soil, environmental conditions and plant nutrition.

Conflict of Interest

Authors have declared that they do not have any conflict of interest regarding this manuscript.

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