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Postharvest quality of pepino melon (*Solanum muricatum* Aiton) as influenced by NPK fertilizer rates, growing environment and storage temperature

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All relevant data are within the paper and its Supporting Information files.

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Abstract: The present study evaluated the effect of NPK fertilizer (17:17:17) rates (0, 100, 200, 300 and 400 kg ha^{-1}) on the postharvest quality of field and greenhouse grown pepino melons (*Solanum muricatum* Ait.) stored at room temperature (15-22°C) and at low temperature (7°C). The study was carried out in randomized complete block design with fruits from the field and greenhouse, five NPK fertilizer rates as treatments and the two storage temperatures replicated three times. Data were collected on percentage fruit weight loss (PWL), total soluble solids (TSS), firmness and shelf life. Results indicated that greenhouse and field grown fruits from the control and plants supplied with 100 kg NPK ha^{-1} had low PWL at both storage temperatures. Field grown fruits from the control stored at room temperature had the highest TSS and were firmer after 28 days of storage. Field grown fruits not supplied with fertilizer and stored at low temperature had a shelf life of 27 and 26 days in trial one and two respectively. Application of 100 kg NPK ha^{-1} and storage of pepino melon fruits at low temperature can be used to enhance quality and shelf life.

1. Introduction

Pepino melon (*Solanum muricatum* Aiton) is a little-known vegetable crop which belongs to the family solanaceae. It originated from the tropical and subtropical region of Andes and is grown for its edible fruits (Heiser, 1964). Pepino melon fruits are aromatic, juicy, scented, mild sweet, and vary in size, shape and colour depending on the cultivar (Martinez-Romero *et al*., 2003). The fruits mature 30 to 80 days after pollination and the skin is usually golden yellow with purple stripes (Nuez and Ruiz, 1996). Several studies have reported significant losses in horticultural produce after harvest (Toktam *et al*., 2019). Such losses are caused by dehydration, decay, and physiological disorders during postharvest handling. Fresh fruits and vegetables also undergo rapid transformation in nutritional and sensory quality after harvest, some of which contribute to loss of market value (Ahmad and Siddiqui, 2015). The losses can be reduced through good management of pre- and postharvest factors (Toktam *et al*., 2019).

Postharvest quality is also affected by climatic factors such as temperature and light intensity, and other pre-harvest factors like soil type, fertilization, irrigation, mulching, and other cultural practices (Toktam *et al*., 2019). Temperature affects growth and development of fruits and vegetables as well as cellular compounds, their structure and this in turn affects produce firmness (Toktam *et al*., 2019). Fertilizers have also been shown to influence postharvest quality of most fruits and vegetables. The type of fertilizer used and the amount applied will dictate the quality of the resulting vegetables (Arah *et al*., 2015). Application of potassium fertilizers on tomato has been shown to improve fruit colour, reduce the occurrence of yellow shoulder and enhance titratable acidity (Passam *et al*., 2007). On the other hand, application of high doses of nitrogenous fertilizers to greenhouse grown tomatoes reduces fruit quality by reducing total soluble solids (Passam *et al*., 2007).

Temperature management between the time of harvesting and consumption has been shown to be effective in maintaining the quality of harvested vegetables. High temperatures increase metabolic activities and ethylene production but this is dependent on other factors like oxygen or carbon dioxide levels, time of exposure and the ripening stage (De Wild *et al*., 2003). Storage of vegetables at low temperature slows down metabolic processes and hence extends the shelf life of horticultural produce (Arah *et al*., 2015). The present study sought to investigate the effect of NPK fertilizer rates, growing environment and storage temperature on the postharvest quality of pepino melon.

2. Materials and Methods

Experimental 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. 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 (Jaetzold and Schimdt, 2006). The greenhouse used was 8 m by 60 m and the covering material was polythene with a thickness of 12×150 microns purchased from Amiran Kenya Ltd. The mean monthly temperatures in the greenhouse and field during the experiment are presented in Table 1.

Plant material and experimental design

Pepino seedlings (Ecuadorian Gold variety) were obtained from Garlic and Pepino Farm, Nakuru and planted in the field and greenhouse. The experimental design was randomized complete block design (RCBD) with fruits from the five NPK fertilizer treatments, the two growing environments and two storage temperatures replicated three times. The five NPK fertilizer treatments were [0, 100, 200, 300 and 400 NPK (17:17:17) kg ha^{-1}], two growing environments (field and greenhouse) and two storage temperatures (room and low temperature). Mature green pepino fruits were harvested from the field and greenhouse experiments and stored at low temperature (7°C) in a refrigerator and at room temperature (15-22°C) in the biotechnology laboratory of

Table 1 - Average monthly field and greenhouse temperature (°C) in trial one and two

Experimental conditions	Temperature						
	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

Egerton University. The experimental design was RCBD consisting of fruits from the five treatments replicated three times. The experiment therefore comprised of five treatments similar to those of the field and greenhouse experiments each replicated three times giving a total of thirty experimental units each represented by a plastic tray. Each experimental unit comprised of twenty pepino fruits randomly selected from the harvest of the individual respective treatments in the field and greenhouse experiments.

Data collection and analysis

Data were collected and recorded on percentage fruit weight loss (PWL), firmness, total soluble solids (TSS) and shelf life. To determine PWL, five fruits in each replication for each treatment were marked before storage and weighed using a digital balance (HANGPING JA 12002, Japan). The same fruits were weighed at the beginning of the experiment and weighing continued at an interval of 7 days for 28 days. The results were expressed as the percentage loss of initial weight using the formula:

$$\text{Percentage weight loss} = \frac{\text{Initial weight-final weight}}{\text{Initial weight}} \times 100$$

Fruit firmness was determined using hand held penetrometer (model 62/DR, UK) from the beginning of the experiment and continued at an interval of 7 days for 28 days. The results were reported in kg Force. TSS was determined on the same fruits used for determination of firmness using a hand held refractometer (0-30°Brix) (RHW refractometer, Optoelectronic Technology Company Ltd, UK) was used as per the procedure described by Tigchelaar (1986). Results were expressed as °Brix. This was done at the beginning of the experiment and continued at an interval of 7 days for 28 days.

The shelf life of pepino fruits was determined by counting the number of days at which at least 50% of the fruits had reached senescence and were not marketable (too soft, wrinkled or with fungal rots). Quality evaluation was done using a rating scale of 1-5 (Miguel and Marita, 1996).

Data collected were 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 (SAS Institute, 2005) was used for data analysis.

3. Results

Percentage weight loss (PWL)

NPK fertilizer rates, growing environment and storage temperature had a significant effect at $p \leq 0.05$ on PWL of Pepino fruits after 28 days of storage in trial one. During this trial, highest PWL of 10.863% and 15.77% were recorded in greenhouse grown fruits from plants supplied with 300 and 400 kg NPK ha^{-1} during production as well as in field grown fruits from plants supplied with 400 kg NPK ha^{-1} regardless of the storage temperature (Table 2). The lowest PWL was, on the other hand, recorded in greenhouse and field grown fruits without NPK fertilizer application (control) stored at low temperature although the difference in weight loss for this treatment was not significantly different from that of other treatment combinations. In trial two, NPK fertilizer rates, growing environment and storage temperature had a significant effect on PWL from day 7 to day 28 of the study. On day 28, greenhouse and field grown fruits from plants supplied with 400 kg NPK ha^{-1}, stored at room temperature had the highest PWL of 19.38% and 15.54% respectively (Table 2).

It was noted that as the fertilizer rates increased the PWL also increased in both growing environments and storage temperatures in both trials. Generally, fruits stored at low temperature had lower PWL compared to those stored at room temperature in both trials. Greenhouse grown fruits also had a higher PWL compared to field grown fruits in both trials.

Total soluble solids (TSS)

NPK fertilizer rates, growing environment and storage temperature had a significant effect at $p \geq 0.05$ on TSS of pepino fruits from day 7 to day 28 in both trials. In trial one, field grown fruits from plants which were not supplied with fertilizer (control) and stored at room temperature had the highest TSS from day 7 to day 28. The highest TSS was recorded after 28 days of storage where field grown fruits from plants not supplied with NPK fertilizer and stored at room temperature had a TSS of 8.67 °Brix which was significantly higher than that recorded from fruits from all other treatment combinations. Greenhouse grown fruits from plants supplied with the highest fertilizer rate of 400 kg NPK ha^{-1} and stored at low temperature had the lowest TSS of 4.40°Brix after 28 days (Table 3). In trial two, field grown fruits from plants not supplied with NPK fertilizer (control) and stored at room tem-

Table 2 - Effect of NPK fertilizer rates, growing environment and storage temperature on percentage weight loss of pepino fruits in trial one and two

Storage temperature	Environment	Fertilizer (kg ha^{-1})	Weight loss			
			Day 7	Day 14	Day 21	Day 28
Trial one						
Room temperature	Field	0	1.067	2.050	2.837	3.987def
		100	1.423	2.800	3.620	5.303 def
		200	1.980	3.580	4.713	6.383 cdef
		300	2.500	5.147	5.717	9.120 bcd
		400	4.417	7.280	11.353	12.457 ab
	Greenhouse	0	1.213	1.840	2.820	3.413 ef
		100	2.037	4.317	5.590	7.047 cde
		200	2.673	5.540	7.160	8.913 bcd
		300	3.167	6.400	8.720	10.863 abc
		400	5.810	9.327	11.410	15.770 a
Low temperature	Field	0	0.523	1.043	1.283	1.557 f
		100	0.917	1.720	1.997	4.300 def
		200	1.057	2.170	2.763	2.310 ef
		300	1.740	3.883	4.040	7.120 cde
		400	2.737	5.497	8.020	15.123 a
	Greenhouse	0	0.543	1.087	1.630	2.173 ef
		100	1.063	1.353	2.070	2.633 ef
		200	1.543	2.417	2.867	4.012 def
		300	2.240	2.977	5.080	3.183 ef
		400	3.950	6.107	9.067	8.630 bcd
Trial two						
Room temperature	Field	0	0.940 ij	1.173 kl	1.443 kl	4.187 fghi
		100	1.893 fghi	2.633 fghijk	3.123 fghij	7.100 defg
		200	2.507 efgh	3.130 defghi	4.590 cdefg	8.723 cde
		300	3.667 bcd	4.773 cde	5.653 cd	11.690 bc
		400	4.550 b	7.363 b	10.883 b	15.543 ab
	Greenhouse	0	1.156 hij	1.670 ijkl	1.943 ijkl	3.360 fghi
		100	3.067 cdef	3.077 efghi	4.230 defgh	7.293 def
		200	3.703 bcd	4.333 cdef	5.327 cd	9.290 cd
		300	4.113 bc	4.813 cd	6.190 c	11.600 bc
		400	6.617 a	10.477 a	14.703 a	19.397 a
Low temperature	Field	0	0.663 j	0.917 l	1.283 l	1.653 i
		100	1.047 ij	1.420 ijkl	1.997 ijkl	2.243 hi
		200	1.970 efghi	2.173 hijkl	2.783 hijkl	2.487 hi
		300	2.720 defg	2.887 fghij	3.533 efghi	3.017 ghi
		400	4.127 bc	3.997 cdefg	4.740 cdef	5.967 defgh
	Greenhouse	0	1.607 ghij	1.337 jkl	1.720 jkl	2.190 hi
		100	2.313 efgh	2.473 ghijkl	2.993 ghijk	4.593 efghi
		200	3.117 cde	3.520 defgh	4.223 defgh	5.330 defghi
		300	3.693 bcd	4.163 cdefg	4.823 cde	4.880 efghi
		400	4.473 b	5.487 c	6.20 c	5.930 defgh

* Means followed by the same letters in a given day and trial are not significantly different according to Tukey's Honestly Significant Difference Test at $p \leq 0.05$. Room storage temperature varied between 15 and 22°C. Low temperature was 7°C.

Table 3 - Effect of NPK fertilizer rates, growing environment and storage temperature on TSS (°Brix) of pepino melon fruits in trial one and two

Storage temperature	Environment	Fertilizer (kg ha^{-1})	TSS (°Brix)				
			Day 0	Day 7	Day 14	Day 21	Day 28
Trial one							
Room temperature	Field	0	4.00	6.00 a	6.93 a	7.83 a	8.67 a
		100	4.00	4.37 cde	5.73 b	6.13 c	6.40 bcde
		200	4.00	4.53 cde	4.97 c	5.73 cd	6.13 cdef
		300	4.00	4.53 cde	4.90 c	5.47 de	5.80 defg
		400	4.00	4.17 de	4.67 cde	4.80 ghi	5.20 ghi
	Greenhouse	0	4.00	5.00 b	6.00 b	6.77 b	7.07 b
		100	4.00	4.40 cde	4.90 c	5.47 de	5.80 defg
		200	4.00	4.47 cde	4.90 c	5.23 ef	5.67 fgh
		300	4.00	4.17 de	4.63 cde	4.86 fghi	5.10 ghij
		400	4.00	4.10 e	4.30 ef	4.53 hijk	4.80 ij
Low temperature	Field	0	4.00	5.00 b	5.63 b	6.00 c	6.83 bc
		100	4.00	4.60 bcd	4.83 c	5.13 efg	5.77 efg
		200	4.00	4.43 cde	4.63 cde	4.97 fg	5.27 ghi
		300	4.00	4.30 de	4.40 def	4.73 ghij	4.97 hij
		400	4.00	4.10 e	4.13 f	4.33 jk	4.56 ij
	Greenhouse	0	4.00	4.77 bc	5.00 c	5.90 c	6.50 bcd
		100	4.00	4.60 bcd	4.77 cd	4.93 fghi	5.23 ghi
		200	4.00	4.47 cde	4.63 cde	4.80 ghi	4.97 hij
		300	4.00	4.30 de	4.33 ef	4.50 ijk	4.73 ij
		400	4.00	4.17 de	4.10 f	4.20 k	4.40 j
Trial two							
Room temperature	Field	0	4.00	5.60 a	6.70 a	7.60 a	8.133 a
		100	4.00	4.50 cde	5.36 c	5.67 d	6.10 cd
		200	4.00	4.33 defg	4.97 cde	5.26 ef	5.77 def
		300	4.00	4.17 efg	4.53 fghi	4.80 ghi	5.00 hij
		400	4.00	4.60 g	4.13 ijk	4.27 j	4.50 jkl
	Greenhouse	0	4.00	4.70 bc	5.23 c	6.07 c	6.50 bc
		100	4.00	4.50 cde	4.80 def	5.10 efg	5.50 efgh
		200	4.00	4.33 defg	4.97 cde	4.87 ghi	5.13 ghi
		300	4.00	4.13 fg	4.53 fghi	4.60 ij	4.90 ijk
		400	4.00	4.03 g	4.07 k	4.27 j	4.47 kl
Low temperature	Field	0	4.00	5.27 a	5.83 b	6.47 b	6.93 b
		100	4.00	4.60 bcd	5.00 cde	5.37 de	5.83 def
		200	4.00	4.30 defg	4.70 efg	4.93 fghi	5.43 fgh
		300	4.00	4.13 fg	4.50 fghij	4.70 hi	5.00 hij
		400	4.00	4.07 fg	4.10 jk	4.27 j	4.60 jkl
	Greenhouse	0	4.00	4.87 b	5.17 cd	5.67 d	6.00 cde
		100	4.00	4.50 cde	4.77 defg	5.00 efgh	5.53 efg
		200	4.00	4.30 defg	4.53 fghi	4.73 ghi	5.00 hij
		300	4.00	4.13 fg	4.37 ghijk	4.60 ij	4.83 ijk
		400	4.00	4.03 g	4.13 ijk	4.23 j	4.30 l

* Means followed by the same letters in a given day and trial are not significantly different according to Tukey's Honestly Significant Difference Test at $p \leq 0.05$. Room storage temperature varied between 15 and 22°C. Low temperature was 7°C.

perature had the highest TSS from day 14 to day 28. On day 7, field grown fruits from plants not supplied with NPK fertilizer and stored at room or under low temperature had the highest TSS of 5.6 and 5.27 °Brix, respectively (Table 3). The highest TSS was recorded after 28 days of storage where field grown fruits from plants not supplied with NPK fertilizer and stored at room temperature had a TSS of 8.13 °Brix which was significantly higher than for greenhouse grown fruits from plants supplied with 400 kg NPK ha^{-1} and stored at low temperature with a TSS of 4.3°Brix. It was observed that TSS increased as the storage time progressed and decreased as the fertilizer rates increased regardless of the environment under which the fruits were produced and the temperature during storage. Generally, field grown fruits had higher TSS compared to greenhouse grown fruits regardless of the storage temperatures in both trials. On the other hand, fruits stored at low temperature had lower TSS values compared to those stored at room temperature in both trials.

Firmness

NPK fertilizer rates, growing environment and storage temperature had a significant effect on firmness of pepino melon fruits on day 7 and day 28 in trial one, and day 21 and 28 in trial two. In day 7 of trial one, field grown fruits from plants which were not supplied with NPK fertilizer and stored at either room or low temperature had the highest firmness of 4.67 kg F and 4.83 kg F, respectively. However, this was not significantly different from the firmness of 4.57 kg F recorded for greenhouse grown fruits harvested from plants not supplied with NPK fertilizer and maintained under low temperature during storage. On day 28, the highest firmness was recorded in field grown fruits from plants not supplied with NPK fertilizer and stored at low temperature with a firmness of 3.83 kg F. The lowest firmness of 0.52 kg F was recorded in greenhouse grown fruits from plants supplied with 400 kg NPK ha^{-1} and stored at room temperature after 28 days of storage (Table 4).

In trial two, NPK fertilizer rates, growing environment and storage temperature had a significant effect on firmness of pepino melon fruits at day 21 and day 28 of storage. In day 21 of storage, field grown fruits from plants not supplied with NPK fertilizer and stored at low temperature had the highest firmness of 4.13 kg F but this was not significantly different from the firmness of 3.93 kg F recorded from greenhouse fruits from plants not supplied with NPK fertilizer and stored at low temperature, field grown fruits from plants not supplied with NPK fertilizer stored at room temperature with a firmness of 3.70 kg F and field grown fruits from plants supplied with 100 kg NPK ha^{-1} maintained under low temperature with a firmness of 3.67 kg F (Table 4). The lowest firmness of 1.70 kg F was recorded in greenhouse grown fruits from plants supplied with 400 kg NPK ha^{-1} stored at low temperature but this was not significantly different from the other treatment combinations.

Generally, it was observed that field grown fruits were firmer compared to greenhouse grown fruits and fruits stored at low temperature were firmer compared to those stored at room temperature. Firmness also decreased as the fertilizer rates and storage days increased.

Shelf life

NPK fertilizer rates, growing environment and storage temperature had a significant effect ($p \leq 0.05$) on the shelf life of pepino melon fruits in both trials. In trial one, field grown pepino fruits from plants which were not supplied with NPK fertilizer (control) and stored at low temperature (7°C) had the longest shelf life of 27 days. Field grown fruits from plants supplied with 100 kg NPK ha^{-1} stored at low temperature had shelf life of 22 days but this was not significantly different from the shelf life of greenhouse grown fruits from plants not supplied with NPK fertilizer and those supplied with 100 kg NPK ha^{-1} and maintained at low temperature with a shelf life of 21 and 19 days respectively (Table 5). The lowest shelf life of 11 days was recorded in greenhouse grown fruits from plants supplied with 400 kg NPK ha^{-1} and stored at room temperature although this was not significantly different from that of field grown fruits from plants supplied with 300 and 400 kg NPK ha^{-1} and stored at room temperature, greenhouse grown fruits from plants supplied with 200 and 300 kg NPK ha^{-1} and stored at room temperature and field grown fruits from plants supplied with 400 kg NPK ha^{-1} and stored at low temperature.

In trial two, field grown pepino fruits from plants not supplied with NPK fertilizer and stored at low temperature had the longest shelf life of 26 days, followed by field grown fruits from plants supplied with 100 kg NPK ha^{-1} stored at low temperature with a shelf life of 21 days. The shelf life recorded for fruits from this treatments was, however, not significantly different from that of greenhouse grown fruits from plants not supplied with fertilizer, those supplied with 100 kg NPK ha^{-1} and stored at low temperature and field grown fruits from the control and stored at room temperature (Table 5). The lowest shelf life was recorded in greenhouse grown fruits from plants supplied with 400 kg NPK ha^{-1} stored at room temperature with a shelf life of 10 days but this was not significantly different from the shelf life recorded for greenhouse grown fruits from plants supplied with 200 and 300 kg NPK ha^{-1} stored at room temperature and that of field grown fruits from plants supplied with 400 kg NPK ha^{-1} and stored at room temperature.

Generally, it was observed that fruits stored at

Table 4 - Effect of NPK fertilizer rates, growing environment and storage temperature on firmness (kg) of pepino melon fruits in trial one and two

Storage temperature	Environment	Fertilize (kg ha-1)	Firmness (Kg)				
			Day 0	Day 7	Day 14	Day 21	Day 28
Trial one							
Room temperature	Field	0	5.00	4.67 a	4.03	3.60	3.03 b
		100	5.00	3.90 c	3.27	3.03	2.77 bc
		200	5.00	3.57 cde	3.20	2.87	2.37 cdef
		300	5.00	3.03 ef	2.57	2.00	1.57 hijk
		400	5.00	2.83 f	2.33	1.50	1.02 kj
	Greenhouse	0	5.00	3.97 bc	3.57	2.90	2.47 cdef
		100	5.00	3.73 cd	3.13	2.23	2.07 efgh
		200	5.00	3.43 cdef	2.83	2.13	1.80 ghij
		300	5.00	2.93 ef	2.20	1.83	1.50 ijk
		400	5.00	2.17 g	1.87	1.27	0.52 l
Low temperature	Field	0	5.00	4.83 a	4.77	4.33	3.83 a
		100	5.00	3.97 bc	3.67	3.37	2.70 bcd
		200	5.00	3.83 cd	3.40	3.07	2.50 bcde
		300	5.00	3.57 cde	3.20	2.83	2.17 defg
		400	5.00	3.33 cdef	2.97	2.17	1.50 ijk
	Greenhouse	0	5.00	4.57 ab	4.40	3.30	3.03 b
		100	5.00	3.53 cde	3.30	2.73	2.27 cdefg
		200	5.00	3.20 def	2.93	2.40	1.93 fghi
		300	5.00	3.00 ef	2.57	2.13	1.57 hijk
		400	5.00	2.87 f	2.20	1.80	1.27 jk
Trial two							
Room temperature	Field	0	5.00	4.63	4.07	3.70 abc	2.73 bc
		100	5.00	3.90	3.67	3.10 def	2.60 bc
		200	5.00	3.80	3.17	2.87 efgh	2.13 def
		300	5.00	3.43	2.87	2.17 ijk	1.87 fg
		400	5.00	3.00	2.43	1.90 jk	1.20 ij
	Greenhouse	0	5.00	4.27	3.80	3.07 def	2.47 cde
		100	5.00	3.93	3.27	2.80 fgh	2.03 efg
		200	5.00	3.60	3.00	2.40 hij	1.70 fgh
		300	5.00	3.13	2.63	2.00 jk	1.30 hi
		400	5.00	2.90	2.20	1.70 k	0.85 j
Low temperature	Field	0	5.00	4.70	4.37	4.13 a	3.83 a
		100	5.00	4.40	3.93	3.67 abc	2.83 bc
		200	5.00	4.13	3.60	3.33 cde	2.93 b
		300	5.00	3.93	3.37	3.07 def	2.63 bc
		400	5.00	3.63	3.07	2.77 fgh	2.07 defg
	Greenhouse	0	5.00	4.27	4.07	3.93 ab	3.40 a
		100	5.00	4.03	3.87	3.50 bcd	2.83 bc
		200	5.00	3.83	3.20	2.97 efg	2.50 bcd
		300	5.00	3.43	2.87	2.53 ghi	2.10 def
		400	5.00	3.20	2.53	2.17 ijk	1.63 ghi

* Means followed by the same letters in a given day and trial are not significantly different according to Tukey's Honestly Significant Difference Test at $p \leq 0.05$. Room storage temperature varied between 15 and 22°C. Low temperature was 7°C.

low temperature had a longer shelf life than those stored at room temperature. Field grown fruits had a longer shelf life compared to greenhouse grown fruits. The shelf life decreased as the NPK fertilizer rates increased.

4. Discussion and Conclusions

There was a progressive increase in percentage fruit weight loss as the storage days advanced. Field and greenhouse grown fruits from plants which

Table 5 - Effect of NPK fertilizer rates, growing environment and storage temperature on shelf life (days) of pepino melon fruits in trial one and two

Storage temperature	Environment	Fertilizer (kg ha^{-1})	Shelf life (Days)	
			Trial 1	Trial 2
Room temperature (15-22°C)	Field	0	18 cd *	20 bcd
		100	17 cde	18 cdef
		200	15 defg	16 fghij
		300	14 fghi	14 ijk
		400	12 hi	11 lm
	Greenhouse	0	18 cd	17 efgh
		100	16 defg	14 hijk
		200	13 ghi	12 klm
		300	12 hi	10 lm
		400	11 i	10 m
Low temperature (7°C)	Field	0	27 a	26 a
		100	22 b	21 b
		200	18 cd	17 defg
		300	16 def	15 ghij
		400	14 fghi	13 jkl
	Greenhouse	0	21 b	21 bc
		100	19 bc	19 bcde
		200	17 cdef	16 efghi
		300	16 defg	15 ghij
		400	15 efgh	14 ijk

* Means followed by the same letters are not significantly different according to Tukey's Honestly Significant Difference Test at p≤0.05. Room storage temperature varied between 15 and 22°C. Low temperature was 7°C.

received 400 kg NPK ha^{-1} and stored at room temperature had the highest PWL. Similar results were reported in sweet potato in which excessive application of nitrogen led to an increase in percentage weight loss during storage (Mark *et al.*, 2003). Nitrogen fertilizer rates affect the rate of water loss in fruits and vegetables (Warner *et al.*, 2004). Transpiration is the main cause of deterioration because it results in direct loss of weight. Weight loss is the major cause of softening and shriveling of fruits and vegetables damaging the appearance of fruits and loss of market value (Wilson *et al.*, 1999). The quality of most fruits and vegetables is affected by weight loss but this depends on the temperature and humidity during storage (Perez *et al.*, 2003). Storage of pepino fruits at room temperatures (15-22°C) could also have resulted in production of high levels of ethylene, increased respiration and subsequent weight reduction. High temperatures during storage leads to increased water loss resulting to shriveling and loss of fresh appearance of the fruits (Wills *et al.*, 1989). Fruits lose weight when metabolic activities increase and this is accelerated by an increase in temperature around the produce resulting in loss of water. Weight loss is mainly as a result of water loss and as temperature increases the rate of water loss also increases. In this study, pepino melon fruits were harvested when green mature and as ripening progressed there was an increase in ethylene production which led to senescence and shriveling of the fruits during storage (Wills *et al.*, 1989). Greenhouse fruits had a higher percentage weight loss probably because of the high preharvest temperature (Table 1). At room temperature the temperatures were higher than at low temperature (7°C) and this could have resulted to faster ripening, increased respiration rates and hence high PWL. Fruits stored at low temperature had lower PWL compared to those stored at room temperature. Vanitha and Mehalai (2016) also reported that pepino fruits stored at room temperature had a higher weight loss compared to those stored at low temperature. Temperatures above 20°C can lead to abnormal physiological processes in fresh produce, respiration occurs and water is lost to the surrounding environment and hence reduction in weight. Although there was an increase in PWL as the storage days increased, the rate was much lower in pepino fruits stored at low temperature. Loss in weight could also be due to activity of polygalacturonase which increases cell wall permeability and hence increase in transpiration. Low temperature reduces respiration and metabolic processes thereby slowing down the rate of fruit weight loss during storage. Low temperature also reduces the sensitivity of fruits to ethylene and senescence is reduced (Wills *et al.*,1989). In both trials, field and greenhouse grown pepino fruits supplied with the highest NPK fertilizer rate had the highest PWL. This is in agreement with the findings of Hailu *et al*. (2008) and Mark *et al*. (2003) where application of highest nitrogen fertilizer rates had the highest physiological weight loss of carrots and sweet potatoes during storage. The increased PWL due to increased level of nitrogen supply may be attributed to the higher moisture content in the fruits which may lead to decreased shelf-life due to rapid metabolic activity, moisture loss and shrinkage in storage (El-Tantawy and El-Beik, 2009). On the other hand, fruits from the control (no NPK fertilizer) had the lowest PWL which could be attributed to low moisture content in the fruits, slowed metabolic activities and hence reduced moisture loss. The PWL decreased as the phosphorous and potassium rates in the NPK fertilizer increased. This could be due to the fact that potassium plays a role in maintaining fruit firmness but high rates do not result to further increase in firmness. The firmer the fruit the less the PWL and reduction in firmness results to more PWL. On the other hand, high nitrogen levels coupled with high phosphorous levels reduce fruit quality because most of the carbohydrates are translocated to the shoots rather than to the developing fruits resulting to dense vegetative growth. Fruits produced by plants which have dense vegetative growth tend to be less firm resulting to high PWL while fruits from plants with less vegetative growth are firmer and hence low PWL. In summary, PWL progressively increased with increase in storage time in both room and low temperatures. As the fruit continues to ripen the rate of respiration also increases and this also leads to increase in weight loss. However, low temperature leads to delayed ripening and hence reduced respiration resulting to low PWL compared to ambient room temperatures.

TSS increased as the storage days increased. Our results are in agreement with Harman *et al.* (1986) and Hailu (2016) who reported that as pepino melon and mango fruits mature TSS increases significantly during maturation and ripening. The increase in TSS might be due to alteration of cell wall structure and the breakdown of complex carbohydrates into simple sugars. At room temperature, the temperatures were high and this led to an increase in metabolic processes, respiration and ripening resulting to high TSS. Increase in TSS could also be due to excessive moisture loss of fruits which led to increased concentration of pepino fruits stored at room temperature (Nath *et al*., 2011). At high temperatures the rate of ripening is higher than at low temperatures and this increases TSS. Field grown pepino fruits had a higher TSS compared to greenhouse grown pepino fruits in both storage temperatures. The high TSS recorded in field grown pepino fruits could be due to high light intensity and thus high photosynthesis leading to more accumulation of sugars in the fruit compared to greenhouse grown fruits where the light intensity was low leading to reduced photosynthesis and hence low accumulation of sugars in the fruits (Beckmann *et al*., 2006). Any factor that interferes with photosynthesis will affect glucose and sucrose accumulation in the fruit and thus alter TSS (Rana *et al.*, 2014). High relative humidity in the greenhouse may also have led to reduced transpiration and this enhances flow of water in the xylem vessels and this is good for the fruits because fruits act as drains for high concentrations of organic molecules leading to low water potential (Bertin *et al*., 2000). The low water potential in the fruits promotes absorption of water by the fruits leading to “dilution effect” making the fruits to have low TSS compared to those grown in the field (Rana *et al*., 2014). The low TSS recorded in greenhouse grown fruits could also be due to the fact that high temperatures during ripening of pepino melon reduce sugar content of the fruits (Pluda *et al*., 1993). Fruits stored at low temperature had a lower TSS compared to that of fruits stored at room temperature. This could be due to delayed fruit ripening and slow conversion of carbohydrates into simple sugars. During ripening there is breakdown of complex carbohydrates into simple sugars and this increase TSS. At high temperatures the conversion of carbohydrates into simple sugars is accelerated and this results to high TSS whereas at low temperature ripening is delayed and the hydrolysis of carbohydrates to sugars is slower, resulting to low TSS. In the present study, TSS ranged from 4.00-7.07 and 4.00-8.13 °Brix in trial one and two respectively. Other studies have reported lower TSS of pepino melon in the range of 4.91-5.40 °Brix (Kola, 2010) and 5.04-5.46 °Brix (Maruapey and Yuwono, 2016). The low TSS could be attributed to high water content in pepino fruits in the range of 90-92% (Gonzalez *et al*., 2000) and the fact that the quality of pepino melon fruits is greatly influenced by the environment in which these studies were conducted which is quite different from the environment in this study. TSS decreased as the fertilizer rates increased in both growing environments and storage temperatures in both trials. Field grown fruits from control plants had the highest TSS and this could be due restriction of vegetative growth because no NPK fertilizer was applied and thus the fruits became the only sink for sugars and hence increase in TSS (Pluda *et al*., 1993). Greenhouse grown fruits from plants supplied with the highest fertilizer rate of 400 kg NPK ha^{-1} had the lowest TSS and this might be due to excessive vegetative growth of both the main and side shoots therefore most of the photosynthates were directed to the young developing shoots rather than to the fruits leading to low sugar concentration in the fruits (Pluda *et al.*, 1993). Excess nitrogen fertilizers make plants be more succulent, thus fruits from plants supplied with 400 kg NPK ha^{-1} had a high water content and this might have led to dilution of sugars in the fruit resulting to low TSS.

Fruit firmness decreased as the storage days increased. Decrease in firmness is strongly related to increased weight loss because as the fruits lose weight they become soft hence decreased firmness. In this study, firmness decreased as the NPK fertilizer rates increased. Fruits from plants which were supplied with 400 kg NPK ha^{-1} had the lowest firmness and this could be due to the fact that plants with dense vegetative growth are less firm than those with low or moderate vegetative growth (Toktam *et al.*, 2019). Fruits which were not supplied with NPK fertilizer (control) were firmer due to decreased vegetative growth. Loss of moisture and enzymatic changes results to change in firmness (Ball, 1997). Hemicelluloses and pectins become more soluble and this causes changes and loosening of the cell wall (Paul *et al*., 1999). In the present study, both trials field grown pepino fruits were firmer than greenhouse grown fruits. This could be due to the fact that lower temperature during the growing season increases firmness (Anagnostou and Vasilakakis, 1995). In the greenhouse the temperatures (Table 1) were high and it has been reported that high preharvest temperatures tend to decrease firmness (Paul *et al*., 1999). Previous studies reported that loss of firmness in pepino melon is due to softening which is caused by breakdown of structural cell wall carbohydrates and an increase in soluble pectic substances during storage (Heyes *et al*., 1994). Increase in pectic substances leads to weakening of cell walls and reduction of cohesive forces binding cells together resulting to loss of firmness (Heyes *et al*., 1994). In summary, fruit softening is caused by structural as well as compositional changes in various components of the cell wall carbohydrates partly as a result of fruit softening enzymes (Abbasi *et al*., 2011). Other studies have reported that fruit softening is as a result of cell wall digestion by pectinesterase, polygalacturonase and other enzymes and this is increased by an increase in storage temperature (Ahmed *et al*., 2009). Low temperature storage maintained firmness of pepino melon fruits.

Pepino fruits stored at low temperature had a longer shelf life compared to those stored at room temperature. This could be attributed to reduced ethylene production, respiration, ripening, weight loss, senescence, retention of firmness and reduction of other metabolic activities and this enhances shelf life and quality of produce (Lei Yi *et al*., 2019). On the other hand, pepino fruits stored at room temperature had a shorter shelf life because high temperature results to increased ethylene production, respiration, ripening, weight loss, senescence, loss of firmness and other metabolic processes and this reduced shelf life (Mutari and Debbie, 2011). Field grown fruits had a longer shelf life compared to greenhouse grown fruits. This could be attributed to lower temperature in the field during the growing season (Table 1) as low temperatures have been reported to increase firmness (Anagnostou and Vasilakakis, 1995). In the greenhouse the temperatures were high and it has been reported that high temperatures tend to decrease firmness (Paul *et al*., 1999). Therefore, field grown fruits remained firmer than greenhouse grown fruits and hence the former had a longer shelf life. Fruits from the control had the longest shelf life and this could be attributed to low nitrogen levels and low water content in this fruits hence they remained firmer. On the other hand, fruits from plants supplied with high NPK fertilizer rates had a short shelf life and this might be due to high water content in the fruits due to excess nitrogen which also leads to postharvest decay especially fruits which were stored at room temperature.

Based on the foregoing results and discussion, we conclude that application of high amounts of NPK fertilizer leads to increased weight loss, less firm fruits and low TSS of pepino fruits stored at room temperature. Storage of pepino melon fruits at 7°C maintains quality through reduced weight loss and maintaining firmer fruits. We therefore recommend application of 100 kg NPK ha^{-1} for both field and greenhouse grown pepino melon and storage at low temperature (7°C) for enhanced quality and shelf life of the fruits.

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