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Effect of Nitrogen, Mulch and Gibberellic Acid on Quality of Multi-Purpose Pumpkin (*Cucurbita moschata* Duchesne) Fruits

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Abstract*— Emergence of multi-purpose pumpkin *(Cucurbita moschata Duchesne)* as an African indigenous vegetable is attracting great attention. This is due to its adaptation to a wide range of climates and high-yielding potential. Sub-optimal pre- and post-harvest factors have greatly contributed to low returns to the farmers through poor yields and high post-harvest loss of pumpkins. There is therefore need to determine the optimal pre- and post-harvest inputs which will provide nutritious pumpkin fruits to consumers. To contribute in solving this challenge, knowledge on the effect of nitrogen fertilizer, mulch and gibberellic acid on the fruit size, flesh thickness and firmness of multipurpose pumpkin (Cucurbita moschata Duchesne) is very important. A field experiment was therefore set at the Chuka University farm for two seasons between January 2019 and July 2020.It was arranged in a split-plot in randomized complete block design and replicated three times. Nitrogen (CAN) (0, 50, 100 and 150 kg N/ha), mulch (no mulch, black-painted and unpainted rice straws) and gibberellic acid (GA_3) (0 mg/L, 40 mg/L and 80 mg/L) were assigned to the main plots, split plots and sub-plots respectively. Data was collected fortnightly from the fourth week after emergence. Data values were subjected to analysis of variance using the SAS software and means separated using least significant difference. Application of N fertilizer was significant on fruit size (0.013) during the second season, flesh thickness during the first and the second season (0.002and 0.04respectively) and fruit firmness of 0.02 upper and 0.009 lower during the second season. Application of N at150kg N/ha and black-painted mulch resulted to fruit size of 2172 cm^2 and 2199 cm^2respectivelyand flesh thickness of 3.387cm and 3.856cm respectively which was higher than the other treatments. The effect of GA_3 on fruit size, flesh thickness and firmness of multipurpose pumpkins was insignificant during both seasons. These results show that application of N at 150kg N/ha and black painted mulch would give the best fruit quality to the farmers while application of GA_3 may not necessarily result to beneficial returns.

***Keywords*— AIVs, Fruit size, Flesh thickness, Fruit firmness, Fruit set, Plant growth regulators.**

I. INTRODUCTION

Pumpkins are important horticultural crops worldwide. Pumpkin is a fruit-vegetable belonging to the Cucurbitaceae family together with gourds, melons and squashes. In Kenya, pumpkin production increased from 599 ha in 2015 to 681 ha in 2016, with a volume increase from 3580 metric tonnes to 4017 metric tonnes respectively (Horticulture Validated Report, 2015-16). In Kenya, pumpkin is regarded as a traditional vegetable that is grown in the high potential areas and the arid and semi-arid lands (Karanja et al., 2014). FAO (2005) reported that pumpkin has immense economic potential for use both as a food and as an industrial crop. Pumpkin is famous for its edible seeds, fruit and greens (Matsui et al., 1998).

Fertilizer affects the productivity of crops (Oloyede et al., 2013). Poor fruit setting, low crop yield and low nutritional quality result from inadequate levels of the primary nutrients namely: Nitrogen, Phosphorus and Potassium (Martinetti& Paganini, 2006; Liu et al., 2010).Application of N, P and K has been reported to increase the growth and productivity of pumpkin and crops generally (Johannes et al., 2003). Nitrogen (N) is by far the most critical plant growth element, yet soil testing for N is usually not practical due to its mobility in the soil. The use of chemical fertilizers as a supplemental source of nutrients has been on the increase in pumpkin production but they are not applied in balanced proportions by most farmers. Further, NPK fertilizer has been found to increase the leaf area, stem diameter, number of leaves and nutrient contents (N, P, K, Ca, Na and Mg) in the soil in pumpkin production (Okonwu& Mensah, 2012).

Mulches and particularly the clear form have been reported to enhance germination of direct-seeded pumpkins since they increase soil temperatures. The higher soil temperatures associated with mulches should also accelerate establishment of transplants and promote subsequent crop development thereby increasing yields and promoting crop maturity at harvest (Waterer, 2000). The exposed soil is exceptionally susceptible to the destructive effects of heavy rainfall, which causes the soil structure to break apart and intensifies the elimination of nutrients making mulching very necessary (Bucki&Siwek, 2019). Mulches of organic origin typically enter into a relationship with the soil, increasing the activity of the enzymes which break down plant residues (Sas-Paszt et al., 2014). Organic mulches with a high carbon to nitrogen ratio (such as sawdust) may cause temporary soil impoverishment in nitrogen due to the activity of microorganisms (Fang et al., 2007).

According to Yamaguch and Kamiya (2000), gibberellin (GA) hormone plays an essential role in many aspects of plant growth and development of pumpkins such as seed germination, stem elongation and flower development. Gibberellic acid (GA3) is an important PGR that affects plant growth and development by inducing metabolic activities and regulating nitrogen utilization (Sure et al., 2012). It also plays a significant role in seed germination, endosperm mobilization, stem elongation, leaf expansion, reducing the maturation time and increasing flower and fruit set and their composition (Roy &Nasiruddin, 2011). GA_3delays senescence, improves growth and development of chloroplasts and intensifies photosynthetic efficiency which could lead to increased yield (Yuan &Xu, 2001).

II. MATERIALS AND METHODS

2.1. Site and Experiment

The experiment was conducted at Chuka University Ndagani research farm. The farm lies at0^0 19' S, 37^0 38’ E and 1535 m above sea level. The average annual temperature is 19.5 ºC (from 12.2 ºC and 23.2 ºC). The area experiences two rainy seasons with the long rainy season occurring in March through June and the short rainy season from October to December. The average annual rainfall is 1200 mm annually (http://en.climate-data.org). The soils are humicNitisols, deep, strongly weathered, well drained tropical soils with a clayey subsurface horizon made of angular, blocky structural elements that easily crumble into polyhedricipeds with shiny faces. The soil has a high cation exchange capacity (Koskey et al, 2017).

A three factor split-split block experiment embedded in a randomized complete block design (RCBD) with three replications was used. Individual plots in a block measured 2m x 2m separated from each other by 1 m. The three factors were four nitrogen rates, three mulch types and three gibberellic acid (GA) rates. Nitrogen occupied the main plot; mulch the split plots and gibberellic acid the subplots. The four nitrogen rates were 0, 50, 100 and 150 kg/ha. Nitrogen in CAN was applied in two split equal dosages for each rate, at three weeks post-emergence and at the beginning of flowering. Single fertilizers were used. The mulch factor included no mulch, black-painted rice straw and unpainted rice straw. Rice straw was easily available in a close proximity to experimental site and quantities required are easy to get. The black-painted dry rice straw and unpainted dry rice straw was placed on the respective split plots after land preparation. Painting of the rice straw was done by dipping them in a 200 L drum containing the black paint solution and afterwards spread out to air dry. The ingredients of the paint were noted based on the paint that was used. The mulch was uniformly spread to achieve 20 cm thickness. Planting holes were marked and opened during sowing.

Gibberellic acid rates were 0 mg/L, 40 mg/L and 80 mg/L. Gibberellic acid was dissolved in 50ml alcohol then the volume was made up to one liter stock solution by adding distilled water. The required concentration of spray solution was then prepared from stock solution by diluting with distilled water. A few drops of acceptable commercial sticker was added to solutions to facilitate the uptake of the GA. The gibberellic acid solution was sprayed to the plants with a hand sprayer of one liter capacity. Stock solution of lower rate was sprayed first followed by next higher rate. It was done once during the fourth week after emergence. To avoid drift, spraying was done on a calm morning.

Soil analysis was done before plant establishment. It was done at the KALRO National laboratories Kabete. Testing was done to establish the nutrient contents which informed the effects of nitrogen applied in the experiment. The soil was sampled using a zigzag sampling design across the experimental field. A soil auger and plastic containers were used. Two different composite samples were prepared, taken from 0-15 cm and 16-30 cm respectively. The soil pH, total N, available P, K, Ca, Mg, organic carbon, and trace elements were assessed (Chang & Laird, 2002). .

2.2. Data Collection

Data was collected for two seasons (long and short rain seasons). Fruits with dry fruit stalk and hard skin were harvested from each experimental unit, counted, their size, (length and diameter was measured using a tape measure then translated using a ruler) and weight measured. Three fruits were randomly selected per treatment for flesh thickness data which was measured using a Vernier caliper.Fruit firmness was determined through a flesh penetration test which was carried out at room temperature. A penetrometer was used to give direct readings of fruit toughness in kilogram-force.

2.3. Data Analysis

Data values were subjected to analysis of variance to determine effects of the treatments using the SAS software version 9.3. Means separation was performed using the least significant difference (LSD) test at $\alpha = 0.05$.

III. RESULTS

3.1 Effects of Nitrogen Fertilizer on Fruit Size, Flesh Thickness, Upper and Lower Firmness

Nitrogen fertilizer had no significant effect ($P>0.05$) on fruit size during season one (S1)but was significant during season two (S2) ($P<0.05$) (Table 1). Application of 150kg N/ha produced the larger fruit sizes of 2172 cm^2 and 2199 cm^2 respectivelyduring S1 and S2 respectively. In both seasons, the fruit size increased with increase in N fertilizer up to 150kg N/ha. Non-application of N produced the lowest fruit sizes of 1513 cm^2 and 1643 cm^2 at S1 and S2 respectively.

N fertilizer had significant effect on the flesh thickness in both seasons ($P<0.05$). Application of 150kg N/ha produced the highest flesh thickness in both seasons; 3.387 cm and 3.856 cm respectively (Table 1). Flesh thickness increased with increase in N fertilizer up to 150kg N/ha during S1. Non-application of N produced flesh thickness of 3.752 cm during the S2. N fertilizer had no significant effect ($P>0.05$) on fruit firmness (upper and lower) during S1 but was significant during S2 ($P<0.05$) (Table 1). Application of 100kg N/ha produced the highest fruit firmness (upper and lower) of 39.63and 39.07, 38.58 and 38.03 respectively at S1 and S2 respectively. In both seasons, the lower fruit firmness increased with increase in N fertilizer up to 100kg N/ha. This was also the case with upper fruit firmness during S2. Non-application of N produced the least fruit firmness of 37.27 and 35.42 at S1 and S2 respectively.

Table 1: Effects of Nitrogen Fertilizer on Fruit Size, Flesh Thickness, Upper and Lower Firmness

Treatments	Fruit size (cm^2)		Flesh thickness (cm)		Upper Firmness		Lower Firmness	
	S1	**S2**	**S1**	**S2**	**S1**	**S2**	**S1**	**S2**
Control	1513	1643c	2.677b	3.752	38.77	36.66bc	37.27	35.42b
50	1870	1683c	2.837b	3.519	38.69	37.24b	37.46	36.24b
100	2013	1976b	3.191a	3.626	39.63	39.07a	38.58	38.03a
150	2172	2199a	3.387a	3.856	39.31	38.76a	38.24	37.76a
Significance	0.119	0.013*	0.002*	0.04*	0.533	0.02*	0.116	0.009*
LSD 5%	563.8	308.3	0.259	0.221	1.717	0.908	1.243	1.332

*Means followed by the same letters or no letters within a column are not significantly different according to the LSD Test at $P = 0.05$

3.2 Effects of Mulch on Fruit Size, Flesh Thickness, Upper and Lower Firmness

The effect of mulch on fruit size was not significant during S1 ($P>0.05$) but significant during S2 ($P<0.05$) (Table 2). Largest fruit sizes were produced when black-painted rice straws mulch was applied during both seasons at 1948 cm^2 and 2016 cm^2 for S1 and S2 respectively. The effect of mulch was insignificant during both seasons ($P>0.05$). According to the results, when black-painted rice straws mulch was applied, edible fruit flesh thickness was higher compared to the unpainted rice straws mulch or no mulch was applied. Results further showed that application of mulch was only significant (*P*<0.05) on fruit upper firmness during S2. Fruit firmness was highest when black-painted rice straws mulch was applied. However, the difference in firmness was negligible with the application of unpainted rice straws mulch on both the lower and upper fruit firmness.

Table 2: Effects of Mulch on Fruit Size, Flesh Thickness, Upper and Lower Firmness

Treatments	Fruit size		Flesh thickness		Upper Firmness		Lower Firmness	
	S1	**S2**	**S1**	**S2**	**S1**	**S2**	**S1**	**S2**
Control	1812	1726c	3.053	3.522	38.55	36.82b	37.41	36.03
BL	1948	2016a	3.053	3.836	39.58	38.90a	38.25	37.69
BR	1917	1884b	2.963	3.706	39.16	38.08a	37.99	36.87
Significance	0.496	0.001*	0.546	0.605	0.923	0.001*	0.920	0.996
LSD 5%	250	131.8	0.198	0.264	0.822	0.904	0.961	1.639

BL- black-painted rice straws mulch, BR- unpainted rice straws mulch

3.3 Effects of Gibberellic Acid on Fruit Size, Flesh Thickness, Upper and Lower Firmness

Gibberellic acid had no significant effect on fruit size, flesh thickness, upper and lower firmness during both seasons (*P*>0.05). Application of 80 mg/L produced the larger fruit sizes of 1935 cm^2 and 1928 cm^2 respectively at S1 and S2 respectively. In S2, the fruit size increased with increase in GA_3 up to 80 mg/L. Results also showed that application of 40 mg/L of GA_3 resulted to 3.102 cm and 3.744 cm of flesh thickness which was highest compared to when 80 mg/L was applied and when no GA_3 was applied. In S2, both lower and upper fruit firmness increased with increase in GA_3 up to 80mg/L. The effect of GA_3 produced highest fruit firmness when GA_3 of 80mg/L was applied.

Table 3: Effects of Gibberellic Acid on Fruit Size, Flesh Thickness, Upper and Lower Firmness

Treatments	Fruit size		Flesh thickness		Upper Firmness		Lower Firmness	
	S1	**S2**	**S1**	**S2**	**S1**	**S2**	**S1**	**S2**
Control	1911	1825	2.929	3.614	38.99	37.56	37.89	36.82
40	1831	1872	3.102	3.744	38.90	37.89	37.78	36.66
80	1935	1928	3.038	3.706	39.41	38.36	37.99	37.11
Significance	0.717	0.188	0.240	0.312	0.200	0.396	0.152	0.706
LSD 5%	269.4	111.5	0.205	0.175	0.634	1.185	0.666	1.094

IV. DISCUSSION

In this study, quality traits of the multi-purpose pumpkins were enhanced by N fertilizer, mulch and GA_3 across both seasons. The optimum N rate of fertilizer was 150kg N/ha, black painted mulch produced the highest fruit qualities while 80 mg/l of GA_3 positively affected the fruit size, flesh thickness and fruit firmness of multipurpose pumpkins.

Fertilizers have been denoted as sources of plant nutrients that can be added to soil to supply its natural fertility (Oloyede et al., 2013).They are intended to supply plant needs directly rather than indirectly through modification of soil properties like the pH and structure. When appropriate fertilizers are added in the soils, the result is dramatic improvement in both quantity and quality of plant growth (Nahed & El-Aziz, 2007).According to Oluoch (2012), pumpkins tend to develop extensive root systems that efficiently explore the soil for water and available nutrients and thus, timely and appropriate applications of fertilizer can make a significant difference in the quality and quantity of fruit produced which the findings of this study corroborated with.

In this study, application of N fertilizers up to 150kg N/ha increased the fruits size and flesh thickness. The present findings are in agreement with the results of Kazemi (2014) which revealed an increase in fruits sizes of tomatoes using different combinations of fertilizers. This increment might be interpreted that plants during flowering and fruit setting stages need a high amount of nutrients to perform the biological operations like photosynthesis. However, application of N fertilizers beyond 100kg N/kg reduced fruit firmness of the multi-purpose pumpkins. This shows that application of N fertilizer beyond 100kg N/kg makes the pumpkin fruit softer and of inferior handling quality.

Results showed that black painted mulch positively affected fruit size, flesh thickness and fruit firmness of multipurpose pumpkins. The results supports studies done by Lorenzo et al. (2001) and Ibarra-Jimenez et al. (2008) on mulching using black polythene showed higher cucumber yields in comparison with yields from plants cultivated in soil without mulching. Jodaugiene et al. (2010) denoted that as a result of the use of such mulches, increased presence of worms and their greater mass was observed positively affecting the quality of crops.

Results showed that largest fruit sizes were obtained when 80mg/Lof GA_3 was applied. The increase in fruit sizes might be attributed to increased cell division and cell elongation induced by the application of GA3 as also observed by Shah et al. (2006) & Roy &Nasiruddin (2011). Application of GA_3 beyond 40 mg/L reduced fruit flesh thickness. Upper and lower firmness were also highest when 80mg/L of GA_3 was applied. This could be attributed by the fact that GA_3 promotes DNA, RNA and protein synthesis resulting in increased biomass as denoted by Khan and Samiullah (2003).

V. CONCLUSIONS AND RECOMMENDATIONS

A number of studies that have been carried out on the multipurpose pumpkins are usually directed towards the effect of NPK fertilizers and different concentrations of gibberellic acid on the yield without evaluating the specific fertilizer component like N. whatever happens during growth and development of fruits will have a bearing on the fruit size, flesh thickness and fruit firmness. Additionally, the studies on quality parameters like firmness and flesh thickness of crops are not common. The main findings achieved and conclusions arrived at are:

- Nitrogen fertilizer influenced multi-purpose pumpkin fruit quality traits such as fruit size, flesh thickness and fruit firmness. N rate of 150 kg/ha significantly increased the traits and it is recommended for use by the farmers.
- Mulch also significantly affected positively fruit size and fruit firmness of multi-purpose pumpkin. Black painted rice straws produced higher quality traits compared to unpainted rice straws and therefore suitable for use by the farmers.
- Gibberellic acid did not significantly affect fruit size, flesh thickness and fruit firmness of multi-purpose pumpkin and therefore, the study recommends its use by the farmers for other traits other than those tested in this experiment.

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