# INTEGRATED NITROGEN, MULCH AND $GA_3$ SIGNIFICANTLY ENHANCE PHOTOSYNTHATES IN MULTIPURPOSE PUMPKIN FRUITS

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**IJASR 2022**
**VOLUME 5**
**ISSUE 2 MARCH – APRIL** **ISSN: 2581-7876**

**Abstract:** Among the various *Cucurbitaceae* species is multi-purpose pumpkin (*Cucurbita moschata* Duch.),whose seeds, fruits and young leaves are consumed, thereby contributing medicinal, nutritional and food security values. It can also be commercialised to generate income. Photosynthates are crucial building blocksthat drive plant growth, development and yields.It is there fore imperative to enhance photosynthates in plants as they are cornerstones of food production mission. However, in Kenya, multi-purpose pumpkin is often left to grow as a volunteer crop, leading to poor productivity. Consequently, a study was conducted to determine effects of combined nitrogen, mulch and gibberellic acid($GA_3$) onphotosynthate accumulation in multi-purpose pumpkin fruits. Nitrogen rates assessed were 0, 50, 100 and 150 kgN/hasupplied as CAN, mulch types were none, unpainted and black-painted rice straws, and $GA_3$rates were 0, 40 and 80mg/L. The experiment was arranged in split-split plots in randomized complete block design, replicated three times in two seasons, and each plant was spaced at2mx2m. Nitrogen occupied main, mulch sub, and $GA_3$split-plots. Moisture, fat, protein, ash, and total carbohydrates were measured and subjected to analysis of variance using SAS Version 9.3. Significant means were separated using the least significant difference test (α=0.05).Nitrogen had a significantly ($P$≤0.05) negative effect on moisture and total carbohydrates, positive on fat and proteins, and no significant ($P$≥0.05) effect on ash. The effect of mulch was significantly positive on fat, proteins and total carbohydrates, negative on moisture, and not significant on ash. Gibberellic acid had a significantly positive effect on fat and total carbohydrates, negative on moisture and protein contents, and not significant on ash. The interactive effect of combined nitrogen, mulch and $GA_3$on moisture, fat, protein, ash and total carbohydrates was consistently significant, where highest 3.5% proteinswere for $N_3M_0GA_0$ and lowest 4.2% carbohydrates were for $N_3M_2GA_2$. Thus, application of nitrogen, mulch and $GA_3$rates that promote the desired best photosynthates in pumpkin fruits is recommended.

**Keywords:** Fruit-vegetable cultivation, Proximate analysis, Secondary metabolites, Plant nutrients

## 1. Introduction

Pumpkin is a fruit-vegetable belonging to the Cucurbitaceae family together with gourds, melons and squashes. Pumpkin is a native of Central America but is now domesticated in other tropical and subtropical countries (Fedha, 2008). Globally, China is the major producer followed by India (FAOSTAT, 2009). In Africa, Egypt and South Africa are the leading producers. FAO (2005) report stated that pumpkin has immense economic potential for use both as a food and industrial crop. In Kenya, pumpkin production and utilization has been increasing (Horticulture Validated Report, 2015-16). Pumpkin is famous for its edible seeds, fruits and young leaves (Matsui *et al.*, 1998; Fruhwirth and Hermetter, 2007).

Pumpkin production and consumption have risen due to several reasons including medicinal properties through the antioxidant beta-carotene that helps improve immune function and reduce cancer and heart disease risks (Caili *et al.*, 2006; Jun *et al.*, 2006; Glew *et al.*, 2006; Ghanbari *et al.*, 2007). Pumpkin contains mineral nutrients such as calcium, iron, magnesium, potassium, zinc, selenium, niacin, foliate, vitamins A, C, and E, fats, carotenoids and g-aminobutyric acid (Murkovic *et al.*, 2002; Koike *et al.*, 2005; Glew *et al.*, 2006; Ondigi *et al.*, 2008). Quality is equivalent to a combination of traits, attributes and features that give rise to human pleasure. Colour, nutrition and flavour are some factors considered in determining good quality by consumers (Kitinoja *et al.,* 2011). The final indicator of quality is the inter-relationship between the produce and its environment. Plant genetic characteristics and physiological status establish typical post-harvest behaviour that produces quality (Kitinoja, 2010).

Despite all these reported benefits, limited pumpkin is commercially produced and consumed in Africa (Ondigi *et al.*, 2008). It is still regarded as a traditional vegetable that is mainly grown on subsistence scale (Karanja *et al.*, 2014).

 

Currently, there are no documented pumpkin value chain preferences and consumption trends in Kenya (Ondigi *et al*., 2008). Nevertheless, pumpkin can grow in almost any part of East Africa and storage after harvesting can last for many months provided the fruit stalk is retained, making it an appropriate food security crop (Horticultural Crops Development Authority, 2012). Temperature, relative humidity, water potential, light, cultural practices and pest management techniques are key pre-harvest factors that determine the inherent quality of the produce (Hewett, 2006).

Nitrogen is by far the most critical plant growth element, yet soil testing is usually not practical due to nitrogen mobility (Cameron *et al.,* 2013). Cucurbits require from 22.5 to 45 kg of actual nitrogen per acre per season (Bratsch, 2009). Use of chemical fertilizers as supplemental sources of nutrients has been on the increase in pumpkin production but they are not applied in balanced proportions by most farmers. The composite NPK fertilizer has been found to increase leaf area, stem diameter, leaf number, and mineral nutrient contents (N, P, K, Ca, Na and Mg) in the soil under pumpkin production (Okonwu and Mensah, 2012).

Mulch has been reported to enhance germination of direct-seeded pumpkins since it increases soil temperature. The higher soil temperatures associated with mulch also accelerate establishment of transplants and promote subsequent crop development, thereby hastening crop maturity and increasing yields (Waterer, 2000). According to Yamaguch and Kamiya (2000) gibberellin ($GA_3$) plays an essential role in many aspects of pumpkin growth and development such as seed germination, stem elongation and flower development. The present study evaluated the combined effects of nitrogen, mulch and $GA_3$ on photosynthates in multi-purpose pumpkin fruits.

## 2. Materials and Methods

### 2.1. Research Site and Experimental Design

The study was done in a field between January 2019 and August 2020. The field lies at0$^{o}$ 19' S, 37$^{o}$ 38' E and 1535 m above sea level and has average annual temperature of 19.5$^{o}$C (12.2°C to 23.2°C). The field site experiences two rainy seasons with the long rains occurring from March to June and short rains from October to December (Jaetzold *et al.,* 2006). The average annual rainfall is 1200 mm (http://en.climate-data.org). The soils are humic nitisols, deep, strongly weathered, well drained with a clayey subsurface horizon and have high cation exchange capacity (Koskey *et al.,* 2017).

A three-factor experiment embedded in a randomized complete block design (RCBD) with three replications was set up in two seasons. Season 1 lasted from March 2019 to July, 2019 with 1,004.3 mm rainfall, and Season 2 lasted from October 2019 to February 2020 with 1,259.6 mm rainfall. Each experimental plant occupied 2 m x 2 m separated from others by 1 m. The three factors assessed consisted four N rates (0, 50, 100 and 150 kg N/ha), three mulch types (none, unpainted and black-painted rice straws) and three $GA_3$ rates (0, 40 and 80 mg/L). Nitrogen was assigned to main-plots, mulch to sub-plots and gibberellic acid split-plots.

Nitrogen was applied as CAN in two equal doses at three weeks post-emergence and at the beginning of flowering. Amount of CAN fertilizer used per experimental unit was derived as: a) 50 Kg N/ha = 76.9 g CAN/4 m$^2$, b) 100 Kg N/ha= 153.8 g CAN/4 m$^2$, c) 150 Kg N/ha = 230.7 g CAN/4 m$^2$.

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 black paint solution and spreading out on the soil to air-dry. The rice straw was uniformly spread on plots to achieve 20 cm thickness. Planting holes were marked and opened in the rice straws during pumpkin seed sowing.

The $GA_3$ was dissolved in 50 ml alcohol and topped up to 1 L stock solution using distilled water. The required rate of spray solution was then prepared from the stock solution by diluting with distilled water. A few drops of commercial sticker were added to the solutions to facilitate uptake of the $GA_3$ intoleaves. The $GA_3$ solution was sprayed to the plants using a 1-L hand-held sprayer. Spray solution of lower rate was applied first followed by next higher rate. Spraying was done once during the fourth week after emergence. To avoid chemical drift, spraying was done during a calm morning and wind direction was observed.

### 2.2. Pumpkin Plant Establishment and Management

Three multipurpose pumpkin fruits of uniform size, free from diseases and pests and from one mother plant were used. The fruits were sourced from farmers near the present research site. Seeds were used immediately after extraction (AOAC, 1995). The field was prepared to appropriate tilth required for pumpkin growth. All recommended phosphorus and potassium straight fertilizers were applied just before seed sowing.

Two seeds were planted in each split plot and one seedling was uprooted two weeks after emergence. All plots were kept weed-free through cultivation. Irrigation was done using drip tubes to supplement rain during drought. Insect pest and disease control was done when necessary using recommended pesticides. Pumpkin vines were coiled around the stool when required while leaving them in contact with the soil. Data was taken from all plants, except those in guard rows.

### 2.3. Data Collection and Analysis

Data values were collected for the two experimental seasons as described hereunder. Moisture content was determined using oven-drying method. The Mitamula MRK oven was calibrated to keep a steady temperature of 105°C for three hours. Aluminum dishes were cleaned and dried in the oven for one hour and then cooled in a desiccator with dry silica gel for 15 minutes and weighed. The same process was repeated until their weights were constant and then the average weight for the dry empty dish was recorded as $w_o$. About 2 g of sample was placed onto each dry dish and the weight recorded as $w_i$. The dishes with samples were place in the oven in triplicates and dried for one hour, three times, until a constant weight was obtained for cooled dry samples. The final weight was recorded for dry dish and sample as $w_i$. Moisture content was calculated using the formula: *% moisture content* $= 100 - [(w_i - w_o / w_i - w_o) \times 100]$.

Determination of total ash used dry-ashing method (Ali *et al.,* 1988). Muffle furnace was set at steady temperature of 550°C and clean dry porcelain crucibles were heated in the furnace for five hours. The crucibles were cooled in a desiccator with dry silica gel for 15 minutes and weighed to get weight zero ($w_o$). A 2 g sample in the dry crucibles was weighed in triplicates to get weight one ($w_i$). The crucibles with samples were then burnt until they produced no smoke and placed inside the furnace where they were incinerated for five hours. They were then removed from the furnace, cooled in a desiccator for 15 minutes and weighed to get weight two ($w_i$). Ash was calculated using the formula (Jones, 2001): *% ash* $= (w_i - w_o / w_i - w_o) \times 100$.

Total carbohydrates were determined after proximate analysis results were obtained, using McCready *et al.,* (1950) formula stating that: *% total carbohydrates = 100 – (% moisture + % ash + % fat + % protein)*. The total carbohydrates included simple sugars, crude fibre, starch and all other polysaccharides.

Crude nitrogen content was determined using the semi-micro-Kjeldhal procedure by multiplying the nitrogen value with a factor of 6.25, which represented the general protein factor. A sample of 1 g was transferred into 300 ml Kjeldahl digestion flask of which 5 g of potassium sulphate and 0.5 g of copper (II) sulphate were added. To the sample, 15 ml of concentrated sulphuric acid was added and digested on a heater in a fume hood until it turned clear blue. The digest was diluted to 100 ml volume using distilled water. An aliquot of 10 ml of the diluted digest was transferred to Pannas and Wagner distillation apparatus and 15 ml of 40% sodium hydroxide added. Steam distillation was then done. About 70 ml of distillate was received in 4% boric acid with several drops of mixed indicator. A blank was set up using the same procedure. The received aliquot was titrated with 0.02 N hydrochloric acid and crude protein was calculated using the formula: *% crude protein* $= [(V-B) \times 0.02 \times 0.014 \times 100/v \times 100/s] \times 6.25$, where: V= Tire volume of 0.02 N HCl, B= Blank titre volume of 0.02 N HCl, V= volume of the diluted digest taken for distillation, and S= sample weight taken.

Fat content was determined using Soxhlet continuous extraction method, whereby 300 ml fat receiver flasks were cleaned, dried at 105°C, cooled in a desiccator, weighed and recorded as $w_0$. A 5 g of sample was added into cellulose thimble, flagged with defatted cotton wool and inserted in the Soxhlet extraction apparatus. The receiver flask was half-filled with analytical grade 40 – 60 petroleum ether and connected to the Soxhlet extraction apparatus. The apparatus was then connected to a condenser and the whole assembly was heated at the flask base on a water bath. Extraction was carried out for 16 hours. The ether was evaporated from the receiver flasks using Rotary evaporator and the flasks were dried for one hour at 105°C in a hot air circulation oven. The flasks were cooled in a desiccator and then weighed. The final weight was obtained and recorded as $w_1$. The percent fat content was determined using the formula suggested by AOAC (1990) as: $\% fat = [(w_1-w_0)/sample\ weight] \times 100$.Data values on photosynthates were subjected to analysis of variance, using the SAS software version 9.3. Separation of significantly different means was performed using the least significant difference test at $a = 0.05$.

## 3. RESULTS AND DISCUSSION

### 3.1. Effect of Nitrogen Fertilizer on Moisture Content and Photosynthates in Fruit Pulp

Nitrogen had a significant ($P<0.05$) effect on moisture in both seasons (Table 1). The 0 kg N/ha had the highest moisture of 89.73% and 89.63%in S1 and S2, respectively. In both seasons, 100 kg N/ha had the lowest moisture of 86.65% and 85.57% in S1 and S2, respectively. Moisture reduced as nitrogen rate was increased up to 100 kg N/ha. A significant ($P<0.05$) promotive effect of N on fat content resulted in both seasons. The 150 kg N/ha had the highest fat content of 0.14% and 0.33% in S1 and S2, respectively. The lowest fat content of 0.07% and 0.08% in S1 and S2, respectively, was for 100 kg N/kg (Table 1).

There was a significant ($P<0.05$) positive effect of N on protein content in both seasons. The 150 kg N/ha produced the highest protein content of 2.18% and 2.75% in S2 and S2, respectively. The 0 kg N/ha had the lowest protein content of 0.33% and 0.38% in S1 and S2, respectively. No significant ($P>0.05$) effect of nitrogen fertiliser on ash content was noted in both seasons (Table 1). Nevertheless, the 50 kg N/ha produced the highest ash contentof 0.76% and 0.81% in S1 and S2, respectively. On the other hand, the ash content was lowest at 0.60% and 0.64% when 100 kg N/ha nitrogen fertiliser was applied during S1 and S2, respectively. The effect of N was significant ($P<0.05$) on carbohydrates in both seasons. Applying 100 kg N/ha produced the highest carbohydrates of 11.98% and 12.76% in S1 and S2, respectively. Lowest carbohydrates of 9.16% and 9.18% in S1 and S2, respectively, were for 0 kg N/ha.

Results showing that nitrogen fertiliser significantly reduced moisture content probably occurred through enhancement of metabolites synthesis and accumulation in the pumpkin fruits. Rajasree and Pillai (2012) found that crude protein content of bitter gourd fruits increased with increasing nitrogen rate, thereby concurring with the results of the present study. Ash content, ranging from 6.42% to 7.45%, indicated high deposit in pumpkin fruits (Aruah *et al.*, 2011). In the present study, ash content was less than 1%, while total carbohydrates increased with increase in nitrogen up to 100 kg N/ha, similar to what Khalid (2012) observed with increase in nitrogen and phosphorus fertilization of Apiaceae plants.

### 3.2. Effect of Mulch Type on Moisture Content and Photosynthates in Fruit Pulp

Mulch had a significant ($P<0.05$) effect on moisture in both seasons (Table 2). The no mulch treatment produced the highest moisture of 88.53% and 88.14%in S1 and S2, respectively. Moisture content of 88.46% and 86.72% for S1 and S2, respectively, was obtained when black-painted mulch was used. Lowest moisture content of 86.65% and 85.28% for S1 and S2, respectively, were obtained when unpainted rice straw mulch was applied. A significant effect of mulch on fat content resulted in both seasons (Table 2). Lowest fat content of 0.09% and 0.14% was for no mulch. Mulch had a significant effect on protein content in S1 only. Where black-painted mulch was applied, the 1.13% and 1.38% protein content in S1 and S2, respectively, was the highest amount of protein content attained. Protein content of 1.05% and 1.30% in S1 and S2, respectively, was lowest for no mulch.

There was no significant ($P>0.05$) effect of mulch on ash content in pumpkin fruits in both seasons (Table 2). No mulch produced the lowest ash contentof 0.62% and 0.66%in S1 and S2, respectively. The ash content of 0.71% and 0.76% in S1 and S2, respectively, was highest when unpainted rice straw mulch was applied. The effect of mulch on total carbohydrates in pumpkin fruit pulp in both seasons was significant ($P<0.05$). Unpainted rice straw mulch produced highest total carbohydrates of 11.46% in S1, while painted rice straw mulch had highest total carbohydrates of 12.52% in S2.

No mulch probably enhanced uptake of water into plants that ended up in pumpkin fruits. Fat and protein contents were highest when black-painted rice straws were applied, while ash and total carbohydrates were highest when unpainted rice straws were applied. The results implied that mulching promotes their accumulation in pumpkin fruit pulp. Spizewski *et al.* (2010) and Kosterna *et al.* (2010) also reported that fruits obtained from cucumbers and watermelons cultivated in mulched soil had slightly higher total carbohydrates.

### 3.3. Effect of $GA_3$ rate on moisture content and photosynthates in fruit pulp

The applied $GA_3$ had a significant ($P<0.05$) effect on moisture content in S1 and no significant ($P>0.05$) effect during S2 (Table 3). The moisture content was highest 88.33% and 87.22% in S1 and S2 when 40 mg/L $GA_3$ was applied. In both seasons, lowest moisture content of 87.53% and 85.86% in S1 and S2, respectively, was obtained when 80 mg/L $GA_3$ was applied.

There was a significant ($P<0.05$) effect of $GA_3$ on fat content in both seasons. Lowest fat content of 0.08% and 0.14% in S1 and S2, respectively, resulted when no $GA_3$ was applied, while the highest fruit pulp fat content of 0.13% in S1 was obtained when 80 mg/L $GA_3$ was applied and 0.23% when 40 mg/L $GA_3$ was applied in S2. The protein content was significantly ($P<0.05$) affected by $GA_3$. Where no $GA_3$ was applied, protein content was highest of 1.16% and 1.43% in S1 and S2, respectively (Table 3). Protein content was lowest of 0.99% in S1 and 1.27% in S2, when 80 mg/L $GA_3$ was applied.

The effect of $GA_3$ on ash content was not significant ($P>0.05$). Nevertheless, treatment with 40 mg/L $GA_3$ produced the highest ash contentof 0.72% and 0.76% in S1 and S2, respectively. Ash content was lowest of 0.62% and 0.64% when 80 mg/L $GA_3$ was applied. The $GA_3$ significantly ($P>0.05$) affected on carbohydrates in both seasons. The 80 mg/L $GA_3$ yielded the highest carbohydrates of 10.76% and 12.06% in S1 and S2, respectively. Lowest carbohydrates in S1 and S2 were consistently obtained when 40 mg/L $GA_3$ was applied.

In the present study, moisture, fat, proteins and total carbohydrate contents in fruit pulp were significantly affected by $GA_3$, but the effect on ash content was not significant. Increasing $GA_3$ up to 80 mg/L reduced moisture, protein and ash contents in fruit pulp, thereby revealing a negative relationship. The fat and carbohydrate contents and $GA_3$ concentration revealed a positive relationship. Thus $GA_3$ promotes synthesis of these components in pumpkin fruits. Basu *et al.* (1999) and Banerjee and Basu (1992) also demonstrated that $GA_3$ significantly increased total carbohydrates in *Trichosantjies dioica* Roxb and *Momordica charantia*.

### 3.4. Effect of Nitrogen, Mulch and $GA_3$ on Moisture Content and Photosynthates in Fruit Pulp

The highest moisture content of 92.17% was for $N_1M_0GA_2$, while the lowest of 82.59% was for $N_1M_2GA_2$ during S1 (Table 4). During S2, highest moisture content of 92.21% was for $N_0M_2GA_0$, while lowest of 76.96% was for $N_1M_1GA_2$. The $N_1M_0GA_2$ (50 kg N/ha, no mulch and 80 mg/L $GA_3$) and $N_0M_2GA_0$ (0kg N/ha, unpainted rice straw mulch and 0 mg/L $GA_3$) had the highest interactive effect on moisture content in S1 and S2, respectively. A significant ($P<0.05$) effect was observed due to interactive effect on the moisture content during both seasons.

**Table 1: Effect of nitrogen on moisture content and photosynthates in fruit pulp**

| Nitrogen (kg/ha) | Moisture content (%) | | Fat (%) | | Protein (%) | | Ash (%) | | Total carbohydrates (%) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | S1 | S2 | S1 | S2 | S1 | S2 | S1 | S2 | S1 | S2 |
| 0 (Control) | 89.73a | 89.63a | 0.10c | 0.11c | 0.33d | 0.38d | 0.67 | 0.70 | 9.16d | 9.18c |
| 50 | 87.62b | 85.80b | 0.11b | 0.19b | 1.08b | 1.30b | 0.76 | 0.81 | 10.43b | 11.89a |
| 100 | 86.65d | 85.57b | 0.07d | 0.08c | 0.73c | 0.95c | 0.60 | 0.64 | 11.98a | 12.76a |
| 150 | 87.51c | 85.86b | 0.14a | 0.33a | 2.18a | 2.75a | 0.67 | 0.71 | 9.49c | 10.35b |
| *P-value* | *0.001** | *0.001** | *0.001** | *0.001** | *0.001** | *0.001 ** | *0.422* | *0.443* | *0.001** | *0.001** |
| LSD 5% | 0.042 | 0.891 | 0.0007 | 0.032 | 0.069 | 0.097 | 0.213 | 0.238 | 0.224 | 0.99 |

**Table 2: Effect of mulch on moisture content and photosynthates in fruit pulp**

| Mulch type | Moisture content (%) | | Fat (%) | | Proteins (%) | | Ash (%) | | Total carbohydrates (%) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | S1 | S2 | S1 | S2 | S1 | S2 | S1 | S2 | S1 | S2 |
| None | 88.53a | 88.14a | 0. 09c | 0.14b | 1.05b | 1.30 | 0.62 | 0.66 | 9.71b | 9.64c |
| Black | 88.46b | 86.72b | 0.12a | 0.21a | 1.13a | 1.38 | 0.70 | 0.73 | 9.63b | 10.98b |
| Brown | 86.65c | 85.28c | 0.10b | 0.18a | 1.06b | 1.36 | 0.71 | 0.76 | 11.46a | 12.52a |
| *P-value* | *0.001** | *0.001** | *0.001** | *0.001** | *0.012** | *0.210* | *0.424* | *0.500* | *0.001** | *0.001** |
| LSD 5% | 0.028 | 1.077 | 0.0007 | 0.028 | 0.055 | 0.090 | 0.164 | 0.191 | 0.179 | 1.091 |

**Table 3: Effect of $GA_3$ on moisture content and photosynthates in fruit pulp**

| $GA_3$rate( mg/L) | Moisture content (%) | | Fat (%) | | Proteins (%) | | Ash (%) | | Total carbohydrates (%) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | S1 | S2 | S1 | S2 | S1 | S2 | S1 | S2 | S1 | S2 |
| 0(Control) | 87.77b | 87.06 | 0.08c | 0.14b | 1.16a | 1.43a | 0.70 | 0.74 | 10.28b | 10.63b |
| 40 | 88.33a | 87.22 | 0.10b | 0.23a | 1.09b | 1.34b | 0.72 | 0.76 | 9.75c | 10.45b |
| 80 | 87.53c | 85.86 | 0.13a | 0.16b | 0.99c | 1.27b | 0.62 | 0.64 | 10.76a | 12.06a |
| *P-value* | *0.001** | *0.087* | *0.001** | *0.001** | *0.001** | *0.003 ** | *0.157* | *0.101* | *0.001** | *0.043** |
| LSD 5% | 0.028 | 1.316 | 0.0006 | 0.029 | 0.054 | 0.087 | 0.109 | 0.117 | 0.138 | 1.369 |

S1= Season 1 (March 2019-July 2019), S2= Season 2 (October 2019-February 2020)

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

**Table 4: Nitrogen, mulch and $GA_3$effect on fruit pulp moisture content and photosynthates**

| Treatment | Moisture content (%) | | Fat (%) | | Proteins (%) | | Ash (%) | | Total carbohydrates (%) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | S1 | S2 | S1 | S2 | S1 | S2 | S1 | S2 | S1 | S2 |
| $N_0M_0GA_0$ | 90.8 | 90.3 | 0.07 | 0.09 | 0.27 | 0.28 | 0.74 | 0.77 | 8.1 | 8.6 |
| $N_0M_1GA_0$ | 86.5 | 89.1 | 0.07 | 0.08 | 0.36 | 0.37 | 1.05 | 1.03 | 12.5 | 9.4 |
| $N_0M_2GA_0$ | 92.1 | **92.2** | 0.08 | 0.08 | 0.45 | 0.49 | 0.40 | 0.48 | 6.7 | 6.7 |
| $N_0M_0GA_1$ | 91.2 | 89.4 | 0.07 | 0.06 | 0.35 | 0.55 | 0.77 | 0.85 | 7.8 | 9.1 |
| $N_0M_1GA_1$ | 91.3 | 91.5 | 0.06 | 0.07 | 0.28 | 0.28 | 0.47 | 0.48 | 7.6 | 7.7 |
| $N_0M_2GA_1$ | 89.4 | 90.7 | 0.09 | 0.09 | 0.39 | 0.40 | 0.77 | 0.88 | 9.1 | 8.0 |
| $N_0M_0GA_2$ | 90.1 | 89.7 | 0.09 | 0.11 | 0.37 | 0.45 | 0.62 | 0.67 | 9.1 | 9.1 |
| $N_0M_1GA_2$ | 87.9 | 85.4 | 0.07 | 0.06 | 0.42 | 0.46 | 0.66 | 0.65 | 10.9 | 13.4 |
| $N_0M_2GA_2$ | 88.3 | 88.4 | 0.27 | 0.30 | (0.10) | (0.17) | 0.55 | 0.48 | 10.8 | 10.7 |
| $N_1M_0GA_0$ | 87.0 | 87.2 | 0.08 | 0.09 | 1.10 | 1.50 | 0.82 | 0.91 | 11.1 | 10.3 |
| $N_1M_1GA_0$ | 88.7 | 88.4 | 0.11 | 0.17 | 1.06 | 1.10 | 0.76 | 0.84 | 9.4 | 9.5 |
| $N_1M_2GA_0$ | 89.3 | 87.8 | 0.06 | 0.35 | 0.79 | 0.90 | 0.75 | 0.81 | 9.2 | 10.1 |
| $N_1M_0GA_1$ | 90.4 | 90.9 | 0.07 | 0.33 | 0.80 | 1.08 | 0.75 | 0.79 | 8.0 | 6.9 |
| $N_1M_1GA_1$ | 83.7 | 83.5 | 0.21 | 0.25 | 2.64 | 3.01 | 0.92 | 0.97 | 12.6 | 12.3 |
| $N_1M_2GA_1$ | 85.2 | 85.2 | 0.10 | 0.13 | 0.65 | 0.86 | **1.07** | **1.10** | 13.0 | 12.7 |
| $N_1M_0GA_2$ | **92.2** | 90.7 | 0.23 | 0.26 | 1.22 | 1.55 | 0.47 | 0.52 | 5.9 | 7.0 |
| $N_1M_1GA_2$ | 89.6 | (77.0) | 0.08 | 0.08 | 0.72 | 0.99 | 0.49 | 0.54 | 9.1 | **21.4** |
| $N_1M_2GA_2$ | (82.6) | 81.5 | 0.06 | 0.07 | 0.72 | 0.71 | 0.80 | 0.83 | **15.8** | 16.9 |
| $N_2M_0GA_0$ | 87.4 | 87.5 | (0.04) | (0.04) | 0.96 | 1.08 | 0.44 | 0.46 | 11.0 | 10.9 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| $N_2M_1GA_0$ | 89.4 | 88.0 | 0.06 | 0.08 | 0.77 | 1.04 | 0.76 | 0.80 | 9.1 | 10.1 |
| $N_2M_2GA_0$ | 83.3 | 83.4 | 0.07 | 0.07 | 0.88 | 1.19 | 0.71 | 0.79 | 15.0 | 14.5 |
| $N_2M_0GA_1$ | 88.9 | 87.1 | 0.06 | 0.06 | 0.35 | 0.47 | 0.41 | (0.41) | 10.3 | 12.0 |
| $N_2M_1GA_1$ | 91.5 | 90.4 | 0.09 | 0.11 | 0.72 | 0.93 | 0.53 | 0.58 | 7.1 | 8.0 |
| $N_2M_2GA_1$ | 82.8 | 81.5 | 0.07 | 0.08 | 0.87 | 0.99 | 0.81 | 0.89 | 15.7 | 16.5 |
| $N_2M_0GA_2$ | 88.9 | 88.3 | 0.09 | 0.13 | 0.74 | 0.96 | (0.38) | (0.41) | 10.0 | 10.2 |
| $N_2M_1GA_2$ | 84.3 | 84.8 | 0.07 | 0.07 | 0.18 | 0.28 | 0.66 | 0.69 | 15.0 | 14.2 |
| $N_2M_2GA_2$ | 83.6 | 79.1 | 0.08 | 0.08 | 1.10 | 1.60 | 0.72 | 0.78 | 14.6 | 18.4 |
| $N_3M_0GA_0$ | 85.6 | 85.1 | 0.10 | 0.27 | **2.65** | **3.54** | 0.72 | 0.74 | 10.9 | 10.3 |
| $N_3M_1GA_0$ | 86.8 | 86.5 | 0.09 | 0.11 | 2.25 | 2.90 | 0.59 | 0.63 | 10.3 | 9.8 |
| $N_3M_2GA_0$ | 86.5 | 79.1 | 0.17 | 0.24 | 2.41 | 2.73 | 0.59 | 0.62 | 10.3 | 17.3 |
| $N_3M_0GA_1$ | 87.0 | 87.9 | 0.17 | 0.19 | 1.88 | 2.37 | 0.58 | 0.60 | 10.4 | 9.0 |
| $N_3M_1GA_1$ | 91.3 | 86.4 | 0.10 | **1.31** | 2.01 | 2.37 | 0.81 | 0.86 | (5.8) | 9.1 |
| $N_3M_2GA_1$ | 87.4 | 82.3 | 0.09 | 0.09 | 2.14 | 2.74 | 0.71 | 0.77 | 9.7 | 14.1 |
| $N_3M_0GA_2$ | 83.0 | 83.7 | **0.41** | 0.56 | 1.89 | 2.71 | 0.69 | 0.74 | 14.0 | 12.3 |
| $N_3M_1GA_2$ | 90.7 | 89.7 | 0.09 | 0.12 | 2.17 | 2.54 | 0.66 | 0.73 | 6.4 | 7.0 |
| $N_3M_2GA_2$ | 89.4 | **92.1** | 0.05 | 0.10 | 2.23 | 2.85 | 0.68 | 0.70 | 7.6 | (4.2) |
| *P-value* | *0.001* | *0.001* | *0.001* | *0.001* | *0.001* | *0.001* | *0.387* | *0.509* | *0.001* | *0.001* |
| LSD 5% | 0.095 | 4.115 | 0.002 | 0.097 | 0.182 | 0.292 | 0.433 | 0.484 | 0.510 | 4.273 |

S1= Season 1 (March 2019-July 2019); S2= Season 2 (October 2019-February 2020).

Bolded values = Highest; Bracketed values = Lowest

Fat content was highest of 0.41% for $N_3M_0GA_2$, while it was lowest 0.04% for $N_2M_0GA_0$ in S1 (Table 4). In S2, highest fat content of 1.31% was for $N_3M_1GA_1$, while the lowest of 0.04% was for $N_2M_0GA_0$. The $N_3M_0GA_2$ (150 kg N/ha, no mulch and 80 mg/L $GA_3$) and $N_3M_1GA_1$ (150 kg N/ha, unpainted rice straw mulch and 40 mg/L $GA_3$) had the highest combined effect on fat content in S1 and S2, respectively. A significant ($P<0.05$) effect of interaction on fat content resulted in S1 and S2.

Protein content was highest 2.65% for $N_3M_0GA_0$, while the lowest 0.10% was for $N_0M_2GA_2$ in S1 (Table 4). The 3.54% was the highest protein content obtained for $N_3M_0GA_0$, while $N_0M_2GA_2$ had the lowest protein content of 0.17% in S2. The $N_3M_0GA_0$ (150 kg N/ha, no mulch and 0 mg/L $GA_3$) had the highest interactive effect on protein content in both seasons. There was a significant interactive effect on protein content realised in S1 and S2.

Ash content of 1.07% was the highest for $N_1M_2GA_1$, while the least ash content of 0.38% was obtained for $N_1M_1GA_2$ during S1 (Table 4). On the other hand, 1.10% was the highest ash content obtained for $N_1M_2GA_1$, while $N_2M_0GA_2$had the least fat content of 0.41% during S2. The $N_1M_2GA_1$ (50 kg N/ha, unpainted rice straw mulch and 40 mg/L $GA_3$) had the highest combined effect on ash content in both seasons. No significant ($P>0.05$) effect of interaction on the ash content resulted in S1 and S2.

There was a significant interactive effect on total carbohydrates produced in both seasons. Highest carbohydrates of 15.84% were for $N_1M_2GA_2$, while the lowest of 5.78% were for $N_3M_1GA_1$ in S1 (Table 4). During S2, highest carbohydrates of 21.44% were for $N_1M_1GA_2$, while the lowest of 4.20% were for $N_3M_2GA_2$. The $N_1M_2GA_2$ (50 kg N/ha, unpainted rice straw mulch and 80 mg/L $GA_3$) and $N_1M_1GA_2$ (50 kg N/ha, black-painted rice straw mulch and 80 mg/L $GA_3$) had the highest combined effect on carbohydrates in S1 and S2, respectively. The significant combined effect of nitrogen, mulch and $GA_3$ on moisture, fat, protein and carbohydrate contents in pumpkin fruit pulp agreed with a similar one observed due to the interactive effect of NPK and mulch in maize grains (Oladele *et al.,* 2017; Rafiq *et al.,* 2010). Thus, use of the three inputs benefits photosynthate accumulation in pumpkin fruits.

**4. Conclusions and Recommendations**

Results showed that nitrogen fertilizer has significantly negative effect on moisture and total carbohydrate contents, positive on fat and protein contents, and no significant effect on ash content in multipurpose pumpkin fruit pulp. The effect of mulch is significantly positive on fat, protein and total carbohydrate contents, negative on moisture content, and no significant effect on ash content. Gibberellic acid has a significantly positive effect on fat and carbohydrate contents, negative on moisture and protein contents, and no significant effect on ash content. The interactive effect on moisture, fat, protein, ash, total carbohydrates is consistently significant. Therefore, adoption of rates of nitrogen, mulch and $GA_3$ that promote the desired photosynthates of multi-purpose pumpkin fruits is recommended.

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