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Effect of some Growth Regulators on Productivity, Fruit Quality and Storability of Sugar Apple *Anona squamosa, L.*

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Abstract
Many developmental processes in plants require growth regulators such as CPPU, NAA, and brassinosteroids (BRs). In this study, ten-year-old sugar apple trees were subjected to eight treatments: control (Only Water), hand pollination, CPPU at 4 mg/L, CPPU at 6 mg/L, BRs at 1.5 mg/L, BRs at 2 mg/L, NAA at 50 mg/L, NAA at 75 mg/L. Hand pollination was installed at the same time as the trees were sprayed with plant growth regulator during the 2019 and 2020 seasons, respectively, at the anthesis stage or functionally pistillate flowers on stage (pre female to female), and was repeated once weekly for five weeks after anthesis. At harvest, a random sample of fruits from each replication was taken and stored for 12 days at 12° C in air (90-95 percent relative humidity) and measured during cold storage periods in fiberboard boxes with vented plastic liners (every 4 days in both seasons). Results indicated that significantly highest fruit set, fruit retention, number of fruits and yield was observed in the treatment BRs at 2 mg/L, while, the highest fruit drop percentage recorded with control, and the lowest fruit drop percentage recorded with NAA at 75 mg/L, as compared with other treatments. Furthermore, at harvest, physical properties, data induced significantly higher values of fruit length, diameter, weight, pulp weight and number of seeds per fruit with foliar application of 2 mg/L BRs followed by 1.5 mg/L BRs, while, hand pollination significantly increased peel weight, followed by NAA at 75 mg/L and control treatment, as compared to the other treatments during both seasons.

Concerning cold storage period, In both seasons, spraying BRs at (1.5 and 2) mg/L resulted in the highest values of TSS, total sugars, vitamin C, and the lowest values of acidity when compared to other treatments. Fruit weight loss, physiological and pathological disorders were reduced in both seasons with high concentrations of BRs, CPPU and NAA.

Key words: Sugar Apple, CPPU, NAA, Brassinosteroids, Fruit Set, Yield, Fruit Quality and Storability.

INTRODUCTION

Sugar apple (*Annona squamosal,* L.) is one of the most delicious fruits in the family Annonaceae and the genus Annona, which includes approximately 120 genera and over 2000 species (Jalikop, 2011). The Annonas is widely distributed throughout the world's subtropical and tropical regions, but it originated in tropical America. It's a woody, semi-deciduous shrub or small tree with irregularly spreading branches. The greenish yellow flowers appear extra-axillary, usually in clusters and rarely solitary. The flowers are hermaphrodite, with both female (carpels) and male (stamens) organs in the same flower. The female part, however, matures before the male, a condition known as protogynous dichogamy (Campbell and Philips, 1994).

The low percentage of fruit setting previously reported could be due to a different factors such as high and low humidity levels during flowering, soil moisture stress, competition between vegetative and floral growth, and the dichogamy phenomenon, among others. These factors may result in the failure of most or all ovules to fertilize, resulting in poor fruit set and small fruits, affecting fruit yield and quality (Pereira *et al.,* 2011). Hand pollination is well known to increase yield and fruit quality, so it was used to overcome the dichogamy phenomenon; however, it is extremely expensive and time consuming. Furthermore, the large number of seeds in the fruit make it unsuitable for consumption; to address this issue, some regulators may be used (Pereira *et al.,* 2014).

Because self-fertilization is negligible in this genus and natural pollination is not commercially effective, hand pollination (HP) is unquestionably one of the most important. The HP ensures the formation of fruit of excellent commercial quality; its drawbacks include the need for intensive labour and a significant increase in the average number of seeds per fruit (Pereira *et al.,* 2014 and Rodrigues, 2016). It has been claimed, however, that hand pollination can increase fruit yield and quality, but it Attempts were made to replace hand pollination with growth regulators is time consuming and costly. such as NAA and brassinosteroids (BS) to improve fruit set and custard apple production quantitatively and qualitatively. Effective pollination, fertilization, and fruit development are required. Hand pollination is one method for achieving quality production, but it is time consuming and costly due to

a lack of skilled labour. As a result, there is an urgent need to replace hand pollination with growth regulators in order to improve flowering, fruit set, yield, and quality of custard apple.

Plant growth regulators have emerged as an important tool in the production of a variety of fruit crops. Growth regulators have become important in agriculture as a means of improving flowering, fruit set, controlling fruit drop, fruit size, yield, and fruit quality (Guirguis, *et al.* 2010). There are also encouraging results from the use of plant growth regulators, such as NAA in custard apple, in terms of improved fruit set, fruit retention, fruit size, and so on. However, research on this topic in sugar apple is limited and sporadic. Furthermore, new growth regulators such as CPPU and brassinosteroids are available in markets and are commonly used in grapes; however, their suitability in the custard apple must be determined.

Brassinosteroids are a new class of polyhydroxyl steroids that have been identified as phytohormones. These were the first to be investigated when Mitchell *et al.* (1970) discovered that organic extracts from rape plant pollen improved cell division and cell elongation (*Brassica napus*, L.). Michael *et al*. (1979) isolated three biologically active brassinosteroids: brassinolide, 24-epibrassinolide, and 28-homobrassinolide. Brassinosteroids are important regulators of many developmental processes, including cell elongation, pollen tube growth, flowering, senescence, abscission, and maturation Swamy and Rao (2008). According to Mussig (2005), brassinosteroids can regulate and integrate various growth processes via synergistic interactions with phytohormones. Brassinosteroid-induced growth has been linked to increased photosynthesis accumulation in fruits, as well as an increase in RNA and DNA content, protein synthesis, and polymerase activity (Bajguz and Hayat, 2009). The increase in yield caused by brassinosteroids has been linked to an increase in the efficiency of the photosynthesis process in the sprayed trees. And improving metabolic efficiency, resulting in increased yield and enhanced crop quality(Abbas and Hussain,2020). The use of BRs at submicromolar concentrations stimulates a variety of physiological and biochemical responses in a variety of systems, ranging from simple cells to whole plants (Mandava *et al.,* 1981; Clouse and Sasse, 1998; Sasse, 2003). Furthermore, Gomes *et al.* (2006) demonstrated that spraying brassinosteroid into yellow passion fruit increased the number of fruits per plant. Furthermore, the application of BRs to un-pollinated cucumber flowers resulted in seedless fruit similar to those produced by pollinated flowers (Fu *et al.,*

2008).

However, because custard apples are climacteric fruits with high respiration and ethylene production and are chilling sensitive (Valente *et al.,* 2011), they are highly susceptible to spoilage, soften very quickly during ripening, and become squashy and difficult to consume fresh (Okigbo and Obire. 2009). Because the fruits were highly perishable, they could not be shipped to distant markets(Hari Babu *et al.,* 2009). As a result, there is an urgent need to develop appropriate methods to reduce postharvest losses and generate more income (Jagtap and Bapat, 2015). Therefore the current study was designed to assess the effect of sitofex, naphthalene acetic acid, and brassinosteroids on sugar apple fruit set, yield, quality, and storability.

MATERIALS AND METHODS

The experiment was conducted during the two successive seasons 2019 and 2020 on ten years old sugar apple trees (*Annona Squamosa,* L.). The trees were spaced at 4x5 m in clay soil at a private orchard in El-Maamoura region, Alexandria Governorate, Egypt. Trees as uniform as possible in growth and appearance were randomly selected for this study. Selected trees were subjected to the same cultivar practice.

Twenty four trees were subjected to eight application treatments with three replicates. The treatments were: T1: control (Only Water), T2: hand pollination, T3: CPPU at 4 mg/L, T4: CPPU at 6 mg/L, T5: BRs at 1.5 mg/L, T6: BRs at 2 mg/L, T7: NAA at 50 mg/L, T8: NAA at 75 mg/L, Hand pollination was performed by using pollen grains from sugar apple (*Annona squamosa,* L.) which was collected from male flower stamens and deposited on the stigmatic surfaces at the base of the slightly open petals of female flower stamens (Pereira *et al*., 2011). Hand pollination was installed at the same time and the trees were sprayed with plant growth regulator during the 2019 and 2020 seasons, respectively, at the anthesis stage or functionally pistillate flowers on stage (pre female to female), and was repeated once weekly for five weeks after anthesis. The flower was most likely tagged, and plant growth regulators were likely applied with a spray bottle.

Fruit set and Fruit retention:

The number of fruits after fruit set and the number of remained fruits before harvest were counted, and the fruit set and fruit retention percentages were computed using the following equations:

$$\text{Fruit set (\%)} = \frac{\text{Average number of developed fruitlets}}{\text{Average number of flower}} \times 100$$

$$\text{Fruit retention (\%)} = \frac{\text{Average number of retained fruit at harvest}}{\text{Average number of developed fruitlets}} \times 100$$

Yield:

At harvest, the total number of fruits/tree were counted and weighted, and then the yield as kg/tree was calculated.

Fruit weight (g):

The average weight of four fruits of each replication was determined.

Fruit size (cm^3):

The average fruit size was measured using a graduated cylinder of 1000 ml containing tap water.

Fruit dimensions (cm):

Fruit length (cm) and fruit diameter (cm) were measured using a Vernier caliper.

Pulp weight (g):

The pulp was extracted from fruit by separating the outer cover and seeds present. The weight of pulp was taken separately from each fruit.

Peel weight (g):

Peel was separated from each fruit and then weighted as gram peel per fruit.

Number of seeds per fruits (g):

The seeds were separated from pulp after removing outer cover and weight of seeds was recorded on the electronics weighing balance and weight was expressed in grams.

Fruit firmness ($Ib/inch^2$):

Fruit firmness was determined as ($Ib/inch^2$) using Effigi Pressure Tester (mod. Ft327).

Total Soluble Solids Percentage:

Pulp samples were extracted from fruits and the total soluble solids percent (TSS %) was recorded by using a hand refractometer.

Acidity percentage:

Fruit pulp acidity was determined according to (A.O.A.C., 2000) by titration with 0.1 N sodium hydroxide using phenolphthalein as an indicator and expressed as gluconic acid percentage.

Vitamin C (Ascorbic Acid):

Vitamin C content was determined in pulp fruit samples extracted using 2, 6-dichlorophenol-indo-phenol blue dye as mg ascorbic acid per 100 g pulp, (A.O.A.C., 1980).

Total sugars:

Fruit total sugars percent were determined by using the phenol sulfuric acid method outlined by Malik and Singh (1980).

Assessment the fruits during cold storage:

At harvest, a random sample of fourteen fruits from each replication was taken to the laboratory, washed with tap water, surface sterilized for 3 minutes in 0.05 percent sodium hypochlorite, quickly rinsed in distilled water to remove the sterilizer residues, and the initial fruit weight was determined. All fruits were then placed in fiberboard boxes with vented plastic liners and stored at 12^{o} C in air for 12 days (90-95 percent relative humidity). The following measurements were taken during cold storage periods (every 4 days in both seasons):

Fruit weight loss percentage:

It is calculated by adding the amount of water lost through evaporation and transpiration to the amount of dry matter lost through respiration. It was calculated by weighing the fruits. The fruits were weighed every four days during storage and their weight loss was calculated as follows:

$$\text{Fruit weight loss (\%)} = \frac{\text{Average loss in fruit weight}}{\text{Average fruit weight at the beginning of storage}} \times 100$$

Fruit disorders percentage:

Fruits with pathological or physiological disorders were counted visually and calculated as a percentage of the initial number of fruits per sample (replicate) and treatment.

Furthermore, fruit firmness by the Pressure Tester (Effigi Tester), TSS, acidity, vitamin C, total sugars contents by using the same mentioned methods and procedures.

Statistical analysis:

Data of study were subjected to the analysis of variance test (ANOVA) as complete randomized design (CRD). The least significant differences (LSD) at the 5% level of probability were calculated using a computer program SAS according to Gomez and Gomez (1984).

RESULTS AND DISCUSSION

Fruit set, retention and drop:

As revealed from the data presented in Table (1), application of different plant growth regulators significantly influenced fruit set, fruit retention and fruit drop. Significantly highest fruit set mg/L which recorded (67.85 and percentage was observed in the treatment brassinosteroids at 2 76.00%), followed by brassinosteroids at 1.5 mg/L (62.43 and 69.92%), while the lowest fruit set was recorded with control treatment which have recorded (34.29 and 38.41%), during both seasons.

In addition, The treatment of brassinosteroids at 2 mg/L which recorded the highest fruit retention percentage which was significantly superior over rest of the treatments (122.13 and 136.79%), followed by brassinosteroids at 1.5 mg/L (112.37 and 125.85%), while the lowest fruit retention percentage was recorded with control treatment which have recorded (61.73 and 69.13%), during both seasons. Furthermore, the highest fruit drop percentage recorded with control treatment (37.07 and 41.52%), while the lowest fruit drop percentage recorded with NAA at 75 mg/L (16.12 and 18.06%), during both seasons.

Table (1): Effect of hand pollination and plant growth regulators on fruit set, fruit retention and fruit drop percentage of sugar apple trees during 2019 and 2020 seasons.

Treatments	Fruit set (%)		Fruit retention (%)		Fruit drop (%)	
	2019	2020	2019	2020	2019	2020
Control	34.29	38.41	61.73	69.13	37.07	41.52
Hand Pollination	41.50	46.48	74.70	83.67	20.03	22.43
CPPU at 4mg/L	46.12	51.66	83.02	92.99	27.92	31.27
CPPU at 6mg/L	47.79	53.52	86.02	96.34	25.97d	29.08
BRs at 1.5mg/L	62.43	69.92	112.37	125.85	22.13	24.79
BRs at 2mg/L	67.85	76.00	122.13	136.79	20.14	22.56
NAA at 50mg/L	57.13	63.98	102.83	125.19	19.92	22.31
NAA at 75mg/L	62.10	69.55	111.77	136.79	16.12	18.06
LSD $_{(0.05)}$	**3.92**	**4.39**	**7.06**	**7.91**	**2.49**	**2.79**

The results of NAA in terms of its positive effect on fruit set and fruit retention are consistent with the findings of Muarya and Singh (1981), who reported that foliar spray of NAA increased yield and reduced fruit drop in mango trees. Furthermore, Saski and Utsunomiya (2002) stated that spraying

mango trees with CPPU improved fruit retention. Furthermore, Nkansah *et al.* (2012) investigated the effect of naphthalene acetic acid (NAA) sprays of varying concentrations on mango tree fruit retention and discovered that all sprayed chemicals significantly increased fruit retention in both seasons. NAA (25 ppm) produced the best results in terms of increasing fruit set and fruit retention, and it was finally determined that 25 ppm NAA can be used for spraying mango flowers at full bloom to increase mango fruit set and grower retention.

Fruit weight, number of fruit/tree and yield:

In concerning with influences of hand pollination and plant growth regulators treatments on sugar apple, results in Table (2). Results revealed that there was a big tendency for fruits to be heavier when exposed to brassinosteroids (BRs). High concentration of BRs (2 mg/L) significantly increased the fruit weight (245.27 and 274.71g), followed by CPPU at 6 mg/L (234.46 and 262.59g) and BRs at 1.5 mg/L (233.01 and 260.97g), as compared with control treatment which recorded significantly decreased fruit weight (186.37 and 208.73g), in both seasons. Foliar application of growth regulators promotes active polar transport, cell multiplication and enlargement, and increased accumulation of food materials such as sugars and water in expanded cells. Similar results were obtained in custard apple by Chaudhary *et al.* (2014), Patel *et al.* (2010), and guava by Garasiya *et al.* (2013).

The increase in fruit weight was primarily due to cell division in the early stages, followed by faster cell expansion associated with the influx of water and metabolites into the fruits, resulting in an overall increase in fruit weight. According to Sachs and Weaver (1968), the role of hormones in fruit development may be due to the mobilization of elaborated food materials, which is accompanied by an increase in water uptake, solute storage, and organic component synthesis. This could be attributed to BRs, which acted via cell elongation and mobilized metabolites to the fruits, potentially increasing fruit size (Fujioka, 1997), (Bhatia and Kaur, 1997). Brassinolide increased orange fruit weight, according to Kappel and MacDonald (2002), Wang *et al.* (2004), Roghabadi and Pakkish (2014). Engin*et al.* (2016), on the other hand, demonstrated that combined application of brassinosteroid increasedfruit weight in sweet cherry fruits. Furthermore, Eid *et al.* (2016) discovered that foliar application of Milagro (0.2 percent Brassinolide) increased the fruit weight of the avocado tree cv. 'Fuerte.' Furthermore, Bhat *et al.* (2011) discovered that brassinosteroid 0.4 mg/L combined with CPPU (Cytofex) results in the highest bunch and berry weight due to increased photosynthetic carbon assimilation efficiency; however, brassinosteroid stimulates greater CO_2 assimilation in addition to increased cell division by CPPU (Cytofex).

In the other hand, there was significant differences in respect of total number of fruits per tree affected by hand pollination and plant growth regulators treatments on sugar apple, as can be seen from the results presented in Table (2). Maximum number of fruits per tree recorded by brassinosteroid at 2 mg/L (138.68 and 155.32), followed by brassinosteroid at 1.5 mg/L (131.74 and 147.55), as compared with control treatment which recorded the lowest mean values of number of fruits per tree (78.05 and 87.42), during both seasons. The increased number of fruits per tree could be attributed to the fact that both growth regulators positively affected fruit set, fruit retention, cell division, cell elongation, and cell enlargement, which ultimately leads to better fruit growth. The results presented above are consistent with those reported by Patel et al. (2010) on custard apple, Roghabadi and Pakkish (2014) on sweet cheery, and Chaudhari et al. (2016) on custard apple. Furthermore, Khripach et al. (2000) proposed that brassinosteroids confer resistance to plants against biotic and abiotic stresses, which may improve physiological processes ranging from flower opening to fertilization and fruit set. Furthermore, Bansidharrao (2016) discovered that spraying 1.5 mg/L brassinolide at anthesis increased the number of fruits per tree in sapota trees.

The results regarding fruit yield as affected by hand pollination and plant growth regulators treatments as presented in Table (2) the results clearly indicated that maximum yield was observed in brassinosteroids at 2 mg/L (34.01 and 38.09 kg), followed by brassinosteroids at 1.5 mg/L (30.69 and 34.37 kg), applications gave the highest fruit yield (28.76 and 32.21 kg), which was significantly superior over control which gave the lowest fruit yield (14.55 and 16.29 kg), in the both seasons. The increased yield under BRs treatments was associated with an increase in fruit number, more fruit set, fruit retention, and increased fruit growth, which is consistent with the findings of Lal et al. (2013) in guava. The increase in sugar apple yield may be related to improved photosynthetic carbon assimilation efficiency of sprayed plants (Gomes et al., 2006) and the movement of metabolites and

nutrients into developing fruits (Agusti et al., 1994). The use of plant bio-regulators has increased the yield of various fruit crops by improving the internal physiology of developing fruits, resulting in larger fruits (Dussi, 2011). Furthermore, Nkansah et al. (2012) investigated the effect of naphthalene acetic acid (NAA) sprays of varying concentrations on mango tree yield and discovered that all sprayed chemicals significantly increased tree yield in both seasons. In terms of increasing the number of fruits per cluster and per plant, fruit weight, and yield, NAA (25 ppm) produced the best results.

Table (2): Effect of hand pollination and plant growth regulators on fruit weight, number of fruit/tree, yield/tree (kg) and number of seed/fruit of sugar apple tress during 2019 and 2020 seasons.

Treatments	Fruit weight (g)		Number of fruit/tree		Yield/ tree (kg)	
	2019	2020	2019	2020	2019	2020
Control	186.37	208.73	78.05	87.42	14.55	16.29
Hand Pollination	207.08	231.93	86.73	97.14	17.96	20.12
CPPU at 4mg/L	222.73	249.46	109.04	122.13	24.28	27.20
CPPU at 6mg/L	234.46	262.59	114.78	128.56	26.91	30.14
BRs at 1.5mg/L	233.01	260.97	131.74	147.55	30.69	34.37
BRs at 2mg/L	245.27	274.71	138.68	155.32	34.01	38.09
NAA at 50mg/L	211.31	236.67	94.01	105.28	19.86	22.24
NAA at 75mg/L	222.43	249.12	98.96	110.83	22.01	24.65
LSD $_{(0.05)}$	**4.99**	**5.59**	**3.82**	**4.28**	**0.73**	**0.82**

Number of seeds/fruit:

The results in Table (3) revealed that, number of seeds/fruit was influenced by hand pollination and plant growth regulators treatments. However, hand pollination significantly increased number of seeds/tree (66.24 and 74.19), followed by control treatment (64.37 and 72.09) and NAA at 25 mg/L (59.62 and 66.77), during both seasons. This might be due to exogenous supply of gibberellic acid which imparts parthenocarpy in treated fruits. Dass and Randhawa (1968), Patel *et al.* (2010) in sapota, and Bhat *et al.* (2012) in grapes all reported reduced seed number as a result of growth regulators. Exogenous application of growth regulators, according to Paleg (1960), can induce amylolytic activityin isolated endosperm, resulting in the formation and release of reducing sugars. This amylolytic splitting of endosperm and nucellus nutrients may deprive the developing embryo of metabolites required for further growth and differentiation, resulting in abortion.

This decrease in the number of seeds per fruit could be attributed to natural pollination, in which the mother parent's pollen fertilized its own flowers. The naturally pollinated fruit does not have more than 15.07 seeds per fruit, as evidenced by our experimental results. This is consistent with the findings of Jalikop (2010), who also found a lower number of seeds after natural pollination. It could be due to the presence of many seeds and the embryos' ability to produce a high level of natural hormones in the fruits produced by hand pollination (Pereira *et al.,* 2014).

Fruit length and width:

Results presented in Table (3) indicated that BRs showed significant effect on fruit length during both seasons. However, high concentration of brassinosteroids (BRs) at 2 mg/L recorded the highest fruit length (7.06 and 7.76 cm), as compared with control treatment which produced the lowest fruit length (5.47 and 6.02 cm), in the both seasons. In general, BRs increased the fruit dimension comparably better than GA_3 with two concentrations (Engin et al., 2015). Moreover, results presented in Table (3) revealed that BRs showed significant effect on fruit width during both seasons. However, high concentration of brassinosteroids (BRs) at 2 mg/L recorded the highest fruit width (7.24 and 8.11cm), as compared with control treatment which produced the lowest fruit width (5.65 and 6.33 cm), during both seasons.

Using a brassinosteroid produced the longest and widest fruit. This could imply that BRs appeared to

increase cell elongation and cell division, as reported by Yokota (1997) and Engin *et al*. (2015). Furthermore, Gregory and Mandava (1982) and Steber and Mc Court (2001) reported that exogenous application of BRs can act synergistically on each other, resulting in increased fruit length and diameter. Furthermore, brassinosteroid-induced growth has been linked to an increase in RNA and DNA content polymerase activity, as well as protein synthesis (Kalinich *et al.,* 1985).

Peel and pulp weight:

It is apparent from the results presented in Table (3) showed that hand pollination significant effect on peel weight of sugar apple fruits during both seasons. However, hand pollination significantly increased peel weight (126.99 and 142.23g), followed by NAA at 75 mg/L (116.48 and 130.46g) and control treatment (114.29 and 128.01g), as compared with the other treatments during both seasons.

Table (3): Effect of hand pollination and plant growth regulators on fruit length, width, peel and pulp weight of sugar apple during 2019 and 2020 seasons.

Treatments	Fruit length (cm)		Fruit width (cm)		Peel weight (g)		Pulp weight (g)		Number of seeds/fruit	
	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020
Control	5.47	6.02	5.65	6.33	114.29	128.01	72.08	80.73	64.37	72.09
Hand Pollination	6.08	6.68	6.28	7.03	126.99	142.23	80.09	89.70	66.24	74.19
CPPU at 4mg/L	6.44	7.08	6.63	7.42	89.74	100.51	132.99	148.95	49.36	55.29
CPPU at 6mg/L	6.78	7.46	6.98	7.81	94.46	105.80	140.00	156.80	45.42	50.87
BRs at 1.5mg/L	6.70	7.38	6.88	7.70	72.50	81.20	160.50	179.77	39.12	43.81
BRs at 2mg/L	7.06	7.76	7.24	8.11	76.32	85.48	168.95	189.23	35.20	39.42
NAA at 50mg/L	6.27	6.89	6.44	7.21	110.66	123.94	100.65	112.73	54.25	60.77
NAA at 75mg/L	6.60	7.26	6.78	7.59	116.48	130.46	105.94	118.66	49.37	55.30
LSD $_{(0.05)}$	**0.05**	**0.06**	**0.05**	**0.06**	**4.00**	**4.48**	**6.55**	**7.34**	**0.44**	**0.50**

Furthermore, the results concerning to pulp weight of fruit in sugar apple as affected by BRs are presented in Table (3). The maximum pulp weight of fruits was noted in treatments of 2 mg/L BRs (168.95 and 189.23g), followed by 1.5 mg/L BRs (160.50 and 179.77g), 2 mg/L BRs (152.48 and 170.78g), as compared with control which recorded the lowest pulp weight of fruits (72.08 and 80.73g), during both seasons. The increase in pulp weight may also be due to increased berry weight, which is associated with induced cell division and assimilate mobilization in developing berries, as Rizk et al., (2011) found in grapes.

According to previous research, higher pulp content may be due to increased accumulation and translocation of extra metabolites from other parts of the tree to developing fruits (Barkule *et al.,* 2018). The findings agree with those of Bhoye (2010), Patel *et al.* (2010) on custard apple, Debnath *et al.* (2011) on Phalsa, Mulagund *et al.* (2015) on banana, and Chaudhari *et al.* (2016) on custard apple.

Fruit firmness:

Results presented in Table (4) showed the effect of hand pollination and plant growth regulators on fruit firmness at harvest during of sugar apple (Annona squamosa, L.) during 2019 and 2020 seasons. However, results indicated that high concentration of brassinosteroids, CPPU and NAA significantly mg/L recorded increased fruit firmness, as compared with control. In general, brassinosteroids at 2 the highest fruit firmness (26.50 and 27.03 Ib/inch2), followed by brassinosteroids at 1.5 mg/L (23.87 and 24.35 Ib/inch2), CPPU at 6 mg/L (23.80 and 24.28 Ib/inch2) as compared with control treatment which recorded the lowest fruit firmness (16.23 and 16.55 Ib/inch2), during both seasons.

Fruits soften due to either the breakdown of insoluble protopectin into soluble pectin or the hydrolysis of starch (Mattoo et al., 1975). The loss of pectin substances in the cell wall's middle lamella is possibly the most important step in the ripening process that leads to cell wall integrity loss, resulting in firmness and softening (Solomos and Laties, 1973). The increased fruit firmness caused by foliar application of CPPU may be due to a lower rate of respiration, resulting in a lower loss of weight

percentage with maximum fruit firmness, as reported by Hua Huang and Yueming Jiang (2012) in banana.

Table (4): Effect of hand pollination and plant growth regulators on fruit firmness (Ib/inch^2) at harvest and cold storage at 12±1^{o}C in air (90-95% relative humidity) of sugar apple in 2019 and 2020 seasons.

Treatments	Storage Periods (Days)				
	0	4	8	12	Mean
Season 2019					
Control	16.23	13.80	11.31	9.05	**13.41**
Hand Pollination	18.03	15.33	12.57	10.06	**14.00**
CPPU at 4mg/L	21.43	18.22	14.94	11.95	**16.64**
CPPU at 6mg/L	23.80	20.23	16.59	13.27	**18.47**
BRs at 1.5mg/L	23.87	20.29	16.64	13.31	**18.53**
BRs at 2mg/L	26.50	22.53	18.47	14.78	**20.57**
NAA at 50mg/L	17.40	14.79	12.13	9.70	**13.51**
NAA at 75mg/L	19.33	16.44	13.47	10.78	**15.01**
Mean	**20.89**	**17.76**	**14.67**	**11.74**	
LSD $_{(0.05)}$	**Treatments (T): 0.18 Storage Periods (S): 0.13 Interaction (T×S): 0.037**				
Season 2020					
Control	16.55	14.08	10.97	8.24	**12.87**
Hand Pollination	18.39	15.64	12.19	9.15	**13.84**
CPPU at 4mg/L	21.86	18.58	14.49	10.87	**16.45**
CPPU at 6mg/L	24.28	20.63	16.09	12.07	**18.27**
BRs at 1.5mg/L	24.35	20.69	16.14	12.10	**18.32**
BRs at 2mg/L	27.03	22.98	17.92	13.44	**20.34**
NAA at 50mg/L	17.75	15.09	11.77	8.82	**13.36**
NAA at 75mg/L	19.72	16.76	13.08	9.81	**14.84**
Mean	**21.31**	**18.11**	**14.13**	**10.60**	
LSD $_{(0.05)}$	**Treatments (T): 0.19 Storage Periods (S): 0.14 Interaction (T×S): 0.38**				

In this respect, results in the same table indicated that, fruit firmness for all treatments in this study gradually decreased by storage periods advanced in fruits treated on untreated in both seasons. Meanwhile, the lowest fruit firmness was obtained with NAA at 25 mg/L at three storage periods (4, in the first and second seasons. However, the highest fruit firmness was recorded with 8 and 12 days) all brassinosteroids concentrations at all storage periods during both seasons.

During both seasons, the interaction between treatments and cold storage periods had a significant impact on the fruit firmness of sugar apple (*Annona squamosa*, L.). Fruit softening is commonly attributed to cell structure destruction as well as deterioration in cell wall composition and intracellular materials. It is a biochemical process in which enzymes, such as wall hydrolyses, hydrolyze pectin and starch (Seymour *et al.,* 1993).

Fruit weight loss:

Results tabulated Table (5) showed that, fruit weight loss percentage is directly proportional and coincided with the increase of cold storage duration in all treatments under study of sugar apple (*Annona squamosa,* L.) during 2019 and 2020 seasons. However, control treatment and hand pollination gave the highest percentage of fruit weight loss during both seasons. Meanwhile, high concentration of brassinosteroids, CPPU was the most effective on decreasing fruit weight loss percentage compared to the other treatments during two seasons.

In this respect, results in the same table indicated that, fruit weight loss percentage for all treatments in this study gradually increased by storage periods advanced in fruits treated on untreated in both seasons. Meanwhile, the lowest fruit weight loss percentage was obtained with

BRs at 2 mg/L at threein the first and second seasons. However, the highest fruit weight storage periods (4, 8 and 12 days) loss percentage was recorded with control treatment at all storage periods during both seasons.

Table (5): Effect of hand pollination and plant growth regulators on fruit loss percentage at harvest and cold storage at 12±1°C in air (90-95% relative humidity) of sugar apple in 2019 and 2020 seasons.

Treatments	Storage Periods (Days)				
	0	**4**	**8**	**12**	**Mean**
Season 2019					
Control	0	2.23	2.46	2.74	**3.12**
Hand Pollination	0	2.48	2.73	3.14	**1.90**
CPPU at 4mg/L	0	1.99	2.19	2.52	**1.71**
CPPU at 6mg/L	0	1.91	2.10	2.41	**1.63**
BRs at 1.5mg/L	0	1.81	1.99	2.28	**1.54**
BRs at 2mg/L	0	1.73	1.91	2.19	**1.48**
NAA at 50mg/L	0	2.33	2.56	2.95	**1.90**
NAA at 75mg/L	0	2.22	2.45	2.81	**1.82**
Mean	**0**	**2.25**	**2.45**	**2.84**	
LSD (0.05)	**Treatments (T): 0.03 Storage Periods (S): 0.02 Interaction (T×S): 0.07**				
Season 2020					
Control	0	2.53	2.66	3.00	**3.39**
Hand Pollination	0	2.81	2.95	3.33	**2.27**
CPPU at 4mg/L	0	2.25	2.36	2.67	**1.82**
CPPU at 6mg/L	0	2.15	2.26	2.56	**1.74**
BRs at 1.5mg/L	0	2.04	2.14	2.42	**1.65**
BRs at 2mg/L	0	1.96	2.06	2.32	**1.58**
NAA at 50mg/L	0	2.51	2.64	2.98	**2.03**
NAA at 75mg/L	0	2.40	2.52	2.84	**1.94**
Mean	**0**	**2.54**	**2.67**	**3.01**	
LSD (0.05)	**Treatments (T): 0.04 Storage Periods (S): 0.02 Interaction (T×S): 0.07**				

Normal ripening occurred at temperatures ranging from 15 to 30° C, with the fruits susceptible to fungal attack at temperatures higher than 25° C. Chilling injuries were caused by storage temperatures below 15° C. Ripening was accelerated by removing carbon dioxide and adding oxygen to the storage atmosphere, and it was slowed by adding carbon dioxide or removing oxygen. Ethylene had no discernible effect on ripening. Fruits stored in low relative humidity ripened faster than those stored in high humidity (Broughton and Guat, 1979). In addition, Zhihua Cheng *et al.* (2018) reported that, weight loss of custard apple increased for all treated during the whole storage.

Furthermore, the interaction between treatments and cold storage periods was highly significantly on fruit weight loss percentage of sugar apple (*Annona squamosa,* L.) during both seasons. This physiological weight loss is primarily caused by transpiration and respiration (Shanta Krishnamurthy and Subramanyam, 1970). The total moisture loss during storage and ripening, which results in desiccation and a shrivelled appearance of the fruit, is indicated by physiological weight loss (Davies and Hobson, 1981).

Fruit disorders:

In concerning with influences of hand pollination and plant growth regulators treatments on fruit physiological and pathological disorders percentage of sugar apple, results in Table (6 and 7) revealed that all plant growth regulators treatments significantly decreased physiological and pathological disorders percentage of sugar apple as compared to hand pollination and control treatments, during both seasons under this study.

Table (6): Effect of hand pollination and plant growth regulators on fruit physiological disorders (%) at harvest and cold storage at 12±1°C in air (90-95% relative humidity) of sugar apple in 2019 and 2020 seasons.

Treatments	Storage Periods (Days)				
	0	4	8	12	Mean
Season 2019					
Control	0	1.29	2.15	2.69	**1.61**
Hand Pollination	0	1.43	2.39	2.99	**1.48**
CPPU at 4mg/L	0	1.10	1.84	2.30	**1.12**
CPPU at 6mg/L	0	1.22	2.05	2.56	**1.41**
BRs at 1.5mg/L	0	0.99	1.65	2.06	**1.02**
BRs at 2mg/L	0	1.10	1.83	2.29	**1.33**
NAA at 50mg/L	0	1.16	1.93	2.41	**1.09**
NAA at 75mg/L	0	1.29	2.15	2.69	**1.21**
Mean	**0**	**0.64**	**1.96**	**2.53**	
LSD (0.05)	**Treatments (T): 0.13 Storage Periods (S): 0.09 Interaction (T×S): 0.25**				
Season 2020					
Control	0	1.40	2.34	2.93	**1.86**
Hand Pollination	0	1.56	2.60	3.26	**1.85**
CPPU at 4mg/L	0	1.20	2.00	2.51	**1.43**
CPPU at 6mg/L	0	1.33	2.23	2.79	**1.59**
BRs at 1.5mg/L	0	1.08	1.80	2.25	**1.28**
BRs at 2mg/L	0	1.20	1.99	2.49	**1.42**
NAA at 50mg/L	0	1.26	2.10	2.63	**1.50**
NAA at 75mg/L	0	1.41	2.34	2.93	**1.67**
Mean	**0**	**1.33**	**2.21**	**2.76**	
LSD (0.05)	**Treatments (T): 0.03 Storage Periods (S): 0.02 Interaction (T×S): 0.06**				

In this respect, results showed that high concentration of brassinosteroids at 2 mg/L, CPPU at 6 mg/L and NAA at 75 mg/L were significantly decreased fruit physiological and pathological disorders percentage at three storage periods (4, 8 and 12 days), as compared to hand pollination and control treatments, which recorded the significantly increased physiological disorders percentage during both seasons. Moreover, the interaction between treatments and cold storage periods was highly significantly on fruit physiological and pathological disorders percentage of sugar apple (*Annona squamosa*, L.) during both seasons. In previous study, Patel *et al.* (2017) demonstrated that physiological disorders such as internal necrosis are extremely hazardous to aonla cultivation. The foliar application of NAA 40 mg/L + GA_3 50 mg/L percent at the pin head and pea stage (T11) resulted in the lowest internal fruit necrosis (3.02), while the highest internal fruit necrosis was recorded under control.

Table (7): Effect of hand pollination and plant growth regulators on pathological disorders (%) at harvest and cold storage at 12±1°C in air (90-95% relative humidity) of sugar apple fruits in 2019 and 2020 seasons.

Treatments	Storage Periods (Days)				
	0	4	8	12	Mean
Season 2019					
Control	0	1.39	2.21	3.55	**1.99**
Hand Pollination	0	1.54	2.46	3.94	**1.68**
CPPU at 4mg/L	0	1.18	1.89	3.03	**1.48**
CPPU at 6mg/L	0	1.31	2.11	3.37	**1.64**

BRs at 1.5mg/L	0	1.06	1.70	2.72	**1.32**
BRs at 2mg/L	0	1.18	1.88	3.02	**1.47**
NAA at 50mg/L	0	1.24	1.99	3.18	**1.55**
NAA at 75mg/L	0	1.39	2.21	3.55	**1.73**
Mean	**0**	**1.30**	**1.79**	**3.34**	
LSD $_{(0.05)}$	**Treatments (T): 0.03 Storage Periods (S): 0.02 Interaction (T×S): 0.06**				
Season 2020					
Control	0	1.48	2.45	4.07	**2.23**
Hand Pollination	0	1.64	2.72	4.52	**2.22**
CPPU at 4mg/L	0	1.26	2.10	3.48	**1.71**
CPPU at 6mg/L	0	1.40	2.33	3.87	**1.90**
BRs at 1.5mg/L	0	1.13	1.88	3.12	**1.53**
BRs at 2mg/L	0	1.26	2.09	3.46	**1.71**
NAA at 50mg/L	0	1.32	2.20	3.65	**1.79**
NAA at 75mg/L	0	1.48	2.45	4.07	**2.00**
Mean					
LSD $_{(0.05)}$	**Treatments (T): 0.03 Storage Periods (S): 0.02 Interaction (T×S): 0.07**				

Total soluble solids:

Results illustrated in Table (8) indicated that, total soluble solids percentage of all treatments used increased at harvest of sugar apple (*Annona squamosa,* L.) in both seasons. However, the high concentration of brassinosteroids at 2 mg/L and CPPU at 6 mg/L recorded the higher TSS percentage as compared with control. In general, brassinosteroids at 6mg/l recorded the highest percentage of TSS (32.17 and 33.96 %), followed by CPPU at 6 mg/L (29.47 and 34.77 %), as compared with control treatment which recorded the lowest mean values of TSS percentage (18.74 and 20.07%), during 2019 and 2020 seasons.

The increase in TSS and sugars during storage could be due to the breakdown of complex organic metabolites into simple molecules or to the hydrolysis of starch into sugars; however, after complete hydrolysis of starch, no further increase in sugars occurred, and these parameters subsequently declined, as they, along with other organic acids, are primary substrate for respiration (Wills *et al.,* 1980).

The increase in TSS caused by the use of BR could be attributed to the mobilization of metabolites from source to sink as well as the conversion of starch and acids into sugars. These findings support the findings of HongBo *et al.* (2013), who discovered higher TSS in 'Baiyulong' pitaya fruits treated with brassinolide at 1 ppm. Champa *et al.* (2014) reported an increase in TSS with brassinosteroid in grapes, Gomez *et al.* (2006) in passion fruit, and Roghabadi and Pakkish (2014) in sweet cherry.

According to Pereira *et al.* (2014), commercial TSS standards range from 20:32 Brix, demonstrating that trees achieved high volume and excellent quality of all fruits produced. According to Dhananjay (2017), the increase in TSS in custard apple may be due to the rapid metabolic transformation of pectin and starch into soluble compounds, as well as the rapid translocation of sugars from the leaves to the fruits. The increased levels of soluble solids caused by brassinosteroid may be due to the mobilization of metabolites from source to sink, as well as the conversion of starch and acids into sugars, which constitute the majority of soluble solids (Barkule *et al.,* 2018). Furthermore, Gomes *et al.* (2006) discovered that brassinosteroid increased the total soluble solid content of Passion fruit by 1 Brix compared to the control. These findings are consistent with those of Hong Bo *et al.* (2013), who found that applying 1ppm of brassinolide resulted in the highest TSS in "Baiyulong" pitaya fruits.

In this respect, results in the same table indicated that, TSS percentage for all treatments in this study gradually increased by storage periods, as compared with control treatment in both seasons. Whereas, the highest TSS percentage was recorded with brassinosteroids at 2 mg/L and CPPU at 6 mg/L at all storage periods, as compared with control treatment which recorded the lowest mean values of TSS percentage, during both seasons. The interaction between treatments and cold storage

periods was not significant in the first season and second season on total soluble solids percentage of sugar apple (*Annona squamosa,* L.) during both seasons.

Table (8): Effect of hand pollination and plant growth regulators on TSS (%) at harvest and cold storage at 12±1°C in air (90-95% relative humidity) of sugar apple fruits in 2019 and 2020 seasons.

Treatments	Storage Periods (Days)				
	0	4	8	12	Mean
Season 2019					
Control	18.74	20.94	23.88	27.94	**22.91**
Hand Pollination	20.78	23.27	26.53	31.04	**25.41**
CPPU at 4mg/L	26.81	30.03	34.23	40.06	**32.78**
CPPU at 6mg/L	29.47	33.00	37.63	44.02	**36.03**
BRs at 1.5mg/L	29.27	32.78	37.37	43.72	**35.79**
BRs at 2mg/L	32.17	36.03	41.07	48.05	**39.33**
NAA at 50mg/L	22.32	25.00	28.50	33.34	**27.29**
NAA at 75mg/L	24.71	27.68	31.55	36.91	**30.21**
Mean	**25.53**	**28.60**	**32.60**	**38.14**	
LSD (0.05)	**Treatments (T): 0.95 Storage Periods (S): 0.67 Interaction (T×S): 1.90**				
Season 2020					
Control	22.07	24.80	26.74	31.28	**26.26**
Hand Pollination	24.52	27.56	29.71	34.76	**29.12**
CPPU at 4mg/L	31.64	35.44	38.34	44.86	**37.57**
CPPU at 6mg/L	34.77	38.94	42.14	49.30	**41.29**
BRs at 1.5mg/L	34.54	38.68	41.85	48.97	**41.01**
BRs at 2mg/L	37.96	42.51	46.00	53.82	**45.07**
NAA at 50mg/L	26.34	29.50	31.92	37.34	**31.28**
NAA at 75mg/L	29.16	32.66	35.34	41.34	**34.63**
Mean	**30.12**	**33.74**	**36.51**	**42.72**	
LSD (0.05)	**Treatments (T): 1.08 Storage Periods (S): 0.77 Interaction (T×S): 2.17**				

Acidity:

Results presented in Table (9) showed that, fruit recorded the lowest values of acidity with high concentrations of brassinosteroids compared to control which recorded the highest values of acidity during both seasons. However, brassinosteroids at 2 mg/L treatment recorded the minimum percentage of acidity (0.177 and 0.197 %), while control treatment recorded the maximum percentage of acidity (0.309 and 0.345 %) in first and second seasons, respectively. The drop in titratable acids during storage could be attributed to a significant increase in malic acid utilization during ripening (Hulme, 1971).

The reason for the decrease in titratable acidity could be due to metabolic changes involving the rapid conversion of organic acids into sugars and their derivatives via reactions involving the reversal of the glycolytic pathway or being used in respiration Barkule *et al*. (2018).

Moreover, results in this table showed that, acidity percentage for all treatments under this study recorded significantly decreased by storage periods compared with control treatment which recorded significantly increased of acidity percentage in both seasons. However, brassinosteroids at 2 mg/L treatment recorded the lowest acidity percentage at three storage periods (4, 8 and 12 days), while the highest acidity percentage recorded by control treatment at three storage periods during 2019 and 2020 seasons. The decrease in total acidity during storage at different treatments could be due to its consumption in respiratory activities with the progress of storage time and the increase in storage temperature. The interaction between treatments and cold storage periods was highly significantly on acidity percentage of sugar apple (*Annona squamosa,* L.) during both seasons. The storage period results and this respect are consistent with the findings of Brackman *et al.* (1999) on Valencia orange.

Table (9): Effect of hand pollination and plant growth regulators on acidity (%) at harvest and cold storage at 12±1°C in air (90-95% relative humidity) of sugar apple fruits in 2019 and 2020 seasons.

Treatments	Storage Periods (Days)				
	0	4	8	12	Mean
Season 2019					
Control	0.309	0.273	0.231	0.183	**0.310**
Hand Pollination	0.343	0.303	0.257	0.203	**0.277**
CPPU at 4mg/L	0.277	0.243	0.203	0.167	**0.222**
CPPU at 6mg/L	0.247	0.217	0.183	0.147	**0.198**
BRs at 1.5mg/L	0.200	0.177	0.150	0.120	**0.162**
BRs at 2mg/L	0.177	0.157	0.130	0.107	**0.143**
NAA at 50mg/L	0.230	0.200	0.170	0.137	**0.184**
NAA at 75mg/L	0.203	0.180	0.150	0.120	**0.163**
Mean	**0.257**	**0.227**	**0.191**	**0.154**	
LSD (0.05)	**Treatments (T): 0.006 Storage Periods (S): 0.004 Interaction (T×S): 0.037**				
Season 2020					
Control	0.345	0.306	0.258	0.207	**0.344**
Hand Pollination	0.383	0.340	0.287	0.230	**0.310**
CPPU at 4mg/L	0.310	0.277	0.233	0.183	**0.251**
CPPU at 6mg/L	0.277	0.247	0.207	0.163	**0.223**
BRs at 1.5mg/L	0.223	0.200	0.170	0.133	**0.182**
BRs at 2mg/L	0.197	0.177	0.147	0.117	**0.159**
NAA at 50mg/L	0.260	0.230	0.190	0.153	**0.208**
NAA at 75mg/L	0.227	0.203	0.170	0.137	**0.184**
Mean	**0.288**	**0.256**	**0.215**	**0.171**	
LSD (0.05)	**Treatments (T): 0.006 Storage Periods (S): 0.004 Interaction (T×S): 0.039**				

Total sugars:

The results pertaining to total sugars percentage of sugar apple fruits as affected by high concentrations of BRs and CPPU treatments are presented in Table (10). Maximum total sugars percentage was observed in treatment of BRs at 2 mg/L (17.40 and 19.49%), followed by CPPU at 6 mg/L (16.33 and 18.29%) and BRs at 1.5 mg/L (15.66 and 17.54%) which was significantly superior over control which recorded the minimum total sugars (11.25 and 12.60%), during both season. The steroidal hormone BR is involved in increasing the amount of ABA in the body (Symons *et al.,* 2006). The sugar metabolic pathway is activated when ABA levels rise. As a result, the use of BRs indirectly increases the sugar content of fruits. Similarly, Wang *et al.* (2004) discovered that brassinosteroid increased orange sugar content. Padashetti *et al.* (2010) found a synergistic interaction between GA_3 and BRs in Arka Neelamani and Thompson seedless by applying 50 ppm GA_3+1 ppm BRs at fruit set, which resulted in increased sugar content. BRs also play a role in increasing ABA content, which activates the sugar metabolic pathway (Symons *et al.,* 2006). As a result, the use of BRs raises the sugar content of fruits.

In addition, results in the same table indicated that, total sugars percentage of custard apple fruits for all treatments in this study gradually increased by storage periods, as compared with control treatment in both seasons. However, the highest total sugars percentage of custard apple fruits was recorded with BRs at 2 mg/L and CPPU at 6 mg/L at all storage periods, as compared with control treatment which recorded the lowest mean values of sugars percentage of custard apple fruits, during both seasons. Significant differences were observed in total sugars of custard apple fruits due to storage period. These findings are consistent with those obtained by Shailaja *et al.,* 2015, who reported that total sugars increased progressively from the '0' day (9.38) to the 16th day (23.41) of storage. In other hand, in the other hand, the interaction between treatments and cold storage periods was highly significantly on total sugars percentage of sugar apple (*Annona squamosa*, L.)

during both seasons.

Table (10): Effect of hand pollination and plant growth regulators on total sugars (%) at harvest and cold storage at 12±1°C in air (90-95% relative humidity) of sugar apple fruits in 2019 and 2020 seasons.

Treatments	Storage Periods (Days)				
	0	4	8	12	Mean
Season 2019					
Control	11.25	12.93	15.52	18.32	**13.96**
Hand Pollination	12.50	14.37	17.24	20.35	**16.12**
CPPU at 4mg/L	14.69	16.90	20.28	23.93	**18.95**
CPPU at 6mg/L	16.33	18.78	22.53	26.59	**21.06**
BRs at 1.5mg/L	15.66	18.01	21.62	25.51	**20.20**
BRs at 2mg/L	17.40	20.01	24.02	28.34	**22.44**
NAA at 50mg/L	12.30	14.15	16.98	20.03	**15.87**
NAA at 75mg/L	13.67	15.72	18.87	22.26	**17.63**
Mean	**14.17**	**16.30**	**19.56**	**23.08**	
LSD (0.05)	**Treatments (T): 0.24 Storage Periods (S): 0.17 Interaction (T×S): 0.488**				
Season 2020					
Control	12.60	14.49	17.38	20.51	**15.64**
Hand Pollination	14.00	16.10	19.31	22.79	**18.05**
CPPU at 4mg/L	16.46	18.92	22.71	26.80	**21.22**
CPPU at 6mg/L	18.29	21.03	22.23	29.77	**23.58**
BRs at 1.5mg/L	17.54	20.17	24.21	28.57	**22.62**
BRs at 2mg/L	19.49	22.42	26.90	31.74	**25.14**
NAA at 50mg/L	13.78	15.85	19.02	22.44	**17.77**
NAA at 75mg/L	15.32	17.61	21.13	24.94	**19.75**
Mean	**15.87**	**18.26**	**21.91**	**25.85**	
LSD (0.05)	**Treatments (T): 0.27 Storage Periods (S): 0.19 Interaction (T×S): 0.56**				

Vitamin C:

Results presented in Table (11), revealed that, all tested treatments increased fruit ascorbic acid content as compared with control treatment in both seasons. Generally, brassinosteroids (BRs) at 2mg/l recorded the significantly highest ascorbic acids (33.36 and 37.36 mg/100 ml juice), followed by BRs at 1.5 mg/L (30. 20 and 33.62 mg/100 ml juice) and BRs at 2 mg/L (27.02 and 30.27 mg/ 100 ml juice), furthermore, control treatment significantly lowest ascorbic acids (13.54 and 15.17 mg/100 ml juice), during both season.

On another side, results in the same table revealed that, ascorbic acid content of sugar apple fruits for all treatments in this study gradually decreased by storage periods, during both seasons. However, the highest ascorbic acid content of sugar apple fruits was recorded with brassinosteroids at 2 mg/L at all storage periods, as compared with control treatment which recorded the lowest mean values of ascorbic acid content of custard apple fruits, during both seasons.

The interaction between treatments and cold storage periods was highly significantly on ascorbic acid content of sugar apple (*Annona squamosa*, L.) during both seasons. The decrease in ascorbic acid may be attributed to its destruction during processing due to oxidation or heat. The enzyme ascorbic acid oxidase found in fruits easily oxidises it to dehydro-l-ascorbic acid (Abdualrahman *et al.,* 2016). Moreover, the safe range of storage temperature was found to be between 15 and 20°C, with maximum shelf life at 15°C. Furthermore, Broghton and Tan (1979) also found that the ascorbic acid content of custard apples increased as they ripened, peaking at the climacteric stage and then declining. During the ripening of soursop fruit, Paull (1982) observed an increase in ascorbic acid. The ascorbic acid content in ripe fruits decreased as the number of days required to reach the ripe stage

increased with decreasing storage temperature (Vishnu Prasanna *et al.,* 2000).

Table (11): Effect of hand pollination and plant growth regulators on vitamin C (mg/100g fresh juice) at harvest and cold storage at 12±1°C in air (90-95% relative humidity) of sugar apple fruits in 2019 and 2020 seasons.

Treatments	Storage Periods (Days)				
	0	4	8	12	Mean
Season 2019					
Control	13.54	11.91	9.53	6.67	**9.26**
Hand Pollination	15.04	13.23	10.59	7.41	**11.57**
CPPU at 4mg/L	24.10	21.21	16.97	11.88	**18.54**
CPPU at 6mg/L	26.78	23.56	18.85	13.20	**20.60**
BRs at 1.5mg/L	30.02	26.42	21.14	14.80	**23.09**
BRs at 2mg/L	33.36	29.36	23.48	16.44	**25.66**
NAA at 50mg/L	15.60	13.73	10.99	7.69	**12.00**
NAA at 75mg/L	17.34	15.26	12.21	8.54	**13.34**
Mean	**21.78**	**19.17**	**15.34**	**10.74**	
LSD $_{(0.05)}$	**Treatments (T): 0.61 Storage Periods (S): 0.43 Interaction (T×S): 1.22**				
Season 2020					
Control	15.17	13.34	10.67	7.47	**14.76**
Hand Pollination	16.85	14.82	11.86	8.30	**12.96**
CPPU at 4mg/L	26.99	23.75	19.00	13.30	**20.76**
CPPU at 6mg/L	29.99	26.39	21.11	14.78	**23.07**
BRs at 1.5mg/L	33.62	29.59	23.67	16.57	**25.86**
BRs at 2mg/L	37.36	32.88	26.30	18.41	**28.74**
NAA at 50mg/L	17.47	15.38	12..30	8.61	**13.44**
NAA at 75mg/L	19.41	17.09	13.67	9.57	**14.93**
Mean	**24.39**	**21.47**	**18.40**	**12.99**	
LSD $_{(0.05)}$	**Treatments (T): 0.67 Storage Periods (S): 0.48 Interaction (T×S): 1.35**				

CONCLUSION

According to the findings of this study, preharvest applications of BRs, CPPU, and NAA had a positive effect on fruit set percentage, fruit retention, fruit drop, number of fruits, and yield. Furthermore, foliar application of 2 mg/L BRs increased fruit length, diameter, weight, pulp weight, and number of seeds per fruit, while hand pollination increased peel weight, followed by NAA at 75 mg/L and control treatment, as compared to the other treatments during both seasons. Furthermore, during cold storage, brassinosteroids (1.5 and 2) mg/L caused a market increase in firmness, TSS, total sugars, and vitamin C, while causing a significant decrease in acidity, fruit weight loss, physiological and pathological disorders when compared to others.

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