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Foliar Application of Potassium and Gibberellic Acid to Improve Fruit Storability and Quality of Parthenocarpic Cucumber

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ABSTRACT

The study was carried out during the 2013–2014, 2014–2015, and 2015–2016 seasons in an insect-proof nethouse at the Centre of Excellence for Vegetables, an Indo-Israel project, at Gharaunda (Karnal), India. The aim was to examine the effect of foliar application of potassium at 1.0 (K_1), 2.5 (K_2), or 5.0 g/L (K_3), and gibberellic acid (GA_3) at 0.005 (G_1), 0.010 (G_2), or 0.015 g/L (G_3), used alone and in combinations on fruit quality and storability of the parthenocarpic cucumbers (*Cucumis sativus* L.) 'KUK 9' and 'Sevenstar' stored at high (27°C) and low (10°C) temperatures. Among individual treatments, foliar application of K_2 alone resulted in least weight loss, electrolyte leakage, and fruit decay percent. The fruit from the treatment combination of $G_2 + K_2$ was best in total soluble solids, with reduced weight loss, electrolyte leakage, and less decay compared to fruit from other treatments or the control. Fruit of 'KUK 9' exhibited better shelf-life than did 'Sevenstar'. Storability of fruit from plants treated with K and GA_3, either alone, or in combination, was found to be better, as it minimized fruit weight loss and decayed fruit, and extended the storage life of parthenocarpic cucumber.

Keywords: Cucumis sativus, F_1 hybrid, fruit quality, fruit storability, total soluble solids

INTRODUCTION

Most harvested vegetables are lost during postharvest handling due to fungal decay, chilling injury, and rapid maturation that leads to enhanced senescence process (Chan & Tian, 2006). Up to 50% losses of total harvested vegetables occur during postharvest storage in developing countries, including India, seriously affecting

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availability of vegetables to consumers (Sudheer & Indira, 2007). Storage of vegetables at an appropriate temperature is generally the most effective way to maintain quality. Certain reactive oxygen species are produced during postharvest which lead to senescence and short shelf-life of vegetables. Storage temperature and humidity generally control the amount of water loss. Stored vegetables continue to respire and transpire causing water and weight loss (Thompson, 2003). In horticultural crops, several preharvest aspects including irrigation, growing temperature, pest management, light conditions, maturity, mineral nutrition, and growth substance affect produce quality and storability (Wang, 1997). A physiological and pathological disorder of harvested vegetables tends to occur more frequently on softer senescent tissues (Ladaniya, 1997).

Plant growth regulators (PGRs) play an important role in delaying senescence and promoting postharvest life. Exogenous supplies of growth regulators at different stage of developing vegetables, as well as endogenous level, are reflected in vegetable development and quality. High yields would not be achieved without nutrient use efficiency that affected quality and postharvest storability of vegetables (Srivastava & Handa, 2005).

Foliar application is an economical way of supplementing plant growth substances and fertilizers and reduces the amount of nutrient usage (Jamal, Hamayun, Ahmad, & Chaudhary, 2006). Potassium plays an important role in improving the fruit shelf-life of many horticultural crops (Lester, Jifon, & Stewart, 2007). Potassium foliar feeding promotes firmness, an important indicator of shipping quality; texture; and shelf-life of horticultural crops. The effect of potassium on shelf-life is favorable through slowing of senescence and decrease of numerous physiological diseases (Harker, Redgwell, Hallett, Murray, & Carter, 1997).

Cucumber (*Cucumis sativus* L.) contains water (95%), carbohydrate (3%), protein (1%), total fat (0.5%), dietary fiber (1%), vitamins A, C, K, E, and potassium, manganese, calcium, zinc, and phosphorus (USDA, National Nutrient Data Base, 2014).

The present study was carried out to evaluate the effects of foliar application of concentrations of potassium and gibberellic acid applied alone and in combination on fruit storability of F1 hybrid parthenocarpic cucumber.

MATERIAL AND METHODS

A field experiment was carried out in the growing seasons during three successive seasons (September to December 2013–2014, 2014–2015, and 2015–2016) in an insect-proof nethouse at the Centre of Excellence for Vegetables, an Indo-Israel project, at Gharaunda (Karnal), India, located at 29-32°N latitude and 76-59°E longitude at temperatures of 32–34°C (day) and 17–27°C (night). The F_1 hybrid cucumbers ‘KUK 9’ and ‘Sevenstar’ were used and seeds were procured from the Centre of Excellence for Vegetables. The soil in the field plots was sandy loam in texture (sand, silt, and clay content was 82.20, 6.11, and 11.19%, respectively), slightly alkaline (pH 7.70), low to medium in electrical conductivity (EC = 0.27 M/m), with low levels of organic carbon (0.16%) and medium levels of phosphorus (15.23 kg/ha), potassium (146.50 kg/ha), and sulfur (52.39 ppm), and 12.3% moisture availability.

The experiment was carried out in a randomized complete block design, with three replicates per treatment, with concentration of potassium at 1.0 (K_1), 2.5 (K_2), or 5.0 g/L (K_3), and gibberellic acid at 0.005 (G_1), 0.01 (G_2), or 0.015 g/L (G_3) applied alone or in the combinations of G_1K_1, G_2K_2, and G_3K_3 for a total of nine treatments and one control. Stock solutions were prepared fresh in distilled water at the time of each application and dilutions to required concentrations were made from the stock solutions.

Seeds were sown on raised beds, 6 m × 80 cm × 30 cm (length × width × height), separated at a distance of 45 cm from each other and with 40 cm spacing between plants on the same bed. Nitrogen from urea, and potassium from muriate of potash, at 13:00:45 kg/ha was applied with a drip irrigation system for all treatments twice a week. The first foliar application of potassium, from muriate of potash, was at 20 days after sowing and then twice weekly until maturity. The GA_3 (Gibberrellic acid) foliar application was on 21, 30, and 60 days after sowing using a power pump sprayer. Other agriculture practices, that is, irrigation, hoeing, and weeding were carried out throughout the growing season. At fruit maturity, uniform size fruit from each treatment and the control were randomly selected for storage at high (27°C) and low (10°C) temperatures. Fruits were harvested at their commercial maturity stage (45–50 days). Fruits were put in a polythene bags each having 24 holes, 1–2 mm diameter, and stored at the desired temperature. Samples were taken at a 3-day interval for analysis until all fruit were unmarketable.

Weight loss of fruit was determined at the regular intervals according to the Association of Official Analytical Chemists (AOAC, 1994). The total soluble solids (TSS) content of fruit was determined using a hand refractrometer (0-32° Brix). Electrolyte leakage, as percent of total electrical conductivity was determined according to Lutts, Kinet, & Bouharmont (1995). Decay percent of fruit was calculated using the formula of El-Anany, Hassan and Rehab (2009).

The experimental data are presented as the mean and standard error of the mean (SEM) of different parameters studied in the present investigation. Statistical analysis was done using the Statistical Packages for Social Sciences (SPSS) version 8.0.

RESULTS

Weight loss, percent fruits decay, TSS%, and electrolyte leakage increased at 27°C compared to 10°C as time in storage increased. Higher concentrations of gibberellic acid negatively affected postharvest parameters. Fruit of ‘KUK 9’ had better shelf-life than ‘Sevenstar’.

Cultivar KUK 9 better delayed weight loss than fruit of 'Sevenstar' (Figures 1 and 2). During storage, the highest percent weight loss was in the control. Among treatments, the lowest percent weight loss was in 0.01 g/L GA_3 + 2.5 g/L K, followed by 0.005 g/L GA_3 + 1.0 g/L K. The maximum fruit weight loss was for 0.015 g/L GA_3 + 5.0 g/L K at 10°C. Other treatments lost >80% of their weight by the 18th day of storage and were not marketable.

There was a progressive increase in TSS content of cucumber fruits with storage time up to the 12th day and thereafter a decline in TSS% occurred. Decrease in TSS in both cultivars was higher at 27°C (Figures 3 and 4). Fruit of 'KUK 9' maintained higher TSS accumulation at the end of the storage. In control fruit, TSS content declined from 9-18 days of storage; there was a progressive increase in TSS content up to 9 days of storage and then declined. The lowest TSS content occurred from 0.015 g/L GA_3 + 5.0 g/L K on the 9th day of storage with the maximum decrease on the 18th day of storage, followed by 0.005 g/L GA_3 + 1.0 g/L K. The highest TSS content was in 'KUK 9' treated with 0.01 g/L GA_3 + 2.5 g/L K on the 9th day of storage.

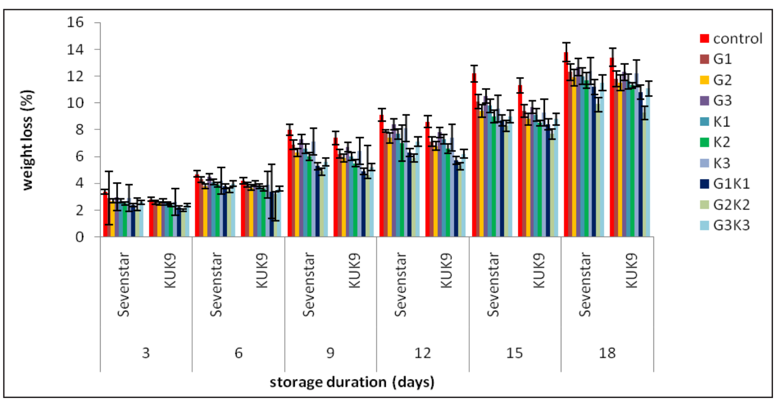

Figure 1. Weight losses (%) during storage of cucumber fruits at 27°C

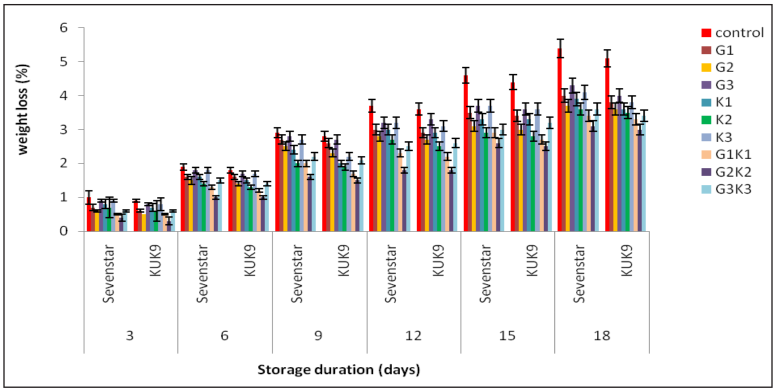

Figure 2. Weight losses (%) during storage of cucumber at 10°C

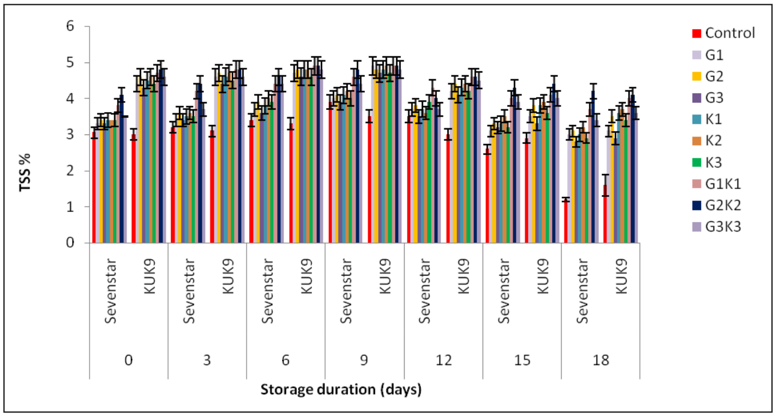

Figure 3. Total soluble solids (%) during storage of cucumber fruits at 27°C

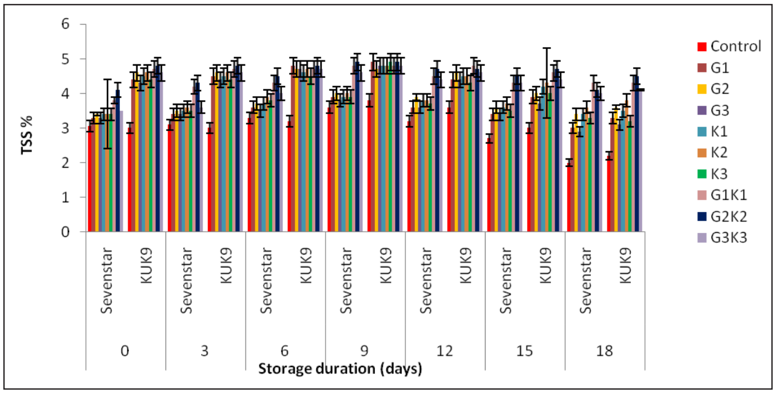

*Figure 4***.** Total soluble solids (%) during storage of cucumber fruits at 10°C

Electrolyte leakage of fruit increased gradually from the 3rd day to the 18th day in storage for both cultivars and all treatments. Storage at 10°C for 18 days caused less decrease in electrolyte leakage of cucumber fruit compared to fruit stored at 27°C (Figures 5 and 6). Fruits of 'KUK 9' maintained the electrolytes better compared to 'Sevenstar'. During storage the highest percent electrolyte leakage was for the control. Individual application of gibberellic acid and potassium influenced electrolyte leakage percent in fruit. The maximum percent electrolyte leakage was found in the 0.015 g/L GA_3 treatment which had higher electrolyte leakage. The maximum percent electrolyte leakage of fruits was found for the 5.0 g/L K treatment at 10°C in 'KUK 9'. Fruit from the combined treatments maintained electrolytes after 18 days of storage compared to the individual treatments including the control. The 0.015 g/L GA_3 + 5.0 g/L K treatment caused increases in electrolyte leakage. Fruit from the 2.5 g/L K + 0.01 g/L GA_3 treatments had lower electrolyte leakage followed by the 0.005 g/L GA_3 + 1.0 g/L K at 10°C for 'KUK 9'. In our study, 2.5 g/L K + 0.01 g/L GA_3 treatment was most effective in maintaining electrolytes.

Percent decay of cucumber fruits increased with length of storage. There was no visible sign of decay in fruit from treatments up to 6 days of storage at 27°C and 9 days of storage at 10°C in both cultivars (Figures 7 and 8). Percent decay was less when fruit were stored at 10°C compared to 27°C. The 'KUK 9' was more effective in maintaining low fruit percent decay. Control fruit had the maximum percent fruit decay over all other treatments. Less percent decay occurred with the 0.01 g/L GA_3 + 2.5 g/L K, followed by the 0.005 g/L GA_3 + 1.0 g/L K treatment. The maximum percent decay was for the 0.015 g/L GA_3 + 5.0 g/L K treatment. Control fruit started spoiling after nine days of storage and almost 90.3% decay occurred by the 15th day of storage; the least percent decay (14.23%) was due to the 0.01 g/L GA_3 + 2.5 g/L K treatment which was more effective in reducing percent decay compared to other treatments.

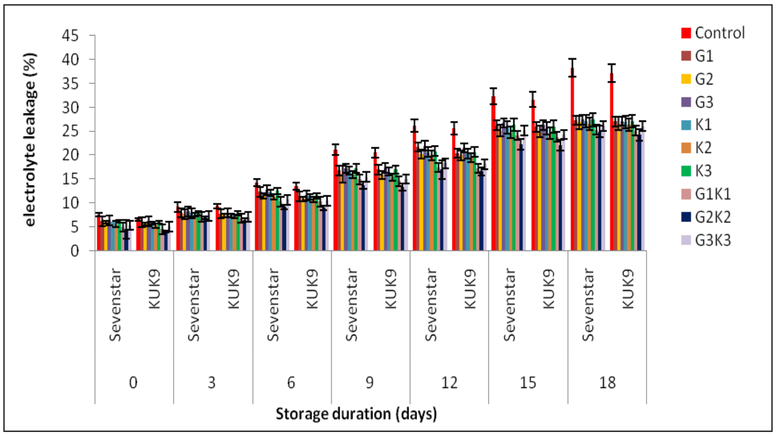

Figure 5. Electrolyte leakage (%) during storage of cucumber fruits at 27°C

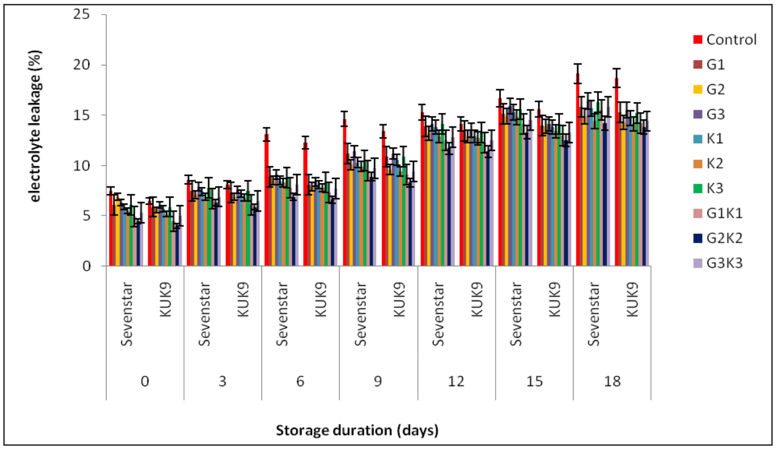

Figure 6. Electrolyte leakage (%) during storage of cucumber fruits at 10°C

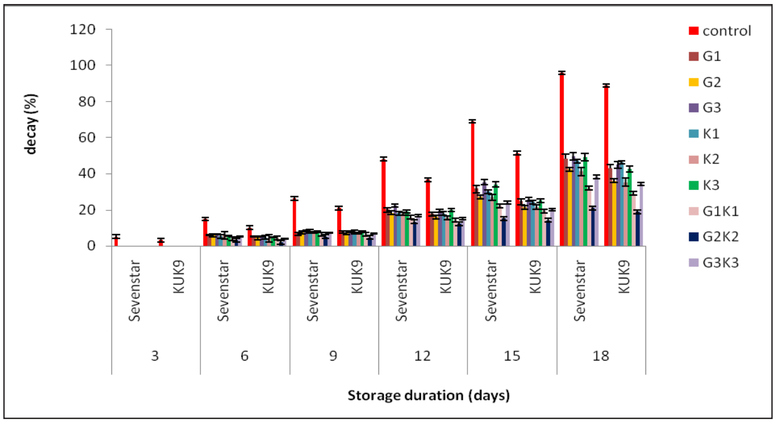

Figure 7. Decay (%) during storage of cucumber fruits at 27°C

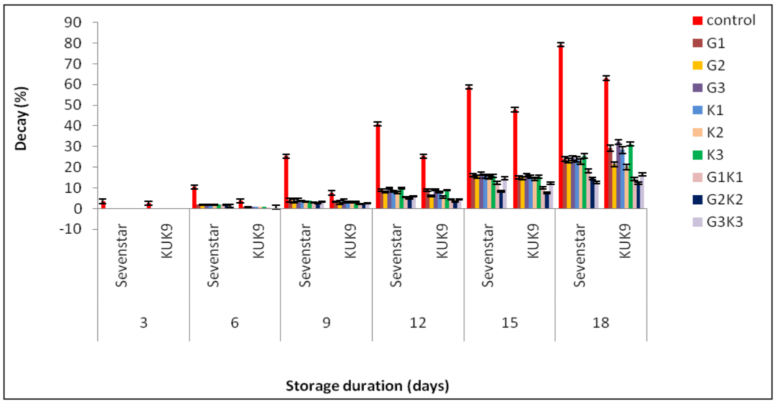

Figure 8. Decay (%) during storage of cucumber fruits at 10°C

DISCUSSION

Kim, Luo and Gross (2004) also observed an increase in weight loss of fruits with storage time in white and violet salad savoy plant. Low storage temperature is the main postharvest way to improve storage life of perishable products due to lowered ethylene production, fruit respiration, and metabolism. Homin and Kuenwoo (1999) reported that packaging produce in perforated polyethylene and storage at 10°C prolonged storage life of fruit and retains fresh weight and firmness.

Weight loss of vegetables is mainly depending on the control of internal gas composition (Park, 2000). After harvesting, a continuous water loss due to respiration leads to shrinkage and weight loss (Mahajan, Oliveira, & Macedo, 2008). In fresh vegetables weight loss might be ascribed to cellular breakdown, deterioration of membrane integrity and respiration, and carbohydrate degradation to yield carbon dioxide and water (Aquero, Ponce, Moreira, & Raura, 2011). Treatment with gibberellic acid resulted in decreased weight loss because of antisenescent action of GA_3. In a general way, it was evident that cucumber fruit need a high amount of water and carbon; water availability is very much affected by endogenous level of gibberellins (Sudha et al., 2007). The exogenous application of PGRs at flowering and fruit setting stage tends to increase fruit water content and their positive effect on fruit quality is evaluated immediately after harvest (Khalid, Malik, Khan, & Jamil, 2012). Physiological weight loss can be reduced through a decrease in tissue permeability by gibberellic acid treatment in *Solanum lycopersicum* L. (Choudhary & Dhruve, 2014). Potassium accumulates in cell vacuoles, with sugars, where it contributes to osmotic pressure, turgor potential, and water uptake in plants (Waraich, Ahmad, Saifullah, & Ehsanullah, 2011). Potassium application stimulates total solids, increases firmness, and reduces Ca availability and lowers physiological weight loss during storage (Voogt & Sonneveld, 1997).

The decay of fruit increased as storage lengthened. Gibberellic acid results in lowered decay rate in tomato fruit (Pila, Gol, & Rao, 2010). Fruit decay due to fungi was the major contributor to loss of fruit quality. Decay incidence greatly increased in fully ripe fruit during storage (Nunes & Morais, 2002). Preharvest gibberellic acid treatment reduced postharvest decay of cucumber and extended shelf-life. There have been relatively few reports on the effect of preharvest application of gibberellic acid. Decrease in peel senescence and increase in peel puncture resistance could reduce decay of fruit, prolong the storage life, and decrease the unmarketable fruit (Siddiqui & Dhua, 2010). Gibberellic acid enhances ultrastructural morphogenesis of plastids which stimulates retention of chlorophyll and delays senescence (Arteca, 1997; Ben-Arie, Mignani, Greve, Huysamer, & Labavitch, 1995). Application of potassium at an optimum level resulted in improved fruit quality, higher doses cause an imbalance of the sugar/acid ratio making more fruit more susceptible to fungal decay (Javaria, Qasim, Rahman, & Bakhsh, 2012).

Bahnasawy and Khater (2014) reported an increased TSS with increased storage temperature. As storage time increases accumulation of TSS increased and then decreased during storage was also noticed in mandarin (Bhardwaj, Sen, & Mukherjee, 2005), guava (Mahajan, 2004), strawberry (Singh, Sharma, & Tyagi, 2007), sapota fruit (Pawar, Patil, & Joshi, 2011). The interaction of gibberellic acid and potassium was best in keeping the level of TSS at an optimum level. Gibberellic acid application maintained the higher TSS% level in papaya fruit during storage (Rajkumar, Karuppaiah, & Kandasamy, 2005). Abd El-Razek, Abd-Allah and Saleh (2013) found that TSS level was influenced by potassium concentration. A possible reason for TSS maintenance under storage may be because of slowed respiration that lowers changes of insoluble sugar into soluble sugar and least utilization of organic acid in respiration (Choudhary & Dhruve, 2014; Pila et al., 2010). The TSS increases as maturity progresses during postharvest storage and is reduced due to utilization of sugar in respiration (Miaruddin, Chowdhury, Rahman, Khan, & Mozahid-E-Rahman, 2011; Salamat, Ghassemzadeh, Heris, & Hajilou, 2013). Kittur, Saroja and Tharanathan (2001) reported that percentage of TSS is correlated with hydrolytic changes in starch and conversion to sugar further reduces TSS during storage. During storage, TSS% level was affected by gibberellic acid because it reduces the ethylene level that stimulates starch synthesis (Abu-El-Ez, Behairy, & Ahmed, 2002). Preharvest foliar application of gibberellic acid caused increased fruit soluble solids in sweet cherry as recorded by Clayton, Biasi, Agar, Southwick and Mitcham (2006). Increased potassium concentration resulted in better firmness and increased TSS (Cakmak, 2005).

Increased electrolyte leakage occurred with increased storage temperature (Sharom, Willemot, & Thompson, 1994). Ion leakage is effective to determine the relative health of cell plasma membranes because it is expressed in rate of change in membrane permeability (Knowles, Trimble, & Knowles, 2000). Electrolyte leakage was indicative of quality loss in fruit. Gibberellic acid and potassium combination treatments were more effective in reducing electrolyte leakage. Potassium nitrate reduces membrane permeability in pepper (Kaya & Higgs, 2003). The effects of potassium on electrolyte leakage agree with Williumsen, Petersen and Kaack (1996) who reported a role for potassium in influencing calcium availability and permeability of cell membranes. Gibberellic acid was effective in reducing electrolyte leakage and K^+ efflux and reducing tissue permeability because of the preservative effects on the solute efflux capacity from intact tissue and survival of protoplasts (Choudhary & Dhruve, 2014; Pila et al., 2010).

CONCLUSION

Foliar spray of gibberlic acid and potassium either alone or in combination at appropriate concentration proved to be beneficial in controlling the fruit weight loss and maintaining TSS during storage. However, the excessive concentration of GA_3 and K imparts negative effect on shelf-life. Fruit of 'KUK 9' had better shelf-life than 'Sevenstar'.

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