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Ghan Shyam Abrol
College of Horticulture and Forestry, Rani Lakshmi Bai Central Agricultural University, Jhansi, Uttar Pradesh, India

K S Thakur
Department of Food Science and Technology, Dr. Y S Parmar UH&F, Nauni Solan, Himachal Pradesh, India

Correspondence
Ghan Shyam Abrol
College of Horticulture and Forestry, Rani Lakshmi Bai Central Agricultural University, Jhansi, Uttar Pradesh, India

Retention of functional and sensory qualities after harvest by application of combination of pre- and post-harvest treatments on snow queen nectarine (*Prunus persica* var. *nucipersica* Schneid.) fruits

Ghan Shyam Abrol and KS Thakur

Abstract
Snow Queen is a mid-season variety among the nectarines fruit grown in the "Peach Ball of Asia". Being a climacteric fruit, it can't be stored for long therefore present study was conducted to retain the quality after harvest by the application of combination of pre- and post-harvest treatments of nutrients, growth regulators and plant extracts. The pre-standardized four treatments of preharvest sprays of CPPU@15 ppm, Salicylic acid@3000 ppm, $CaCl_2$@1.5% and Neemazal@0.45% is combined with five pre-standardized postharvest treatments of 1-MCP fumigation750 ppb, water dip @ 55 °C for 5 minutes, 5 Min dip in 0.15% Neemazal at 55 °C, Starlight Coating @ 50% and Mint leaf extract @ 30% which was compare with water treated fruits i.e. control. All the treatments found to effective in protecting the physico-chemical and antioxidant compounds viz. ascorbic acid and total phenols content. Sensory and PCA analysis for overall acceptability of Snow Queen nectarine fruits generally improved with the advancement of storage period. Among all the combinations of pre- and post-harvest treatments, fruits treated with 1.5 per cent $CaCl_2$ at the preharvest stage combined with postharvest applications of 750 ppb 1-MCP treatment (T_{11}) proved to be most effective in maintaining fruit quality and minimizing deterioration during 28 days storage of nectarine fruit cv. Snow Queen at 3 ±1 ºC.

Keywords: snow queen nectarine, pre-harvest treatments, post-harvest treatments, antioxidant properties

1. Introduction
Nectarine (*Prunus persica* var. *nucipersica* Schneid.) is a smooth-skinned peach of the family Rosaceae. The word "nectarine" is derived from a Latin word which means 'Persian plum' which tastes similar to peaches, but are a bit more acidic and are classified under high ethylene evolution category with a rate of 10.0-100.0 µL/kg h^{-1} (Kader *et al*. 1985) [21]. Recently due to climate change, cultivation of peaches is shifted towards nectarine growing in mid hill areas of Himachal Pradesh particularly Solan and Rajgarh (Peach ball of Asia). The area under different cultivars of nectarines is expanding rapidly as they have a tendency to fetch better prices due to their earlier arrival, attractiveness & more demand in the market.

Preharvest application of growth regulators, nutrients and fungicides can modify the pace and direction of biochemical changes in developing fruit and has the potential to transform its quality at harvest and can influence their postharvest behaviour. Growth regulators play a vital role in modulating the ripening processes by affecting changes in fruit firmness, brought about by changes in cellular events (Wills *et al*. 1980) [49]**.** N-(2-cholor-4-pyridyl)-N-phenyl urea (CPPU), a diphenylurea compound that has a strong cytokinin like activity affects fruit quality through crop load reduction and enhancement of cell elongation and cell division (Greene 1996) [15]. The application of plant nutrients like Ca in the form of calcium chloride has also been found to maintain the cellular integrity and firmness of the fruits during storage (Ochie *et al*. 1993) [30]. Fungicides also help in extension of storage life of fruits by reducing the spore load and hence reducing the incidence of various pathological disorders (Smith and Kiel 1972) [40], which also ensures an extended storage life of fruit.

Similarly, various post-harvest treatments, that include inactivation of ethylene, slowing down the rate of respiration and transpiration and control of micro-organisms affects storage quality and in combination with low temperature storage have a potential to slow down ripening changes and thus, prolong the storage life. Treatment of fruits with substances such as

1-methylcyclopropene (1-MCP), an antagonist of ethylene action, fruit coatings with wax emulsions which acts as a natural barrier to the diffusion of O_2 and CO_2 into and out of fruit, thereby reducing respiratory and transpirational losses, treatments with hot water or plant extracts, which are effective in controlling spoilage by micro-organisms have been successfully exploited for enhancing shelf-life in different fruits and can have beneficial effects in nectarine as well.

Being a climacteric fruit, nectarine undergoes rapid changes during ripening and softens immediately after harvest. It is a delicate crop, well known for its poor shelf life. In order to avoid product wastage and better shelf-life during their postharvest life, the best results of our previous studies of pre- and post-harvest treatments (Abrol 2015; Abrol and Thakur 2018) [2, 1] are a combined and their effect on quality and shelf life is reported in this research paper.

2. Materials and Methods

2.1 Experimental site

The above experiments were laid out in the experimental orchard of Horticultural Research Station, Kandaghat, Dr. Y.S Parmar University of Horticulture and Forestry (Solan). Fruits for the experiment pertaining to see the effect of combination of pre- and post-harvest treatments were also procured from the same orchard. During the course of these investigations the orchard was well maintained and all the sample trees were maintained under a strict uniform schedule of cultural operations. The climate in Kandaghat is little warm and temperate. The summers also experience rainfall, while the winters are mostly dry. The area experiences average annual temperature is 18.1 °C and about 1390 mm of precipitation falls, annually.

2.2 Treatment application, and experimental design

For the experiment, well grown uniformly bearing nectarine Cv. Snow Queen trees were selected randomly in the experimental orchard of Horticultural Research Station, Kandaghat. The trees were maintained under a standardized schedule of cultural operations throughout the season and subjected to preharvest treatments of CPPU (N-(2-Chloro-4-pyridyl)-N-phenyl urea) and salicylic acid that were applied at pea stage and Neemazal and calcium chloride were applied 15 days before the expected date of harvest of fruit. Tween 20@ 0.2 per cent was added to all the solutions as a sticker. The solutions thus prepared were applied to the aerial parts of the tree (5 lit /tree), at the desired stage of fruit development, with a foot sprayer. The spray applications were performed during the morning hours on a clear day till the entire canopy was completely drenched.

Fruits from the experimental field were harvested on attainment of optimum stage of development. The fruits from individual trees were harvested manually and only representative, sound fruits were selected randomly for the investigations. The fruits were harvested during the cool morning hours on a clear day. The fruits were directly placed on moulded paper trays and packed in 5 kg corrugated fibre board (CFB) cartons. After packing the fruits were immediately transported to the Postharvest Physiology Laboratory, Department of Food Science and Technology, for postharvest treatments and further physico-chemical study.

For postharvest application, only fresh, healthy and uniform fruits were selected and the commercial formulation of 1-methylcyclopropene (1-MCP) containing 3.3 per cent of the active ingredient was procured from M/S Rohm and Haas Ltd. and applied as a fumigation treatment by placing the fruits in a closed airtight tent for 24 hours after dissolving the commercial formulation of 1-MCP in demineralised water and placing the solution inside the tent along with fruits. Starlight Fruit Conserve Wax Emulsion (Grade FR72), a material of plant origin and approved as a food grade emulsion under FDA, European regulations and CODEX, manufactured by Pontes industria de cera lida, Brazil was used for waxing of fruit. Wax solutions of required concentrations were prepared with water dilution in which fruits were dipped for 1 minute. Fruits were air dried in shade by spreading them on filter paper sheets with the help of a fan under ambient conditions.

Hot water treatments were given in a water bath maintained at the desired temperature with automatic control for a specific time. The Neemazal solution of required concentrations was also prepared by dissolving the required quantity of Neemazal in a known volume of water and heating to the desired temperature over a water bath. Mint leaf extract was prepared by crushing the equal amount of dried mint leaves with water. Tween 20@ 0.2 per cent was added to the solutions as a sticker. Thus, there were total 21 treatments including one control as T_1 (CPPU 15 ppm + 750 ppb 1-MCP fumigation); T_2 (CPPU 15 ppm + water dip @ 55 °C for 5 minutes); T_3 (CPPU 15 ppm + 5 Min dip in 0.15% Neemazal at 55 °C); T_4 (CPPU 15 ppm + Starlight Coating @ 50%); T_5 (CPPU 15 ppm + Mint leaf extract @ 30%); T_6 (Salicylic acid 3000 ppm + 750 ppb 1-MCP fumigation); T_7 (Salicylic acid 3000 ppm + water dip @ 55 °C for 5 minutes); T_8 (Salicylic acid 3000 ppm + 5 Min dip in 0.15% Neemazal at 55°C); T_9 (Salicylic acid 3000 ppm + Starlight Coating @ 50%); T_{10} (Salicylic acid 3000 ppm + Mint leaf extract @ 30%); T_{11} (CaCl2 1.5% + 750 ppb 1-MCP fumigation); T_{12} (CaCl2 1.5% + water dip @ 55 °C for 5 minutes); T_{13} (CaCl2 1.5% + 5 Min dip in 0.15% Neemazal at 55 °C); T_{14} (CaCl2 1.5% + Starlight Coating @ 50%); T_{15} (CaCl2 1.5% + Mint leaf extract @ 30%); T_{16} (Neemazal 0.45% + 750 ppb 1-MCP fumigation); T_{17} (Neemazal 0.45% + water dip @ 55 °C for 5 minutes); T_{18} (Neemazal 0.45% + 5 Min dip in 0.15% Neemazal at 55 °C); T_{19} (Neemazal 0.45% + Starlight Coating @ 50%); T_{20} (Neemazal 0.45% + Mint leaf extract @ 30%) and T_{21} control. Fruits from all the treatments were packed in separate CFB cartons and stored in a refrigerated storage at 3 ± 1ºC and 90 to 95 per-cent relative humidity.

2.3 Laboratory analysis

2.3.1 Physical analysis

Procedures adopted for evaluating quality by measuring physical parameters PLW and fruit firmness as per method prescribed by Ranganna (1986) [35].

2.3.2 Biochemical analysis

Observations pertaining to changes in bio-chemical characteristics like Total soluble solids (TSS) were measured using an Erma hand refractometer (0 to 32 ^{O}B) and the results were expressed as degree Brix (^{O}B). The readings were corrected by incorporating the appropriate correction factor for temperature variation (Hortwitz 1980) [19]. Titratable acidity was estimated by titrating a known aliquot of the sample against N/10 NaOH solution using phenolphthalein as an indicator. The titratable acidity was calculated and expressed as per cent malic acid (AOAC 1980). The total and reducing sugars of fruits were estimated by Lane and Eynon volumetric method (AOAC 1980) by titrating the sample against Fehlings solutions.

2.3.3 Antioxidant properties
Changes in antioxidant attributes viz. ascorbic acid content was determined as per AOAC (1980) method using 2, 6-dichlorophenol-indophenol dye and total phenols were extracted in 80 per cent ethanol and estimated on the basis of their reaction with an oxidizing agent phosphomolybdate in Folin-Ciocalteau reagent under alkaline conditions (Bray and Thorpe 1954) [6].

2.3.4 Sensory analysis
The sensory evaluation of nectarine fruits was conducted by a panel of trained 10 judges. Each judges were given samples of different treatments on each considered day of storage interval i.e. 0, 7, 14, 21 and 28 days and the panel of judges kept same during whole the experiment. Each judges were provided with a glass of fresh water to rinse mouth before testing the next sample. In this research paper only the overall attribute is presented which is preformed over a prescribed 9 point hedonic scale performa which was further subjected to Principle Component Analysis (PCA).

2.4 Statistical analysis
Observations for various physico-chemical and antioxidant characteristics were recorded from a representative fruit sample at harvest and then at a regular interval of 1 week throughout storage by drawing random samples for each treatment. The experiment was laid out in Completely Randomized Block Design (CRD) with all treatments having three replications each. Data pertaining to sensory evaluation was analysed by RBD (Mahony 1985) [27], while the data was also analyzed for PCA and Dendrogram using IBM SPSS 20.0.

3. Results and Discussion
3.1 Effect on physical characteristics
Physiological loss in weight (PLW) and fruit firmness (kg/cm^2) of fruit, as affected by combination of various pre- and post-harvest treatments at different storage intervals, reveals that there was a progressive increase in PLW of fruits while a steady decrease in firmness with a progressive advancement in storage durations under various treatments up to 28 days of storage. The treatments consisting of 1.5 per cent $CaCl_2$ in combination with 750 ppb1-MCP (T_{11}) proved to be the most effective in reducing PLW although statistically it was at par with the treatments T_{14} and T_{13} as these treatments exhibited mean PLW values of 4.05, 4.07 and 4.11 per cent, respectively. The control fruits (T_{21}) displayed maximum PLW on each sampling date and had the highest mean PLW (10.56 %), which was significantly higher in comparison to all other treatments. Similar to PLW, effect of calcium chloride @ 1.5 per cent in combination with various postharvest treatments resulted in firmer fruits, as such fruits generally recorded significantly higher firmness values throughout the 28 day storage period. The highest mean firmness value (6.68 kg/cm^2) was reported in fruits when they were treated with 1.5 per cent $CaCl_2$ at the preharvest stage followed by a postharvest treatment 750 ppb 1-MCP treatment (T_{11}) and it was followed by the treatments T_{14}, T_{13}, T_{12} and T_6 exhibiting firmness value of 6.65, 6.63, 6.60 and 6.59 kg/cm^2, respectively. The lowest firmness was recorded in control fruit where the mean firmness value of 4.81 kg/cm^2 was recorded. The interaction between treatments and storage intervals was found to be significant.
The weight loss in fruits can be mainly said to occur due to respiration and transpiration. Transpiration not only caused desiccation, shriveling, accelerated softening and loss of attractive appearance of fruit but the resultant water stress also accelerated the senescence (Sonkar *et al*. 2008) [41]. Softening of fruits is caused either by breakdown of insoluble protopectin into soluble pectin or by hydrolysis of starch (Mattoo *et al*. 1975) [29]. The loss of pectic substances in the middle lamella of the cell wall is perhaps the key step in the ripening processes that leads to the loss of cell wall integrity of fruits (Gross and Sams 1984) [16] and consequently leads to softening. The maintenance of higher firmness as a result of 1-MCP treatment may be due to its ability to prevent PLW during storage and to inhibit ethylene production (Dong *et al*. 2002; Mahajan *et al*. 2010) [10]. 1-MCP has been reported to delay softening in avocado, custard apple, mango, papaya and banana (Hofman *et al*. 2001; Ergun *et al*. 2006; Sakhale *et al*. 2018) [18, 11, 37]. The present findings are in confirmation with the studies of Oliveira *et al*. (2005) [31], Hayama *et al*. (2005) [17] and Chen *et al*. (2005) [8] who also reported that 1-MCP treatment of peach retained higher fruit firmness in comparison to control fruits.
The retention of firmness in calcium treated fruits might be due its accumulation in the cell walls leading to facilitation in the cross linking of the pectic polymers which increases wall strength and cell cohesion (White and Broadly 2003; Brummell 2006) [48, 7]. Robertson *et al*. (1990) [36] reported that the weight of 'Cresthaven' peaches decreased significantly during storage with an average weight loss of 3.5 per cent per week. The reduction in weight loss and firmness of 1-MCP treated fruits may also be attributed to lower respiration rate (Dong *et al*. 2002; Aguayo *et al*. 2006) [10, 3] and hence the lower loss of metabolites from fruits. Similar effect of 1-MCP on physiological weight loss has been reported in pear by Mahajan *et al*. (2010) [26] and in banana by Sakhale *et al*. (2018) [37].

3.2 Effect on biochemical characteristics
A perusal of the data reveals that there was a progressive and continuous increase in TSS content of treated fruits with an increase in storage period upto 28 days, except in control fruits (T_{21}) where the increase in TSS was observed only upto 14 days of storage and then declined gradually. The control fruits (T_{21}) therefore exhibited the lowest TSS content (11.70 °B) on last date of sampling. Fruits treated with 15 ppm CPPU at the preharvest stage followed by a postharvest dip 30 per cent mint leaf extract (T_5) exhibited maximum TSS contents and was followed by the treatments T_2, T_3 and T_4, respectively. The lowest TSS content (11.68°B) was observed under the treatment T_{11} and it was followed by T_{14}, T_{13} and T_6 where TSS value of 11.72°B, 11.78°B and 11.86°B, respectively, were recorded. The interaction between treatments and storage intervals was found to be significant.
Total soluble solids (TSS), total sugars and reducing sugars contents of fruit in general, increased during storage under the influence of combinations of pre- and post-harvest treatments. The higher TSS and sugars content in control fruits during the initial sampling dates might be due to faster ripening changes resulting in breakdown of complex carbohydrates into simple sugars at a faster rate thereby increasing these constituents to the maximum extent and also due to the higher transpiration losses (Suni *et al*. 2000) thereby having a concentration effect. Conversely the slower rate of increase of these constituents under T_{11} ($CaCl_2$ 1.5% + 750 ppb 1-MCP) and other treatments may be due to slower metabolism of fruits which might have slowed down the conversion of complex polysaccharides into simple sugars, besides slowing down the

respiration rate of fruits; thereby resulting in a lower decrease of these constituents. Slower reduction in TSS and sugar contents in fruits treated with 1-MCP have earlier been reported in plum (Salvador *et al*. 2003) [38], peach (Chen *et al*. 2005; Cuquel *et al*. 2006) [8, 9] and tomato (Paul and Pandey 2013) [32] which lend further credence to the present results.

There was a gradual declining trend in titratable acidity (TA) content of Snow Queen nectarine fruits with an advancement in storage periods under all the treatment combinations (Table 2). However, calcium chloride treated fruits generally exhibited lower decrease in TA content especially in combination with 1-MCP. The control fruit showed the lowest titratable acidity content throughout storage, thus depicting the lowest mean values (0.62%) which were significantly lower in comparison to all other treatments.

A perusal of the data reveals that there was a progressive and continuous increase in the mean reducing sugars content of fruits with an increase in storage periods upto 28 days, while in control fruits the increase was observed upto 14 days followed by a decline during the remaining storage duration. The highest reducing sugar contents were observed in T_5 (3.97%) on the 28th day of storage, whereas it was lowest in T_{21} (2.76%). The lowest mean values were observed under the treatment T_{11} and it was followed by T_{14}, T_{13}, T_{12} and T_{15} all the value found at par with each other. The highest increase was observed in T_5. At harvest, the total sugars content in fruits was improved substantially by CPPU whereas other treatments generally had significantly lower total sugar contents. Therefore, the maximum total sugar contents (5.99 %) were recorded in T_5 (15 ppm CPPU + 30% mint leaf extract) followed by T_2, T_3 and T_1, respectively, although all these treatments were statistically at par. A significant increase in the total sugar content was observed up to 28 days of storage under all the treatments while in control fruits the increase was upto14 days storage and which subsequently declined as the storage period of 28 days was approached and these fruits therefore recorded the lowest values (5.79 %) on the 28th day of sampling.

There was a gradual declining trend in titratable acidity (TA) content of Snow Queen nectarine fruits with an advancement in storage periods under all the treatment combinations can be ascribed to high metabolic activities resulting in utilization of organic acids as respiratory substrates during prolonged storage (Ulrich 1974) [46]. Titratable acidity is directly related to the concentration of organic acids present in the fruit, which are an important parameter in maintaining the quality of fruits. Ball (1997) [4] suggested that acidity decreases due to fermentation or break up of acids to sugars in fruits during respiration. In the present study $CaCl_2$ 1.5 per cent in combination with 750 ppb 1-MCP fumigation has been observed to result in higher retention of titratable acidity contents and similar results have been reported in various fruits as observed by Fan *et al*. (2002) [12], Girardi *et al*. (2003) [14], Liu *et al*. (2005) [23] and Freitas *et al*. (2007) [13]. Similar decrease in titratable acidity content during storage of mango (Jiang and Doyce 2000) [20], and peach (Vanoli *et al*. 1995) [47] has also been reported earlier.

3.3 Effect on Antioxidant Property

The combination of various pre- and post-harvest treatments considerably enhanced the ascorbic acid content in fruits in comparison to control fruits (Figure 1). However, there was a gradual declining trend in the ascorbic acid content of fruits with the advancement in storage under all the treatments with the fastest decline being recorded in control fruits (T_{21}), which consequently exhibited significantly lowest ascorbic acid contents (9.08 mg/ 100g). The decrease in ascorbic acid contents was lowest in fruits treated with in combination $CaCl_2$ with various postharvest treatments and hence the maximum mean ascorbic acid content of 10.66 mg/100g was recorded in treatments T_{11} and T_{14}, respectively.

The loss in ascorbic acid content during storage might be due to its degradation during metabolic processes or through enzymatic oxidation of L-ascorbic acid to dehydro ascorbic acid (Mapson 1970) [28], as well as utilization by developing microorganisms (Tandon and Tandon 1974; Taneja *et al*. 1983) [44]. Among various combinations, preharvest treatments 1.5 per cent $CaCl_2$ in combination with postharvest treatment of 750 ppb 1-MCP was the most effective in retaining higher ascorbic acid (10.66 mg/100g) content during storage. These results are in consistency with the observations of Mahajan and Sharma (1999) [24] on plums, Su Jin Le *et al*. (2004) [42] on Yutain peach, Rajput *et al*. (2008) [33] on guava and Ramezanian *et al*. (2009) [34] on pomegranate.

Similarly, a gradual decline in phenolic contents of nectarine fruits under all treatments during the entire storage period of 28 days under refrigerated conditions was observed. At harvest, the total phenol contents were considerably enhanced by various preharvest treatments in comparison to control. The maximum mean phenolic contents of 26.48 mg/100 g were recorded in fruits treated with $CaCl_2$ @ 1.5 per cent + 750 ppb 1-MCP fumigation (T_{11}) and it was closely followed by T_{14}, $T_{13,}$ T_6 and $T_{12,}$ respectively. The control fruits exhibited the lowest mean phenol content of 20.10 mg/100 g and it was significantly lower in comparison to all other treatments. The phenolic content of nectarine is high early during development, then decreases and remains fairly steady during ripening (Lakshminarayana *et al*. 1970) [22]. A perusal of pooled data indicates a gradual decline in phenolic contents of nectarine fruits under all treatments during storage and this is associated with loss of astringency of the fruit (Selvaraj and Kumar 1989) [39]. Polyphenol oxidase catalyses the oxidation of mono- and diphenols to o-quinones, which polymerize to produce brown pigments. The maximum mean phenolic contents of 26.48 mg/100 g were recorded in fruits treated with 1.5 per cent $CaCl_2$ in combination with 750 ppb 1-MCP.

3.4 Sensory evaluation

Sensory quality scores for various attributes were usually highest in fruits treated with 1.5 per cent $CaCl_2$ in combination with postharvest 750 ppb 1-MCP fumigation, whereas the control fruits recorded the lowest mean score owing to the faster deterioration in quality of these fruits, as they also exhibited maximum PLW and maximum decrease in fruit firmness, TSS, titratable acidity and sugar contents (Table 3). Results of Principle Component Analysis depicted in Figure 3, clearly shows that results of all the treatments are liked at 28th day of sensory analysis while it is least preferred by panel of judges at 0 day i.e. initial day of analysis. Dendrogram analysis clearly grouped the different treatments in four groups (Figure 4). The first group contains the treatments T_{15}, T_{18}, T_{19}, T_{13}, T_{16}, T_{14}, T_{11}, T_{12}, T_{17} and T_{20} which has the treatments related to mint leaf extract, hot water and calcium chloride with others treatments, second group T_2, T_3, T_1 and T_4 is related to CPPU treatments with others treatments and third group contains T_7, T_8, T_{10}, T_6, T_9 and T_5 which are treatment with salicylic acid with others treatments while the last fourth group which has totally different values is control T_{21}.

Sensory quality is a criterion for determining the acceptability of any food or food product by the consumers. Overall acceptability of food in addition to quality and nutritional attributes also depends on the sensory quality. Improvement in palatability rating of guava fruit with 1-MCP treatment has also been reported by Bassetto *et al*. (2005) [5] and Mahajan and Singh (2008) [25].

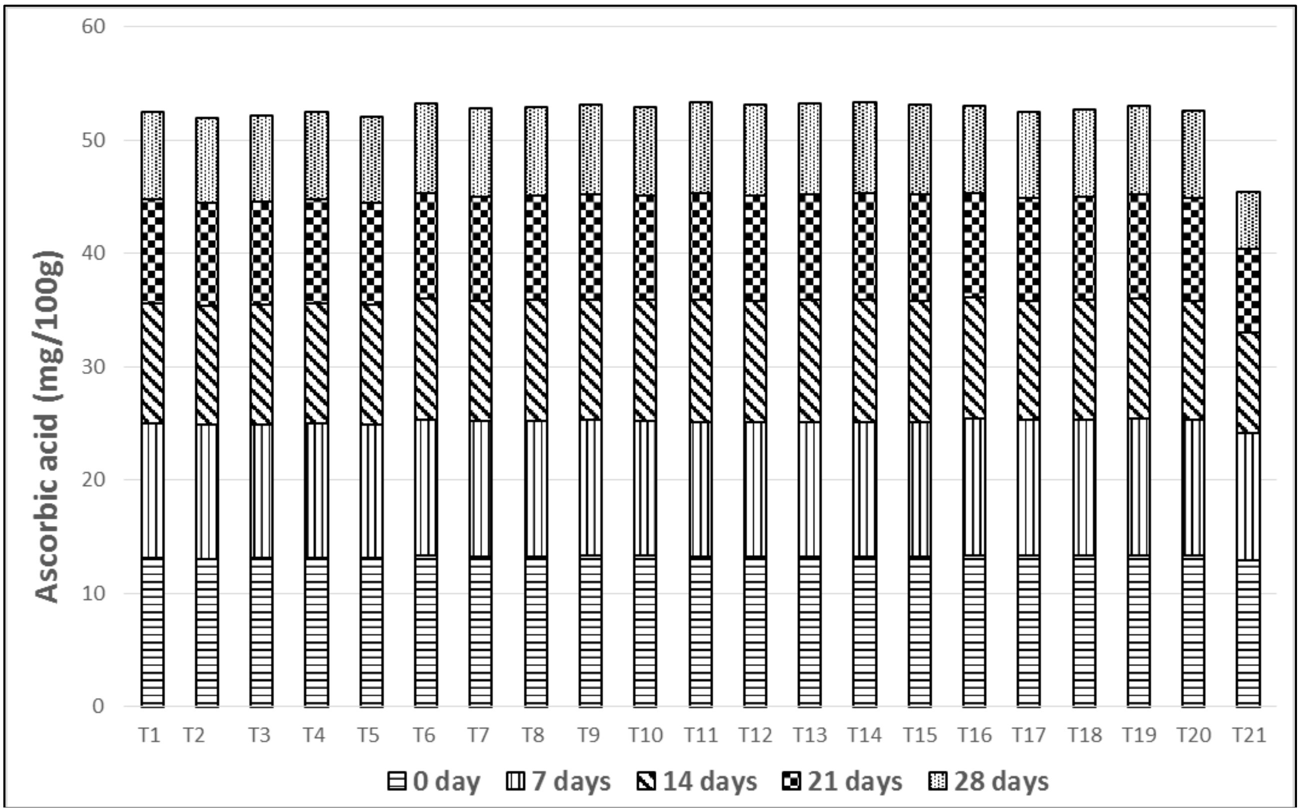

Fig 1: Effect of combination of pre- and post-harvest treatments on ascorbic acid (mg/100g) content of snow queen nectarine fruit during storage at 3±1ºC

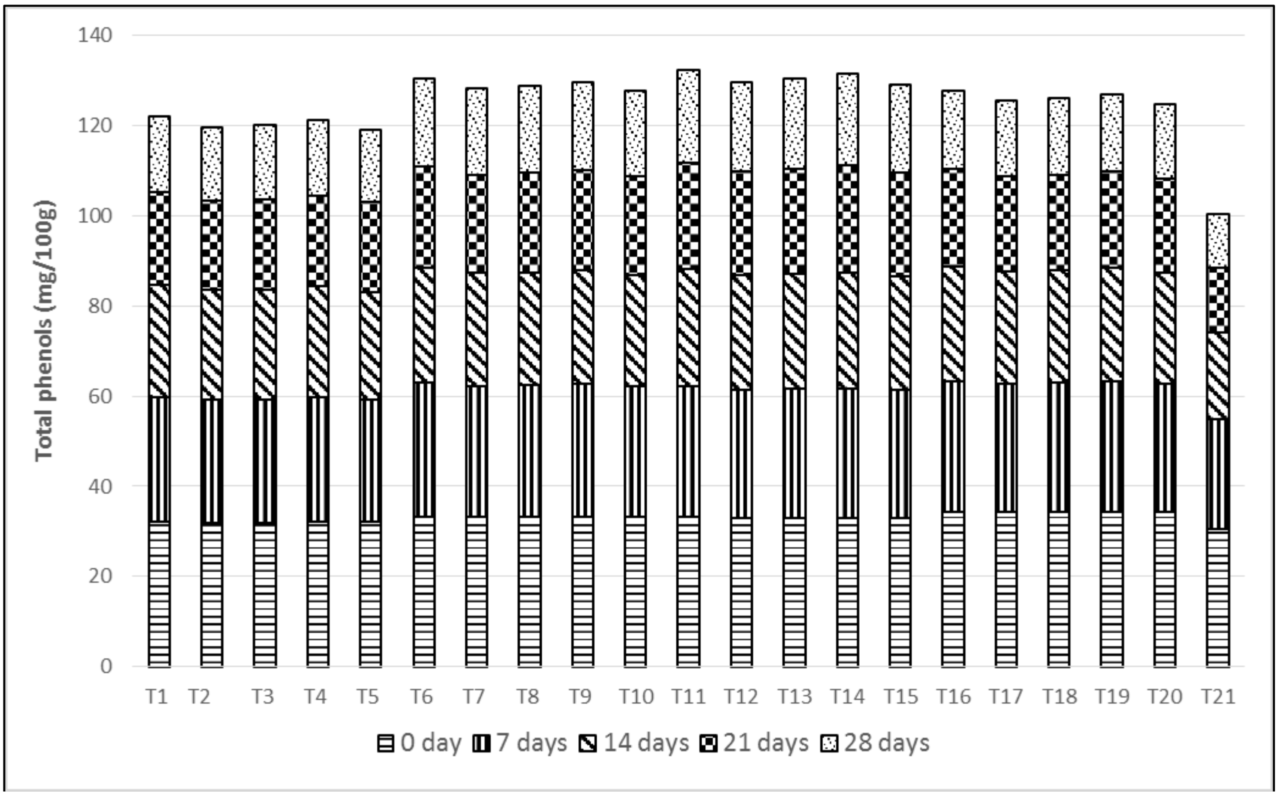

Fig 2: Effect of combination of pre- and post-harvest treatments on total phenols (mg/100g) content of Snow Queen nectarine fruit during storage at 3±1ºC

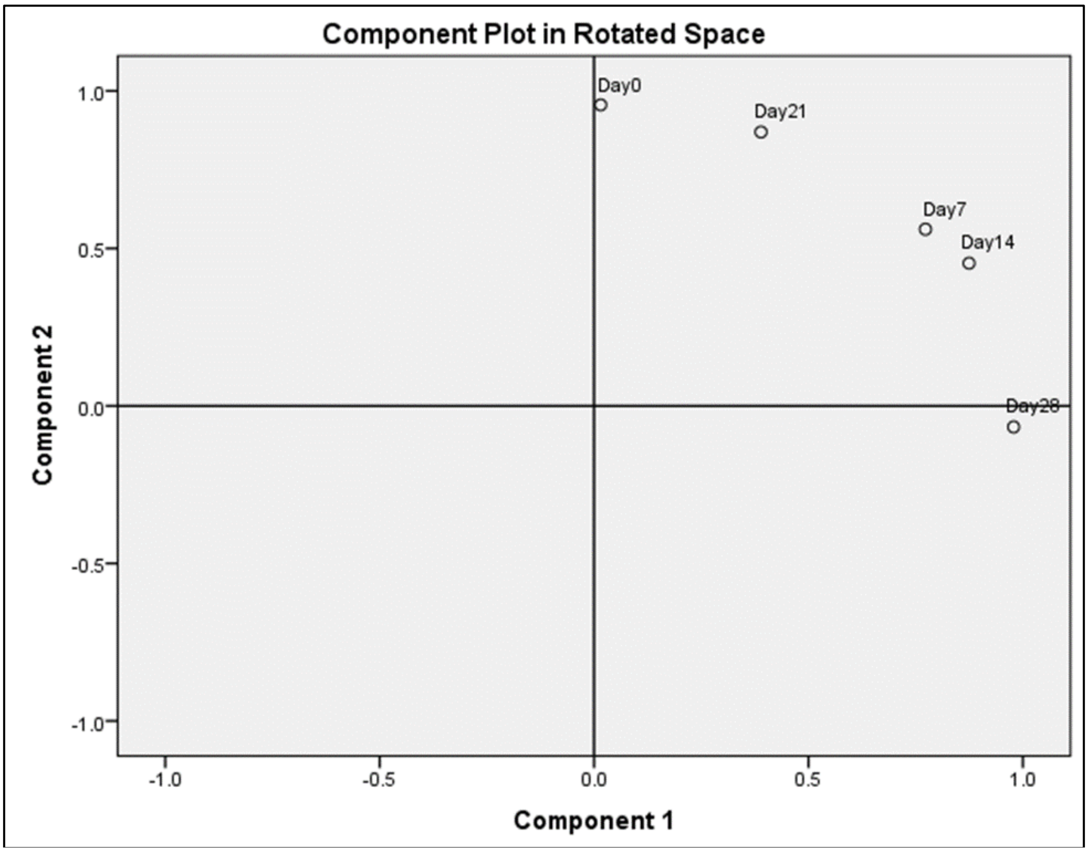

Fig 3: Projection of sensory characteristics of snow queen nectarine fruits effected by different treatments as affected by different storage intervals

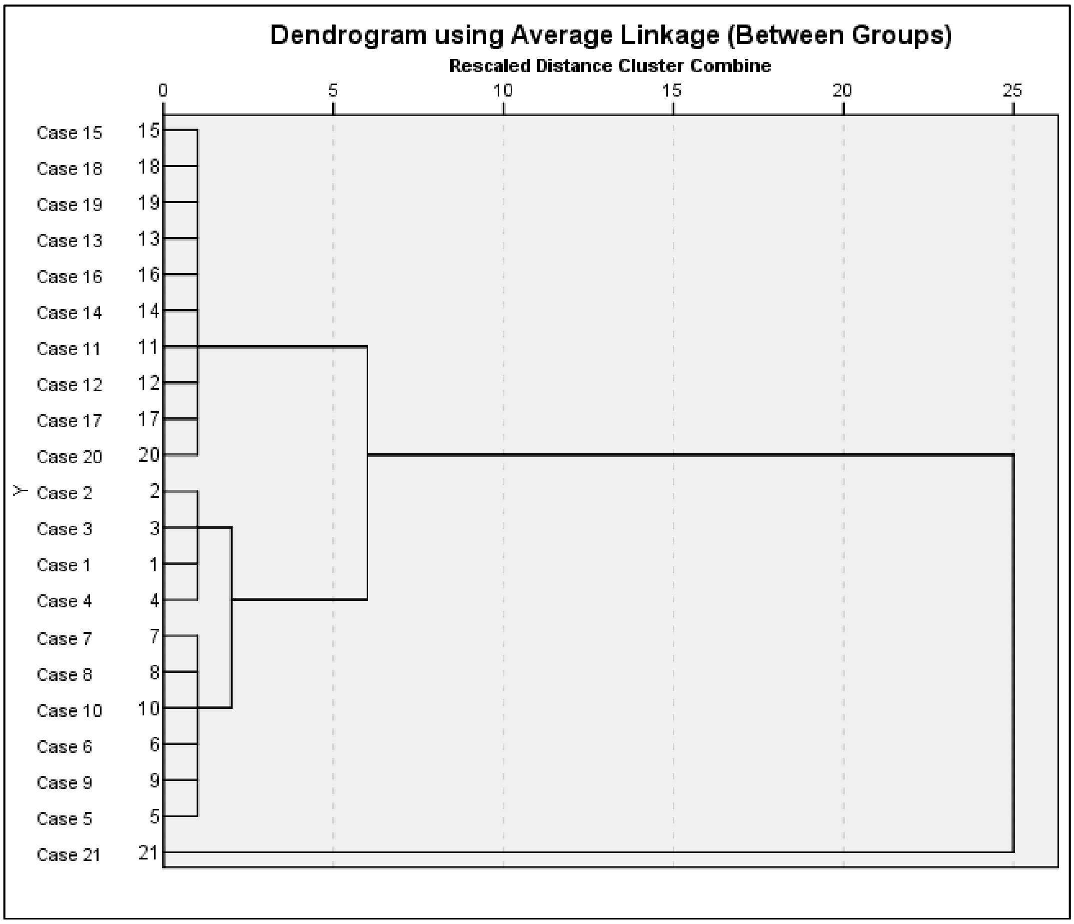

Fig 4: Dendrogram linkage grouping of different treatments affected by storage intervals for overall sensory quality parameter of Snow Queen nectarine fruit

Table 1: Effect of combination of pre- and post-harvest treatments on physiological loss (%) and firmness (kg/cm^2) content of Snow Queen nectarine fruit during storage at 3±1ºC

Treatment (T)	Physiological loss (%)					Firmness (kg/cm^2)				
	Storage Interval in days (I)					Storage Interval in days (I)				
	7	14	21	28	Mean	7	14	21	28	Mean
T_1	1.58	2.70	4.92	7.97	4.29	7.34	6.80	6.17	5.48	6.45
T_2	1.62	2.76	4.99	8.09	4.37	7.27	6.74	6.09	5.40	6.38
T_3	1.60	2.74	4.98	8.05	4.34	7.30	6.76	6.12	5.42	6.40
T_4	1.59	2.72	4.94	8.00	4.31	7.32	6.78	6.14	5.45	6.42
T_5	1.63	2.77	4.99	8.11	4.38	7.26	6.71	6.06	5.37	6.35
T_6	1.44	2.60	4.81	7.89	4.19	7.42	6.95	6.30	5.70	6.59
T_7	1.50	2.68	4.90	7.95	4.26	7.36	6.89	6.22	5.61	6.52
T_8	1.47	2.65	4.87	7.93	4.23	7.38	6.91	6.25	5.64	6.55
T_9	1.45	2.63	4.83	7.91	4.21	7.40	6.93	6.27	5.67	6.57
T_{10}	1.51	2.70	4.91	7.95	4.27	7.34	6.87	6.20	5.59	6.50
T_{11}	1.29	2.38	4.70	7.81	4.05	7.50	7.01	6.38	5.81	6.68
T_{12}	1.35	2.46	4.82	7.90	4.13	7.43	6.96	6.30	5.71	6.60
T_{13}	1.34	2.45	4.77	7.88	4.11	7.46	6.98	6.32	5.74	6.63
T_{14}	1.30	2.40	4.73	7.83	4.07	7.48	6.99	6.35	5.78	6.65
T_{15}	1.34	2.48	4.83	7.92	4.14	7.41	6.94	6.27	5.68	6.58
T_{16}	1.55	2.68	4.90	8.00	4.28	7.40	6.85	6.24	5.65	6.54
T_{17}	1.60	2.74	5.01	8.12	4.37	7.34	6.80	6.18	5.57	6.47
T_{18}	1.60	2.73	4.99	8.09	4.35	7.36	6.81	6.20	5.60	6.49
T_{19}	1.56	2.69	4.93	8.02	4.30	7.38	6.83	6.22	5.62	6.51
T_{20}	1.62	2.76	5.03	8.15	4.39	7.31	6.77	6.15	5.54	6.44
T_{21}	4.30	7.62	12.03	18.29	10.56	6.91	5.64	4.17	2.53	4.81
Mean	1.63	2.87	5.23	8.47		7.35	6.81	6.12	5.46	
Initial value	0					7.63				
$CD_{0.05}$										
T					0.06					0.02
I					0.02					0.01
T×I					0.11					0.04

Table 2: Effect of combination of pre- and post-harvest treatments on total soluble solids (°B), titratable acidity (% Mallic Acid), reducing sugars (%) and total sugars (%) content of Snow Queen nectarine fruit during storage at 3±1ºC

Treatment (T)	Total soluble solids						Titratable acidity						Reducing sugars						Total sugars					
	Storage Interval in days (I)						Storage Interval in days (I)						Storage Interval in days (I)						Storage Interval in days (I)					
	0	7	14	21	28	Mean	0	7	14	21	28	Mean	2.16	2.42	2.80	3.46	3.89	**2.95**	0	7	14	21	28	Mean
T_1	9.80	11.00	12.30	13.60	14.60	12.26	1.26	1.01	0.83	0.72	0.43	0.85	2.18	2.46	2.86	3.53	3.95	3.00	4.15	4.78	5.81	6.98	8.01	5.95
T_2	9.80	11.50	12.70	13.90	14.60	12.50	1.25	1.00	0.78	0.67	0.38	0.82	2.18	2.45	2.84	3.50	3.94	2.98	4.19	4.82	5.85	7.01	8.04	5.98
T_3	9.80	11.10	12.60	13.90	14.80	12.44	1.25	1.00	0.80	0.69	0.40	0.83	2.17	2.44	2.82	3.48	3.91	2.96	4.17	4.80	5.83	7.00	8.03	5.97
T_4	9.60	11.10	12.50	13.90	14.80	12.38	1.24	1.01	0.81	0.71	0.41	0.84	2.20	2.48	2.87	3.55	3.97	3.01	4.14	4.76	5.79	6.95	7.98	5.92
T_5	9.80	11.30	12.70	14.00	14.90	12.54	1.25	0.99	0.76	0.65	0.36	0.80	2.14	2.40	2.78	3.44	3.86	2.92	4.16	4.82	5.85	7.03	8.07	5.99
T_6	9.50	10.70	12.00	13.20	13.90	11.86	1.23	1.07	0.93	0.78	0.51	0.90	2.18	2.46	2.84	3.50	3.90	2.98	3.90	4.53	5.60	6.81	7.85	5.74
T_7	9.70	10.80	12.20	13.60	14.10	12.08	1.23	1.02	0.90	0.72	0.45	0.86	2.17	2.44	2.82	3.48	3.89	2.96	3.93	4.56	5.64	6.83	7.87	5.77
T_8	9.60	10.80	12.30	13.60	14.00	12.06	1.20	1.04	0.91	0.74	0.48	0.87	2.14	2.41	2.80	3.46	3.87	2.94	3.93	4.57	5.65	6.85	7.89	5.78
T_9	9.60	10.70	12.10	13.50	14.20	12.02	1.21	1.05	0.92	0.76	0.50	0.89	2.17	2.48	2.86	3.52	3.91	2.99	3.90	4.52	5.59	6.80	7.83	5.73
T_{10}	9.90	11.00	12.40	13.60	14.20	12.22	1.23	1.00	0.88	0.70	0.44	0.85	2.07	2.30	2.61	3.28	3.60	2.77	3.91	4.58	5.66	6.86	7.90	5.78
T_{11}	9.50	10.50	11.80	13.10	13.50	11.68	1.24	1.14	1.03	0.84	0.73	1.00	2.10	2.37	2.66	3.33	3.66	2.82	3.87	4.20	5.24	6.55	7.70	5.51
T_{12}	9.60	10.90	12.10	13.20	13.70	11.90	1.22	1.09	0.95	0.73	0.63	0.92	2.09	2.36	2.65	3.32	3.65	2.81	3.92	4.52	5.54	6.74	7.82	5.71
T_{13}	9.60	10.70	11.80	13.20	13.60	11.78	1.22	1.12	0.99	0.76	0.67	0.95	2.06	2.32	2.62	3.30	3.62	2.78	3.90	4.50	5.52	6.73	7.81	5.69
T_{14}	9.60	10.70	11.80	13.00	13.50	11.72	1.23	1.09	1.00	0.78	0.69	0.96	2.07	2.38	2.67	3.35	3.69	2.83	3.87	4.27	5.30	6.69	7.76	5.58
T_{15}	9.60	10.80	12.10	13.30	13.80	11.92	1.22	1.07	0.94	0.71	0.63	0.91	2.15	2.40	2.82	3.41	3.70	2.90	3.88	4.52	5.55	6.76	7.85	5.71
T_{16}	9.50	10.90	12.20	13.50	14.10	12.04	1.24	1.12	0.95	0.81	0.60	0.94	2.19	2.46	2.86	3.45	3.75	2.94	4.08	4.60	5.65	6.87	7.89	5.82
T_{17}	9.60	11.30	12.60	13.70	14.40	12.32	1.24	1.11	0.89	0.76	0.54	0.91	2.18	2.45	2.85	3.44	3.73	2.93	4.10	4.64	5.69	6.90	7.91	5.85
T_{18}	9.70	11.10	12.50	13.70	14.50	12.30	1.21	1.12	0.91	0.78	0.56	0.92	2.15	2.42	2.83	3.43	3.73	2.91	4.10	4.62	5.67	6.88	7.90	5.83
T_{19}	9.60	11.00	12.40	13.70	14.50	12.24	1.20	1.09	0.93	0.80	0.59	0.92	2.16	2.43	2.85	3.45	3.76	2.93	4.07	4.60	5.65	6.85	7.84	5.80
T_{20}	9.70	11.10	12.50	13.80	14.60	12.34	1.19	1.11	0.87	0.76	0.51	0.89	2.06	2.80	3.48	3.13	2.76	2.85	4.10	4.64	5.70	6.92	7.93	5.86
T_{21}	9.30	11.70	13.90	13.00	11.70	11.92	1.13	0.93	0.50	0.33	0.20	0.62	2.14	2.43	2.82	3.42	3.75		3.85	5.21	6.48	6.29	5.79	5.52
Mean	9.64	10.99	12.36	13.52	14.10		1.22	1.06	0.88	0.72	0.51								4.01	4.62	5.68	6.82	7.79	
$CD_{0.05}$																								
I						0.04						0.03						0.07						0.02
T						0.09						0.01						0.03						0.01
T×I						0.21						0.06						0.15						0.05

Table 3: Effect of combination of pre- and post-harvest treatments on sensory acceptability rating on first two principle components of Snow Queen nectarine fruit during storage at 3±1ºC

Treatment (T)	Principle component I	Principle Component II
T_1	.02802	.53896
T_2	-.15322	-.76191
T_3	-.03714	-.47507
T_4	.06441	-.06338
T_5	-.69809	-.22000
T_6	-.52517	-.55957
T_7	-.76288	-1.73662
T_8	-.71669	-1.49454
T_9	-.56994	-1.10342
T_{10}	-.83890	-1.22428
T_{11}	1.18731	1.27609
T_{12}	.23191	.57611
T_{13}	1.04660	.29984
T_{14}	1.21420	.53491
T_{15}	.94783	-.09130
T_{16}	.73527	1.02384
T_{17}	-.01094	.50029
T_{18}	.78230	.13710
T_{19}	.72647	.44207
T_{20}	.53925	-.18383
T_{21}	-3.19062	2.58470

Table 4: Summary of Eigen analysis of overall sensory characteristics data by Principal Component Analysis

Component	Initial Eigenvalues		
	Total	% of Variance	Cumulative %
1	3.458	69.163	69.163
2	1.207	24.131	93.294
3	.218	4.361	97.655
4	.108	2.165	99.820
5	.009	.180	100.000

5. Conclusion

Nectarine is important crop of new era of temperate region. The crop is highly perishable due to high ethylene evolution rate. Therefore, present study was very effective to maintain the quality after harvest and improving the shelf life of fruits. In this unique study combination of pre-standardized treatments of pre- and post-harvest were made and proved to be very effective in retaining the quality of treated fruits. However, there was a gradual declining trend in the ascorbic acid content and total phenols content of fruits with the advancement in storage duration under all treatments with the fastest decline being recorded in control fruits, which consequently exhibited significantly lowest ascorbic acid contents. Rating for overall acceptability of Snow Queen nectarine fruits generally improved with the advancement of storage period. However, control fruits scored maximum rating on the 21st day of sampling which was followed by a decline during the remaining storage period. Treatment T_{11} (1.5 per cent $CaCl_2$ + 750 ppb 1-MCP fumigation) secured maximum sensory scores for overall rating. Among all the combinations of pre- and post-harvest treatments, fruits treated with 1.5 per cent $CaCl_2$ at the preharvest stage followed by a postharvest treatment 750 ppb 1-MCP treatment (T_{11}) proved to be most effective in maintaining fruit quality and minimizing deterioration during 28 days storage at 3 ±1 ºC.

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