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Evaluation of Sucrose and Sodium Hypochlorite as Pulsing Solution in Improving the Post-harvest Quality in Chrysanthemum cv. White Star

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ABSTRACT: Chrysanthemum is an important commercial cut flower that is emerging in the floriculture industry. Pulsing is a primary concern in the commercialization of flower as after harvest flowers tends to lose their freshness. Among the different pulsing solution used to improve the vase life of chrysanthemum, Sucrose and Sodium hypochlorite has emerged as potent holding solution that can delay the senescence and improve the post-harvest life of Chrysanthemum. In this experiment, we studied the potential of Sucrose and Sodium hypochlorite in improving the vase life of Chrysanthemum cv. 'White Star'. The challenges of the study Chrysanthemum spike were harvested at the flower bud stage and the temperature was approximately 18°C, the uniform flowers were cut and immediately stood upright in buckets partially filled with de-ionized water. The latter stage proved that sucrose and NaOCl prolonged the vase life of the Chrysanthemum flower. The overall best treatment for different parameters for improving the vase life of chrysanthemum during the season 2021-2022 were recorded under the treatment T8 (Sucrose 20 % + NaOCl 50 ppm) 2 hours followed by the treatment T6 (Sucrose 10 % + NaOCl 50 ppm) 2 hours and T4 (Sucrose 5 % + NaOCl 50 ppm) 2 hours while pulsing with T0 Control (de-ionized water) adversely affected the different post-harvest parameters of Chrysanthemum.

Keywords: Chrysanthemum, Pulsing, Sucrose, Sodium hypochlorite and Vase life.

INTRODUCTION

Chrysanthemum flower (*Chrysanthemum × morifolium* Ramat.) a member of 'Asteraceae' family also called 'Compositae', consists of over 32,000 known species of flowering plant in over 19,000 genera within the order Asterales, Mandel *et al.* (2019), however, it is one of the most popular cut flowers in India and across the world, (Datta and Jankiram 2015). *Chrysanthemum morifolium* is a valid name for the different varieties we grow today (Bailey, 1949). The 'Asteraceae' is highly diverse, self in compatibility is a rule of this family that enforces outcrossing (Drewlow *et al.*, 1973; Anderson, 2007).

Phylogenetically, it is one of the most advanced dicotyledonous family (Hemsley, 1889; Popham and Chan 1950). The genus chrysanthemum has basically a large range of ploidy levels ranging from 2x to 25x, besides a number of aneuploid levels, Bremer (1993). In India *Chrysanthemum morifolium* were found to have a large complex of polyaneuploid levels ranging from 2n = 32-72 (Nazeer and Khoshoo 1983). The wild species of Chrysanthemum represent precious resource for breeding however, Linnaeus was first person in Europe, for discovering two herbarium specimen namely *C. indicum*. In 1999 the International Botanical Congress sanctioned the proposal to conserve the name *Chrysanthemum* L. for cultivated Chrysanthemum, Bailey (1963). The combination Chrysanthemum and the specific epithet morifoliuum for cultivated types were firstly proposed by De Ramatuelle in 1972, Francisco *et al.* (1997). Chrysanthemum is commonly known as 'Guldaudi' or 'Autumn Queen'. Chrysanthemum is ranked as the second most economic important cut flower in the world after rose (Kafi and Ghahsareh 2009) because of its tremendously diverse in morphologies including flower shapes, sizes, colors and plant architecture (Mekapogu *et al.*, 2022).

The genus Chrysanthemum contains about 41 species that are well distributed in East Asia and South East Asia (Hao *et al.*, 2022). 'Guldaudi' or 'Autumn Queen' are two frequent names for chrysanthemum. Since, this crop is sensitive to photoperiod i.e., short day crop which induces flower bud initiation. India's most widely used ornamental flower crops, the Chrysanthemum, unquestionably holds a notable place in Indian flower industry. In the global floricultural trade, it acquires the position among the top ten flowers. As per the report (Bisht *et al.*, 2010).

Chrysanthemum are short-day plant, thus it initiate flowering when the day length duration are shorter than their critical photoperiod phase (14.5 hrs) (Chomchalow *et al.*, 2004).

In the past decade after liberalization floricultural industries majorly took very giant steps in the floriculture export arena. This era has been a dynamic shift globally from sustenance production of flower crops to the area for floriculture production in India falls under 322 thousand hectares with annual production of 2152 thousand tonnes of loose flowers and 828 thousand tonnes of cut flower (NHB, 2020-2021). In several states of India floriculture or flower cultivation is highest in Kerala (16.5%) with respect to area the other flower producing states which have gone ahead are Tamil Nadu (13.3 %), Karnataka (11.4 %), Madhya Pradesh (11.1 %) and Uttar Pradesh (7 %) with states like Andhra Pradesh, West Bengal, Mizoram, Gujarat, Orissa, Jharkhand, Haryana, Assam and Chhattisgarh.

The term 'Pulsing' means placing freshly harvested flowers for a relatively short time for few second to hours in a solution especially formulated to extend their vase life (Sao and Rao 2020). The blockage of Xylem vessel by air and microorganism that might cause xylem occlusion is one of the major problems of cut flowers shelf life (da Silva *et al.,* 2013). In more simple words 'Pulsing' is supplying a solution through 'transpiration stream' mechanism da Silva *et al.* (2003) this process is also called as 'Hydration' (Schulker *et al.,* 2021). Pulsing involves concentration, ambient temperature, Extension of vase life and improvement of flower quality are highly desirable characters. It has been reported that pulsing treatments prevent vascular infection and inhibit ethylene.

Cut flowers are short lived and are prone to rapid deterioration. Shortening vase life of cut flowers could be attributed to destruction of transport vessels of the stem after cutting; hence the inability of stem to absorb water due to blockage may be leading to excessive water loss and short supply of carbohydrates to support respiration. A floral preservative is usually a complex mixture of sucrose, acidifier, an inhibitor of microorganisms and also an anti-ethylene action (Tehrainfar *et al.,* 2013; Darandeh and Hadavi 2012). Sugars are the main source of food for flowers. They are required for carrying out all biochemical and physiological processes after detachment from the mother plant.

Sodium hypochlorite (NaOCl) is considered as a microbial pesticide (Belle *et al.,* 2004). The reduced endogenous carbohydrates used during the post-harvest life of cut flowers are replaced by exogenous sugar. Sucrose is a major structural component employed in cell growth and enlargement, the primary sugar form that transports sugar to flower buds, and it is a soluble component of petal tissues, making it an essential osmotic regulator of water potential. Sugars (sucrose) are essential for maintaining the quality of cut flowers. The most popular floral preserver, sucrose, keeps the pool of dry matter and respirable substrates in flower petals.

Sugars play an important role in keeping the quality of cut flowers because the amount of sugar contained in the cut flower is limited. Exogenous sucrose replaces the depleted endogenous carbohydrates utilized during the post-harvest life of cut flowers. Sucrose is a major structural component employed in cell growth and enlargement, the primary sugar form that transports sugar to flower buds, and it is a soluble component of petal tissues, making it an essential osmotic regulator of water potential (Weerts, 2002). Research is required to find out the impact of pulsing solutions on increasing the vase life of different cut chrysanthemum flowers as one of the most popular cut flowers. Therefore, the objectives of this study were to investigate the effect of pulsing solutions on improving the keeping quality, enhancing water uptake and extending the vase life period of cut chrysanthemum flowers.

MATERIALS AND METHODS

The present work was carried out in the Department of Floriculture and Landscape Architecture Laboratory, College of Horticulture, SVPUAT, Meerut during the year 2021-22. The experimental location, Meerut comes under the semi- arid region and Agro-climatic plain zone of Uttar Pradesh state and lies at North West Plain Zone, India, 28.990 N Latitude and 77.70 E Longitude with an altitude of 220 m above the mean sea level. The general climate in the Meerut region of Western Uttar Pradesh is dry sub-humid type with annual rainfall varying from 900 to 1000 mm approximately every year. The experiment flowers were held at ambient room temperature (average mean temperature of 24°C, Maximum Relative humidity 83% and minimum of 48% under) 40W cool white fluorescent tubes.

Plant material. Chrysanthemum (*Chrysanthemum morifolium* Ramat.) cultivar 'White Star' rooted cuttings were procured from National Botanical Research Institute, (NBRI)-Lucknow. 'White Star' is a spray type. The plant is multi- headed producing white colour flowers with green center making the flower elegant and attractive, which fetches it is a good market price. The cut stem length is about 85-90 cm. Flower head is 6-8 cm diameter with its cut stem is hard and strong. The flowers were continuously held in the vase life was defined as days from the time of immersion in test solution to loss of ornamental value, like stem bending, blackening, wilting and abscission of petals.

Treatments and observations. The experiments were repeated twice for confirmation of the results, with ambient temperature of 15-18°C, 60±5 RH, and average radiation around 5000 Lux for a period of 8±2h/day. When the flowers were in the flower bud stage and the temperature was approximately 18°C, the uniform flowers were cut and immediately stood upright in buckets partially filled with deionized water. After transporting to our laboratory, the stem-ends were crosswise cut under the de-ionized water for approximately 30 cm length with two compound leaves and then, one part was treated with various pulsing solutions *viz.,* Sucrose (5-20%) and Sodium hypochlorite (50 PPM) which have sodium cation and hypochlorite anion, for 2-4 hours while, treatment devoid of pulsing solution used as control (de-ionized water). After pre-treatment, these flowers were all inserted into 2% sucrose solution, and the flask was covered with foils to minimize water loss which was kept indoors, with a temperature of approximately 20°C. The flowers were subjected to 10 treatments of pulsing and holding solutions with 3 replications, arranged in a completely randomized design. Stem were inserted in glass bottles (500 ml) containing 250 ml of one the following pulsing solutions at different levels: T0 -Control (de-ionized water),T1 -Pulsing (sucrose 5%) for 4 hours, T2 -Pulsing (sucrose 10%) for 4 hours,T3 - Pulsing (sucrose 20 %) for 4 hours,T4 - Pulsing (sucrose 5% + NaOCl 50ppm) for 2 hours,T5 - Pulsing (sucrose 5% + NaOCl 50ppm) for 4 hours,T6 - Pulsing (sucrose 10% + NaOCl 50ppm) for 2 hours,T7 -Pulsing (sucrose 10% + NaOCl 50ppm) for 4 hours,T8 -Pulsing (sucrose 20% + NaOCl 50ppm) for 2 hours,T9 -Pulsing (sucrose 20% + NaOCl 50ppm) for 4 hours. After that, the flowers were kept in a holding solution of distilled water alone.

Vase life observation. When beginning to experiment of vase, the appearance changes of chrysanthemum flowers were recorded every day for 12 days and the time that petal wilting and failing occurred was recorded as the end of vase life.

Statistical analysis. The recorded data were statistically analysis (ANOVA analysis) using the software Graph pad prism, USA. Source of variation were pulsing agents viz., Sucrose and Sodium hypochlorite. Mean data were also compared by using Duncan's new multiple range test whereas the effect were significant at 0.05% level of significance.

RESULTS AND DISCUSSION

Days to bud opening. Based on the signs of flower ageing, all the treatments significantly improved the days to bud opening of chrysanthemum as compared to control. Data presented in table 1 revealed that different preservative solution for improving the post-harvest quality had significant influence on days taken to bud opening. During the first season 2021-2022 the minimum days taken for bud opening (3.10 days) were recorded under the treatment T4 (Sucrose 5 %+ NaOCl 50 ppm) 2 hours followed by (3.63 and 3.73 days, respectively) under the treatment T6 (Sucrose 10 % + NaOCl 50 ppm) 2 hours and T8 (Sucrose 20 % + NaOCl 50 ppm) 2 hours while, maximum (6.85 days) was recorded under the treatment T0 Control (de-ionized water). From the present results it is very clear that the above treatments were significantly superior amongst rest of the other treatments used in the study. It may be inferred from the data that sucrose in low concentration when used with high concentration of Sodium hypochlorite, and conversely at later stage when increased used of sucrose with optimum dose of Sodium hypochlorite produced significant results and produced minimum days to bud opening. In the present investigation we noted the minimum days taken for the bud opening was due to the initial application of higher dose of sucrose with sodium hypochlorite and further on reducing the dose helped in achieving minimum days for opening of buds as reviewed by (Han *et al.*, 2003; Kazuo *et al.*, 2005) in Rose, Park and Ya (2018) in Carnation and Nguyen and Lim (2021). It may be noted that bud opening development using the pulsing or the preservative solution contains the sucrose, plant hormones before the immature buds are considered effective as per the findings by Reid (2009); Rabiza *et al.* (2020) in Snapdragon. Previous studies have shown that low sugar concentration during the pulsing is effective in earliness for bud opening. Moreover, pulsing involves treating the flower buds with high concentration of sucrose as per the findings of Srilaong *et al.* (2007) in Rose, Reid (2009); Perez *et al.* (2019) in Tuberose.

Fresh weight of flowers (g). Based on the signs of flower quality, all the treatments significantly improved the vase life of chrysanthemum as compared to control. The fresh weight of flowers (g) was found superior (11.84 g) under the treatment T8 (Sucrose 20% + NaOCl 50PPM) 2 hours followed by (10.24 g and 9.93 g) under the treatment T6 (Sucrose 10% + NaOCl 50PPM) 2 hours and treatment T4 (Sucrose 5% + NaOCl 50PPM) 2 hours. It may be due to the presence of sucrose in the pulsing solution because sucrose can act as a source of nutrition for tissues that fulfil carbohydrate starvation, Kuiper *et al.* (1995) in Rose, O'Donoghue *et al.* (2002) in Sandersonia, Kumar and Singh (2006) in Gladiolus, Yoo *et al.* (2016) in Chrysanthemum, Awan *et al.* (2017) in Rose. Sucrose may also act as an osmotically active molecules which ensures the flower opening and subsequent relations and also in accordance to the reported results of Row *et al.* (2017) in Chrysanthemum.

Flower height (cm). It is clearly revealed from the data that different preservative solution for improving the post-harvest quality had significant influence on flower height. The maximum flower height (7.11cm) were recorded under the treatment T8 (Sucrose 20 % + NaOCl 50 ppm) 2 hours followed by (6.93cm and 5.81cm, respectively) under the treatment T6 (Sucrose 10% + NaOCl 50 ppm) 2 hours and T4 (Sucrose 5 % + NaOCl 50 ppm) 2 hours while, minimum flower height (4.81cm) was recorded under the treatment T0 Control (de-ionized water). From the present results it may be well understood that the above treatments were significantly superior to the other treatments used in the study. From the data clearly depicts that sucrose in low concentration when used with high concentration of Sodium hypochlorite at earlier stages and conversely at later stage produced significant results and produced maximum flower height. Previous studies were similar with the present findings of Cho *et al.* (1999), Eason *et al.*, (2001) in Santonia flower, Malakar and Biswas (2022) in Heliconia spp.

Stem diameter(mm). The stem diameter revealed that different preservative solution for improving the post-harvest quality had significant influence on stem diameter. The maximum stem diameter (4.87mm) during the year 2021-2022 were recorded under the treatment T8 (Sucrose 20 % + NaOCl 50 ppm) 2 hours followed by (4.74mm and 4.65mm, respectively) under the treatment T6 (Sucrose 10 % + NaOCl 50 ppm) 2 hours and T4 (Sucrose 5 % + NaOCl 50 ppm) 2 hours while, minimum stem diameter (4.03mm) was recorded under the treatment T0 Control (de-ionized water). The stem diameter was significantly maximum under the influence of higher concentration of sucrose with optimum concentration of Sodium hypochlorite (NaOCl) which might have resulted the increment in stem diameter, but later on increase of sucrose have slightly decreased the stem diameter when used alone. The present result are in accordance with Cho *et al.*, (1999) also revealed the efficiency of Sucrose in *Eustoma grandiflorum*, Lee and Kim (2010); Lim *et al.* (2016) in Lily, Awan *et al.* (2017) in Rose and Kathari *et al.* (2019) in Lisianthus.

Total solution consumption(ml). The different preservative solution in the present experiment improved the post-harvest quality had a significant influence on total solution consumption. The maximum total solution consumption (24.15 ml) during the first season 2021- 2022 were recorded under the treatment T8 (Sucrose 20 % + NaOCl 50 ppm) 2 hours followed by (21.56 ml and 19.42 ml, respectively) under the treatment T6 (Sucrose 10 % + NaOCl 50 ppm) 2 hours and T4 (Sucrose 5 % + NaOCl 50 ppm) 2 hours while, minimum total solution consumption (15.23 ml) was recorded under the treatment T0 Control (de-ionized water). The total consumption of pulsing solution was maximum on combination of Sucrose and NaOCl when sucrose concentration was slightly higher in the experiment but solution consumption decreased slightly when sucrose dose used in slightly low concentration. The present study is more similar with the findings of Prashanth and Chandrasekhar (2007) in Gerbera, Maiti and Kumari (2016; Buanong and Uthairatanakij (2020) in Orchid and Brahma *et al.* (2023) in Lillium.

Total moisture loss in cut flowers (%). The maximum total moisture loss in cut flowers (77.49) was recorded under the treatment T8 (Sucrose 20 % + NaOCl 50 ppm) 2 hours followed by (68.14 and 65.41, respectively) under the treatment T6 (Sucrose 10 % + NaOCl 50 ppm) 2 hours and T4 (Sucrose 5 % + NaOCl 50 ppm) 2 hours while, minimum total moisture loss in cut flowers (44.85) was recorded under the treatment T0 Control (de-ionized water).The moisture content was significantly higher with the above treatments when used in combination the NaOCl present in the solution has antimicrobial properties which might have improved the water balance by reducing the moisture loss as per reported by Durkin (1980) who well defined the hydration mechanism in cut flowers, Murthy *et al.* (2015) in Gerbera, Simi *et al.* (2016) in Anthurium, Malakar *et al.* (2017) in cut foliages, Kathari *et al.* (2019); Lisianthus and Murthy and Subbaiah (2020) in Gerbera.

Dry weight of spike (g). The maximum dry weight of spike (2.56 gm) were recorded under the treatment T8 (Sucrose 20 % + NaOCl 50 ppm) 2 hours followed by (2.36 gm and 2.17 gm, respectively) under the treatment T6 (Sucrose 10 % + NaOCl 50 ppm) 2 hours and T4 (Sucrose 5 % + NaOCl 50 ppm) 2 hours while, minimum dry weight of spike (1.36 gm) was recorded under the treatment T0 Control (de-ionized water). Dry weight of spike was significantly superior at this above-mentioned treatment. The Sodium hypochlorite present in the solution which is a mild biocide, Mahdi Jowkar (2006). However, when used with sucrose improves causing the two-fold increase in water balance, decrease in the weight loss which is a key factor for dry weight produced in any holding solution Memon *et al.*, (2012) in Gladiolus, Ahmad and Dole (2014); Manzoor *et al.* (2021).

Table 1: Influence of various holding solutions on days to bud opening, fresh weight of spike (g), flower height (cm), stem diameter (mm), total solution consumption (ml), total moisture loss in cut flowers (%), dry weight of spike (g) and vase life of flowers (days) in Chrysanthemum (*Chrysanthemum morifolium*) cv. White Star.

Notation	Treatments	Days to bud opening	Fresh weight of flower (g)	Flower height (cm)	Stem diameter (mm)	Total solution consumption (ml)	Total moisture loss in cut flowers (%)	Dry weight of spike (g)
T_0	Control (de- ionized water)	6.85	6.11	4.81	4.03	15.23	44.85	1.36
T_1	Pulsing (Sucrose 5%) 4 hours	5.51	9.25	5.19	4.16	17.60	58.21	1.54
T_2	Pulsing (Sucrose 10%) 4 hours	4.75	9.46	5.35	4.25	17.54	60.15	1.63
T_3	Pulsing (Sucrose 20%) 4 hours	3.82	9.58	5.45	4.28	17.75	60.43	1.74
T_4	Pulsing (Sucrose 5% + NaOCl 50ppm) 2 hours	3.10	9.93	5.81	4.65	19.42	65.41	2.17
T_5	Pulsing (Sucrose 5% + NaOCl 50ppm) 4 hours	4.71	9.65	5.53	4.34	18.83	62.84	1.86
T_6	Pulsing (Sucrose 10% + NaOCl 50ppm) 2 hours	3.63	10.24	6.93	4.74	21.56	68.14	2.36
T_7	Pulsing (Sucrose 10% + NaOCl 50ppm) 4 hours	4.85	9.73	5.66	4.44	19.03	64.48	2.04
T_8	Pulsing (Sucrose 20% + NaOCl 50ppm) 2 hours	3.73	11.84	7.11	4.87	24.15	77.49	2.56
T_9	Pulsing (Sucrose 20% + NaOCl 50ppm) 4 hours	4.93	9.84	5.69	4.56	19.26	65.15	2.11
	SEM (±)	0.009	0.011	0.015	0.012	0.016	0.018	0.010
	CD$(p=0.05)$	0.028	0.033	0.044	0.035	0.047	0.053	0.031

Flower diameter (cm). Data presented in Table 2 clearly states that maximum flower diameter (8.73 cm) were recorded under the treatment T8 (Sucrose 20 % + NaOCl 50 ppm) 2 hours followed by (8.33 cm and 7.76 cm, respectively) under the treatment T6 (Sucrose 10 % + NaOCl 50 ppm) 2 hours and T4 (Sucrose 5 % + NaOCl 50 ppm) 2 hours while, minimum flower diameter (5.86 cm) was recorded under the treatment T0 Control (de-ionized water).This study showed that combination of Sucrose and NaOCl induced the maximum flower diameter. It may be due to the presence of sucrose in the pulsing solution because sucrose can act as a source of nutrition for tissues which fulfil the carbohydrate starvation, Kuiper *et al.* (1995) in Rose, O'Donoghue *et al.* (2002) in Sandersonia, Kumar and Singh (2006) in Gladiolus, Yoo *et al.* (2016) in Chrysanthemum, Awan *et al.* (2017) in Rose. Sucrose may also act as an osmotically active molecules which ensures the flower opening and subsequent relations and also in accordance to the reported results of Row *et al.* (2017) in Chrysanthemum.

Flower weight (g). The maximum flower weight (9.93 gm) was recorded under the treatment T8 (Sucrose 20 % + NaOCl 50 ppm) 2 hours followed by (9.73 gm and 9.54 gm, respectively) under the treatment T6 (Sucrose 10 % + NaOCl 50 ppm) 2 hours and T4 (Sucrose 5 % + NaOCl 50 ppm) 2 hours while, minimum flower weight (6.49 gm) was recorded under the treatment T0 Control (de-ionized water). In this experiment the flower weight initially increases and later it decreased on lowering the concentration of sucrose with Sodium hypochlorite. It may be noted that post harvest quality assessment of cut flowers can be determined by weight as defined by Son (1995). This study intended to develop a more concise role of Sucrose with Sodium hypochlorite in contrast to flower weight. The present result are in accordance with Cho *et al.*, (1999) also revealed the efficiency of Sucrose in Eustoma grandiflorum, Lee and Kim (2010); Lim *et al.* (2016) in Lily, Awan *et al.* (2017); Rose and Kathari *et al.* (2019) in Lisianthus.

Water uptake (g/f). The maximum water uptake (12.94 g/f) was recorded under the treatment T8 (Sucrose 20 % +NaOCl 50 ppm) 2 hours followed by (12.67 and 12.45) g/f respectively, under the treatment T6 (Sucrose 10 % + NaOCl 50 ppm) 2 hours and T4 (Sucrose 5 % + NaOCl 50 ppm) 2 hours while, minimum water uptake (10.51g/f) was recorded under the treatment T0 Control (de-ionized water). In this experiment the water uptake (g/f) initially increases and later it decreased on lowering the concentration of Sucrose with Sodium hypochlorite. It may be noted here that higher concentration of Sucrose when used acts like soluble salt causing reverse osmosis leading to injury during the pulsing (Gast, 1997). Pulsing with Sucrose is considered as an important factor to accelerate water uptake in cut flowers as reported by Adachi *et al.* (2000) in Chrysanthemum, (Hema *et al.*, 2015; Murthy and Subbaiah 2020) in Gerbera.

Table 2: Effect of pulsing with sucrose and sodium hypochlorite on flower diameter (cm), flower weight (g), water uptake (g/f) and transpiration loss of water of cut Chrysanthemum (*Chrysanthemum morifolium*) cv. White Star.

Notation	Treatments	Flower diameter (cm)	Flower weight (g)	Water uptake (g/f)	Mean Transpiration loss of water
T_0	Control (de- ionized water)	5.86	6.49	10.51	7.14
T_1	Pulsing (Sucrose 5%) 4 hours	6.50	8.75	11.72	6.75
T_2	Pulsing (Sucrose 10%) 4 hours	6.80	8.79	11.75	6.16
T_3	Pulsing (Sucrose 20%) 4 hours	7.06	8.94	11.84	6.13
T_4	Pulsing (Sucrose 5% + NaOCl 50ppm) 2 hours	7.76	9.54	12.45	6.05
T_5	Pulsing (Sucrose 5% + NaOCl 50ppm) 4 hours	7.20	9.06	11.92	6.32
T_6	Pulsing (Sucrose 10% + NaOCl 50ppm) 2 hours	8.33	9.73	12.67	5.71
T_7	Pulsing (Sucrose 10% + NaOCl 50ppm) 4 hours	7.43	9.20	12.08	6.17
T_8	Pulsing (Sucrose 20% + NaOCl 50ppm) 2 hours	8.73	9.93	12.94	5.66
T_9	Pulsing (Sucrose 20% + NaOCl 50ppm) 4 hours	7.50	9.31	12.25	6.34
	SEM (±)	0.137	0.081	0.096	0.193
	CD(p=0.05)	0.411	0.243	0.288	0.577

Mean transpiration loss of water. The minimum mean transpiration loss of water (5.66) was recorded under the treatment T8 (Sucrose 20 % + NaOCl 50 ppm) 2 hours followed by (5.71 and 6.05 respectively) under the treatment T6 (Sucrose 10 % + NaOCl 50 ppm) 2 hours and T4 (Sucrose 5 % + NaOCl 50 ppm) 2 hours while, maximum mean transpiration loss of water (7.14) was recorded under the treatment T0 Control (de-ionized water).The present data clearly stated that increase concentration of Sucrose with Sodium hypochlorite slightly decreased the transpiration loss of water initially but afterward it progressively tends to improve the transpiration loss of water with its efficiency on lower concentration. It may be noted that as water loss increases, the water loss also tends to increase as this is well correlated with the findings of Yeshiwas (2018) in Rose. Further, it is well justified by Durkin (1980) who stated that rapid repair of xylem water column is necessary to avoid transpiration loss as it is damaged due the blockage of xylem water column.

Relative water content of petals (%). Data presented in table 3 reveals that the maximum relative water content of petals (90.96) % was recorded under the treatment T8 (Sucrose 20 % + NaOCl 50 ppm) 2 hours followed by (90.85 and 90.76) % respectively, under the treatment T6 (Sucrose 10 % + NaOCl 50 ppm) 2 hours and T4 (Sucrose 5 % + NaOCl 50 ppm) 2 hours while, minimum relative water content of petals (78.83) was recorded under the treatment T0 Control (de-ionized water). It may be understood here that the above treatments were superior amongst rest of the treatments in this study. Relative water content of petals is improved when sucrose at optimum dose is used in the solution which might improve the maintenance, turgidity and repair of petal injury as reported by Nagh *et al.* (2020). Moreover, Sodium hypochlorite when used in pulsing treatment improves the blockage of xylem vessel as our results well coincide with the findings of Tsegaw *et al.* (2011) in cut Rose, Kathari *et al.* (2019) in Lisianthus and Manzoor *et al.* (2021).

Fresh weight change (g). The maximum fresh weight change (136.86 gm) was recorded under the treatment T8 (Sucrose 20 % + NaOCl 50 ppm) 2 hours followed by (129.27 gm and 125.41 gm, respectively) under the treatment T6 (Sucrose 10 % + NaOCl 50 ppm) 2 hours and T4 (Sucrose 5 % + NaOCl 50 ppm) 2 hours while, minimum fresh weight change (109.03 gm) was recorded under the treatment T0 Control (de-ionized water). The fresh weight change (g) was noticed under the abovementioned treatments which accumulated maximum fresh weight change which gradually decreased further on optimizing low concentration of sucrose with Sodium hypochlorite improves fresh weight as it improves the carbohydrate rate and its metabolism in leaves and decrease the rate of microorganism as NaOCl is a biocide by nature which is well defined in the previous studies as per the reports of Bieleski (1992); Cho *et al.* (1999); Lessa *et al.* (2012); Celikel *et al.* (2020) in Cape jasmine.

Chlorophyll content of calyx. The maximum chlorophyll content of calyx (54.78) was estimated under the treatment T8 (Sucrose 20 % + NaOCl 50 ppm) 2 hours followed by (53.45 and 52.44, respectively) under the treatment T6 (Sucrose 10 % + NaOCl 50 ppm) 2 hours and T4 (Sucrose 5 % + NaOCl 50 ppm) 2 hourswhile, minimum chlorophyll content of calyx (36.21) was estimated under the treatment T0 Control (de-ionized water). The chlorophyll content of calyx was significantly maximum than the rest of the other treatments in this finding. It may be noted here that leaves of cut flower was examined to identify the calyx chlorophyll content. Since, in the present study NaOCl which reduces the microorganism activity, reducing ethylene activity thus enhancing the chlorophyll metabolism as this is well understood with the findings of Macnish (2010) in Iris, (Yoo *et al.*, 2016; Roh *et al.*, 2018) in Chrysanthemum.

Total soluble solids (TSS). The maximum total soluble solids (4.76) during the year 2021-2022 were recorded under the treatment T8 (Sucrose 20 % + NaOCl 50 ppm) 2 hours followed by (4.50 and 4.30, respectively) under the treatment T6 (Sucrose 10 % + NaOCl 50 ppm) 2 hours and T4 (Sucrose 5 % + NaOCl 50 ppm) 2 hours while, minimum total soluble solids (2.50) was recorded under the treatment T0 Control (de-ionized water). It may be recorded here that in this experiment no consistency of TSS with due to pulsing solution was observed under the present study. Sucrose when present in the solution produces a reserve compound 'Sucrose' which is a soluble carbohydrate sometimes, present or deposit in phloem sap which improves the TSS in the medium as suggested by Tsegaw *et al.* (2011) in Rose, TSS content of petal is reduced with storage period Tsegaw *et al.* (2011) in Rose, it might be due to initiation of senescence in petals Figueroa *et al.* (2005) in TSS content is also reduced on increase of Vase life Kaltaler and Steponkus (1976); Babarabie (2018) in Gerbera.

pH of the vase solution. Data presented in Table 4 reveals that the maximum pH of vase solution (7.76) was recorded under the treatment T8 (Sucrose 20 % + NaOCl 50 ppm) 2 hours followed by (7.73 and 7.71, respectively) under the treatment T6 (Sucrose 10 % + NaOCl 50 ppm) 2 hours and T4 (Sucrose 5 % + NaOCl 50 ppm) 2 hours while minimum pH of vase solution (5.94) was recorded under the treatment T0 Control (de-ionized water). In the present experiment, the pH was checked in different pulsing solutions. Adjusting the pH of vase solution is important to improve the vase life of flowers Carillo *et al.* (2016) in Chrysanthemum. Previous research indicated a speculation that sucrose with NaOCl improves the pH of the solution as per the arguments of Borochov (1976) in Rose, another advantage of optimum pH is the reduction of pathogen Nell and Reid (2000).

Electrolyte leakage. The minimum electrolyte leakage (76.32) was recorded under the treatment T8 (Sucrose 20 % + NaOCl 50 ppm) 2 hours followed by (79.16 and 80.84, respectively) under the treatment T6 (Sucrose 10 % + NaOCl 50 ppm) 2 hours and T4 (Sucrose 5 % + NaOCl 50 ppm) 2 hours while, maximum electrolyte leakage (90.85) was recorded under the treatment T0 Control (de-ionized water). In the present study the presence of NaOCl with Sucrose in the holding solution might have checked the stress induced injury and predict the physiological status by improving blockage from bacterial contamination, Marousky, (1971); Kovaleski and Grossman (2021). Many researchers in the past have reported the role of dormancy produced by the plant due to intake of different pulsing/holding solution increases cellular damage as referred by Senthilkumar (2021); Nguyen and Lim (2022).

Overall acceptability of flower. The maximum overall acceptability of flower (9.26) during the year 2021-2022 were recorded under the treatment T8 (Sucrose 20% + NaOCl 50 ppm) 2 hours followed by (9.14 and 9.06, respectively) under the treatment T6 (Sucrose 10 % + NaOCl 50 ppm) 2 hours and T4 (Sucrose 5 % + NaOCl 50 ppm) 2 hours while, minimum overall acceptability of flower (6.50) was recorded under the treatment T0 Control (de-ionized water). The above treatments proved beneficial in the overall acceptability of flower which persist on behalf of its overall quality of flower as presence of NaOCl being a disinfectant, causing alteration of cellular metabolism when placed in holding solution as revealed by Fukuzaki (2006); Costa (2015) in Heliconia wagneriana.

Table 3: Effect of pulsing with sucrose and sodium hypochlorite on relative water content of petals (%), fresh weight change (g), chlorophyll content of calyx and total soluble solids of cut Chrysanthemum (*Chrysanthemum morifolium*) cv. White Star.

Notation	Treatments	Relative water content of petals (%)	Fresh weight change (g)	Chlorophyll content of calyx	Total soluble solids (TSS)
T_0	Control (de- ionized water)	78.83	109.03	36.21	2.50
T_1	Pulsing (Sucrose 5%) 4 hours	83.85	112.08	42.12	3.13
T_2	Pulsing (Sucrose 10%) 4 hours	85.23	113.74	43.13	3.26
T_3	Pulsing (Sucrose 20%) 4 hours	85.29	115.26	46.83	3.30
T_4	Pulsing (Sucrose 5% + NaOCl 50ppm) 2 hours	90.76	125.41	52.44	4.30
T_5	Pulsing (Sucrose 5% + NaOCl 50ppm) 4 hours	88.51	119.05	48.72	3.50
T_6	Pulsing (Sucrose 10% + NaOCl 50ppm) 2 hours	90.85	129.27	53.45	4.50
T_7	Pulsing (Sucrose 10% + NaOCl 50ppm) 4 hours	88.63	121.22	49.85	3.80
T_8	Pulsing (Sucrose 20% + NaOCl 50ppm) 2 hours	90.96	136.86	54.78	4.76
T_9	Pulsing (Sucrose 20% + NaOCl 50ppm) 4 hours	88.73	122.42	51.66	4.20
	SEM (±)	0.261	0.300	0.375	0.051
	CD(p=0.05)	0.781	0.899	1.124	0.152

Table 4: Effect of pulsing with sucrose and sodium hypochlorite of pH of vase solution, electrolyte leakage, over all acceptability of cut Chrysanthemum (*Chrysanthemum morifolium*) cv. White Star.

Notation	Treatments	pH of the vase solution	Electrolyte leakage	Overall acceptability of flower
T_0	Control (de- ionized water)	5.94	90.85	6.50
T_1	Pulsing (Sucrose 5%) 4 hours	7.50	82.77	7.67
T_2	Pulsing (Sucrose 10%) 4 hours	7.53	83.44	7.75
T_3	Pulsing (Sucrose 20%) 4 hours	7.57	85.22	7.87
T_4	Pulsing (Sucrose 5% + NaOCl 50ppm) 2 hours	7.71	80.84	9.06
T_5	Pulsing (Sucrose 5% + NaOCl 50ppm) 4 hours	7.62	86.84	8.60
T_6	Pulsing (Sucrose 10% + NaOCl 50ppm) 2 hours	7.73	79.16	9.14
T_7	Pulsing (Sucrose 10% + NaOCl 50ppm) 4 hours	7.65	88.25	8.75
T_8	Pulsing (Sucrose 20% + NaOCl 50ppm) 2 hours	7.76	76.32	9.26
T_9	Pulsing (Sucrose 20% + NaOCl 50ppm) 4 hours	7.68	89.94	8.86
	SEM (±)	0.008	0.348	0.016
	CD(p=0.05)	0.024	1.041	0.049

Mean water uptake. Data presented in table 5 revealed that the maximum mean water uptake (9.08) during the first season 2021-2022 were recorded under the treatment T8 (Sucrose 20 % + NaOCl 50 ppm) 2 hours followed by (8.48 and 7.52, respectively) under the treatment T6 (Sucrose 10 % + NaOCl 50 ppm) 2 hours and T4 (Sucrose 5 % + NaOCl 50 ppm) 2 hours while, minimum mean water uptake (4.11) was recorded under the treatment T0 Control (de-ionized water). We recorded here that the mean water uptake (g/f) initially increases and later it gradually decreased on lowering the concentration of Sucrose with Sodium hypochlorite. It may be noted here that higher concentration of Sucrose when used acts like soluble salt causing reverse osmosis leading to injury during the pulsing Gast, (1997). Pulsing with Sucrose is considered as an important factor to accelerate water uptake in cut flowers as reported by Adachi *et al.* (2000) in Chrysanthemum, Celikel and Reid (2002) in Stock, Mensuali and Ferrante (2003); Muruthi and Ouma (2011); (Hema *et al.*, 2015; Murthy and Subbaiah 2020) in Gerbera, Abdulla and Celikel (2018) in Helleborus orientalis and Ha *et al.* (2019) in cut roses.

Mean fresh weight change (% of initial weight). The maximum mean fresh weight change (99.98) was recorded under the treatment T8 (Sucrose 20 % + NaOCl 50 ppm) 2 hours followed by (97.45 and 96.27, respectively) under the treatment T6 (Sucrose 10 % + NaOCl 50 ppm) 2 hours and T4 (Sucrose 5 % + NaOCl 50 ppm) 2 hours while, minimum mean fresh weight change (89.78) was recorded under the treatment T0 Control (de-ionized water). In this experiment the water uptake (g/f) initially increases and later it decreased on lowering the concentration of Sucrose with Sodium hypochlorite. This study intended to develop a more concise role of Sucrose with Sodium hypochlorite in contrast to fresh weight change. The present result are in accordance with Cho *et al.* (1999) also revealed the efficiency of Sucrose in Eustoma grandiflorum, Bieleski *et al.* (1992) in Protea eximia, Pulsing with Sucrose is considered as an important factor to accelerate water uptake which increases mean fresh weight change in cut flowers as reported by (Mahdi Jokar (2006) in Narcissus tazetta, Lee and Kim (2010); Lim *et al.* (2016) in Lily, Awan *et al.* (2017) in Rose, Schouten *et al.*(2018) in Gerbera and Kathari *et al.* (2019) in Lisianthus.

Table 5: Effect of post-harvest application of preservative solutions combination on mean water relations during vase life period of cut Chrysanthemum (*Chrysanthemum morifolium*) cv. White Star.

Notation	Treatments	Mean water uptake	Mean fresh weight change (% of initial weight)
T_0	Control (de- ionized water)	4.11	89.78
T_1	Pulsing (Sucrose 5%) 4 hours	4.84	92.77
T_2	Pulsing (Sucrose 10%) 4 hours	5.43	93.16
T_3	Pulsing (Sucrose 20%) 4 hours	5.77	93.85
T_4	Pulsing (Sucrose 5% + NaOCl 50ppm) 2 hours	7.52	96.27
T_5	Pulsing (Sucrose 5% + NaOCl 50ppm) 4 hours	6.15	94.44
T_6	Pulsing (Sucrose 10% + NaOCl 50ppm) 2 hours	8.48	97.45
T_7	Pulsing (Sucrose 10% + NaOCl 50ppm) 4 hours	6.56	95.12
T_8	Pulsing (Sucrose 20% + NaOCl 50ppm) 2 hours	9.08	99.98
T_9	Pulsing (Sucrose 20% + NaOCl 50ppm) 4 hours	6.83	95.01
	SEM (±)	0.020	0.242
	CD(p=0.05)	0.060	0.726

Scape bending curvature (degree). Data presented in table 6 revealed that the minimum scape bending curvature (16.33) was recorded under the treatment T4 (Sucrose 5 % + NaOCl 50 ppm) 2 hours followed by (21.88 and 24.24 days, respectively) under the treatment T6 (Sucrose 10 % + NaOCl 50 ppm) 2 hours and T8 (Sucrose 20 % + NaOCl 50 ppm) 2 hours while, maximum scape bending curvature (53.72) was recorded under the treatment T0 Control (de-ionized water). In the present investigation we noted the minimum scape bending curvature was due to the initial application of low dose of sucrose with high concentration of sodium hypochlorite and further on increasing the dose helped in achieving slightly minimum scape bending curvature as reviewed by Balas *et al.* (2006); Maiti and Kumari (2016); Chen (2021) in Lilium. It may be noted that scape bending curvature using the pulsing or the preservative solution contains the sucrose, plant hormones before the immature buds are considered effective as per the findings by Faust and Dole (2021) in cut foliages.

Total Sugar. The maximum total sugar (3.93) was recorded under the treatment T8 (Sucrose 20 % + NaOCl 50 ppm) 2 hours followed by (3.81 and 3.71, respectively) under the treatment T6 (Sucrose 10 % + NaOCl 50 ppm) 2 hours and T4 (Sucrose 5 % + NaOCl 50 ppm) 2 hours while, minimum total sugar (2.10) was recorded under the treatment T0 Control (de-ionized water). In the present investigation we noted the maximum total sugar intake was due to the initial application of high dose of sucrose with high concentration of sodium hypochlorite and further on reducing the dose helped in achieving slightly minimum total sugar as these results are in agreement with those of Badawy *et al.* (2016) in Chrysanthemum, Hema *et al.* (2018) in cut Gerbera, Nguyen and Lim (2021).

Table 6: Effect of post-harvest application of preservative solutions combination on scape bending curvature (degree) and total sugars (%) of cut Chrysanthemum (*Chrysanthemum morifolium*) cv. White Star.

Notation	Treatments	Scape bending curvature (degree)	Total sugar (%)
T_0	Control (de- ionized water)	53.72	2.10
T_1	Pulsing (Sucrose 5%) 4 hours	41.70	2.74
T_2	Pulsing (Sucrose 10%) 4 hours	46.47	2.89
T_3	Pulsing (Sucrose 20%) 4 hours	26.91	3.14
T_4	Pulsing (Sucrose 5% + NaOCl 50ppm) 2 hours	16.33	3.71
T_5	Pulsing (Sucrose 5% + NaOCl 50ppm) 4 hours	29.29	3.21
T_6	Pulsing (Sucrose 10% + NaOCl 50ppm) 2 hours	21.88	3.81
T_7	Pulsing (Sucrose 10% + NaOCl 50ppm) 4 hours	35.57	3.34
T_8	Pulsing (Sucrose 20% + NaOCl 50ppm) 2 hours	24.24	3.93
T_9	Pulsing (Sucrose 20% + NaOCl 50ppm) 4 hours	36.10	3.54
	SEM (±)	0.384	0.002
	CD(p=0.05)	1.150	0.006

CONCLUSIONS

Results of the present study suggest that the overall best treatment for different parameters for improving the vase life of chrysanthemum during the season 2021-2022 was recorded under the treatment T8 (Sucrose 20 % + NaOCl 50 ppm) 2 hours followed by the treatment T6 (Sucrose 10 % + NaOCl 50 ppm) 2 hours and T4 (Sucrose 5 % + NaOCl 50 ppm) 2 hours, which significantly improved the post-harvest quality of chrysanthemum spikes. The various holding solutions significantly improved the different post-harvest parameters in Chrysanthemum viz., days to bud opening, fresh weight of flower, flower height, stem diameter, total solution consumption, total moisture loss in cut flower, dry weight of spike, flower diameter, flower weight, water uptake, mean transportation loss of water however minimum response was noted under control. The biochemical attributes such as relative water content, electrolyte leakage, total soluble solids and total sugar significantly influenced and performed better under these treatments.

FUTURE SCOPE

There is a wide scope of Pulsing as it improves and maximizes the cut flower quality, by reviewing the different approaches and factors associated with the use of floral preservative solutions under this study for the development of proper handling in the cut flower industry. Research aimed at expanding the range of preservative solutions for cut flowers must be ongoing, and the development of pulsing solutions must be prioritized in the cut flower industry.

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Conflict of Interest. None.

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