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Influence of Silver Nanoparticle (AgNP), Sodium Nitroprusside (SNP) and 8-Hydroxy quinoline citrate (8-HQC) on vase Life of Chrysanthemum (*Chrysanthemum morifolium*) cv.'White Star'

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ABSTRACT: Chrysanthemum is an important commercial cut flower and is vastly traded cut flower for its high demand in the global floriculture business. Among the different vase solution used to improve vase life of chrysanthemum, Silver nanoparticle (AgNP), Sodium nitroprusside (SNP) and 8-hydroxy quinoline citrate (8-HQC) has emerged as potent vase solution that can delay the senescence and improve the vase life of cut Chrysanthemum. The challenges of the study Chrysanthemum spike were harvested at flower bud stage and the temperature was approximately 18^{0}C, the uniform flowers were cut and immediately stood upright into buckets partially filled with de-ionized water. The present study was conducted to derive the potential nature of Silver nanoparticle (AgNP), Sodium nitroprusside (SNP) and 8-hydroxy quinoline citrate (8-HQC) in improving the vase life of Chrysanthemum cv. 'White Star'. The overall best treatment for different parameters for improving the vase life of chrysanthemum during the consecutive seasons (2021-2022 & 2022-2023) were recorded under the treatment T4 (AgNP 20µl) followed by the treatment T14 (8-HQC 200ppm) and T8 (SNP 15ppm) while vase solution with T0 Control (de-ionized water) did not improve the different vase life parameters in Chrysanthemum.

Keywords: Chrysanthemum, Silver nanoparticle, 8-HQC, Sodium nitroprusside and Vase life.

INTRODUCTION

Chrysanthemum (*Chrysanthemum morifolium* Ramat) is commonly known as 'mums' and is considered to be a member of the Asteraceae family (Sevindik *et al.*, 2018). This scented annual or perennial herb is found in 100–200 species. Chrysanthemum species contains 1535 genera and about 23000 species According to Liu *et al.* (2012), Chrysanthemum is indigenous to the Northern Hemisphere, primarily in Europe and Asia with some occurrences in other regions. It is grown commercially in Tamil Nadu, Karnataka, and Maharashtra in India Patanwar *et al.* (2014). It is cultivated under many names in various parts of India, including 'Guldaudi' in the Hindi belt, 'Chandramalika' in the Eastern state, 'Samanti' in the Southern states, and 'Shevanti' in the Western states Gimhavanekar *et al.* (2021). According to numerous sources, the domesticated chrysanthemum was first grown in China more than 2000 years ago Spaargaren & van Geest (2018). Chrysanthemums are primarily planted as ornamentals Rao and Pratap (2006). A hardy or semi-hardy aromatic plant with flowers that come in a variety of colours, the cultivated chrysanthemum used for pot culture is a hardy or semi-hardy plant Verma *et al.* (2009). According to the type of flower, the chrysanthemum has been divided into a number of groupings, including single, cascade and anemone Chen *et al.* (2009). Vase life is a term used in cut flower or cut foliage which retains its appearance in vase life Sun and Brosnan (1999). Vase life (VL) of cut flowers refers to the duration from placement of stems in vase solutions to the loss of visible ornamental value and is synonymous with display life, keeping quality or lasting quality (Halevy and Mayak 1981). Now days, Silver nitrate (AgNO3) is commercially not used as to the risk of human health and the environment, AgNo3 is no longer utilized in commercial vase solutions Baskaran *et al.* (2010). Therefore, creating a new substance as a replacement for these substances is used by the floriculture sector. Pulsed Silver nanoparticle (AgNP) publishes Silver ions Ag^+ Zhang *et al.* (2013) which are used to substitute hydrogen (H^+) cation) of

thiol or sulfhydryl groups (-SH) in the bacterial cell membranes' surface proteins, lowering membrane permeability as a result and ultimately resulting in cell death Morozova *et al.* (2021). Sodium nitroprusside (SNP) is the most common NO-releasing compound whose positive effect has been reported on extending the post harvest longevity Naziri *et al.* (2021). A highly effective and important germicide used widely in daily life is 8-hydroxy quinoline citrate (8-HQC) Damunupola and Joyce (2008).

The objective of our current study was to compare the different vase life solution in extending the life also in the current study we tested and compared the ability of Silver nano particles (AgNP), Sodium nitroprusside (SNP) and 8-Hydroxyquinoline (8-HQC) also known as 'oxine' to improved the longevity and flower quality of the cut Chrysanthemum Carrillo-Lopez *et al.* (2016). Therefore, consuming 8-HQC either as a pulse or in vase solution would restrain microscopic growth, cause subsequent vascular blockage, and therefore promote water uptake. However, only a little amount of work has been done to extend the vase life of cut roses, and much more has to be done. No one who has contributed has offered a definite recommendation regarding chemicals and their relationship to the vase life of cut roses. With the aforementioned information in mind, a study was conducted.

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 (2021-2022 and 2022-2023). 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, 28.99°N Latitude and 77.7°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 Chrysanthemum spikes were held at ambient room temperature (average mean temperature of 24^0C, Maximum Relative humidity 83% and minimum of 48% under) 40W cool white fluorescent tubes.

A. 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 color flowers with green center making the flower elegant and attractive, which fetches it is a good market price.

B. 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 flower bud stage and the temperature was approximately 18°C, the uniform flowers were cut and immediately stood upright into 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 vase solution *viz.*, T_0 -Control (distilled water), T_1 - AgNP 5µl, T_2 - AgNP 10µl, T_3 - AgNP 15µl, T_4 - AgNP 20µl, T_5 - AgNP 25µl, T_6 - SNP 5ppm, T_7 - SNP 10ppm, T_8 - SNP 15ppm, T_9 - SNP 20ppm, T_{10} - SNP 25ppm, T_{11} -8-HQC 50ppm, T_{12} -8-HQC 100ppm, T_{13} - 8-HQC 150ppm, T_{14} -8-HQC 200ppm, T_{15} - 8-HQC 250ppm with 3 replications, arranged in a completely randomized design.

C. Statistical analysis

The recorded data were statistically analysis (ANOVA analysis) using the software Graph pad prism, USA. Source of variation were vase solutions agents *viz.*, Silver nanoparticle (AgNP), Sodium nitroprusside (SNP) and 8-hydroxy quinoline citrate (8-HQC). Mean data were also compared by using Duncan's new multiple range test whereasthe effect were significant at 0.05% level of significance.

RESULTS AND DISCUSSION

A. Fresh weight (g) change at different interval (days)

The data presented in Table 1 and 1a for fresh weight (g) change at 1stday *viz.*, (19.40,21.45 and 20.43), 3rd day (18.12,18.75 and 18.43) 5th day (17.13,17.48 and 17.30) 7th day (16.02,16.56 and 16.29) and 9thday (14.50, 15.28 and 14.89) for during the first season 2021-2022 and second season 2022-2023 followed by the Pooled data for both year were recorded under the treatment T4 (AgNP 20µl) followed by at 1stday *viz.*, (17.37, 18.79 and 18.08), 3rd day (16.17, 16.77 and 16.47) 5th day (15.03, 16.17 and 15.60) 7th day (13.91, 14.32 and 14.11) and 9th day (12.70, 13.46 and 13.08) under the treatment T14 (8-HQC 200ppm) and at 1stday *viz.*, (15.32, 15.99 and 15.65) , 3rd day (14.18, 14.81and 14.50) 5th day (13.35, 13.92 and 13.63) 7th day (12.22, 12.41 and 12.31) and 9th day (11.01, 11.14 and 11.07) under T8 (SNP 15ppm) respectively, while minimum was observed at 1st day *viz.*, (11.04, 11.45 and 11.24), 3rd day (10.35, 10.58 and 10.47) 5th day (9.77, 9.44 and 9.60) 7th day (7.94, 8.00 and 7.97) and 9th day (6.72, 6.89 and 6.80) under Control (de-ionized water) under the treatment T_0. The fresh weight change (g) was noticed under the above mentioned treatments which accumulated maximum fresh weight change under silver nano particles (AgNP) which gradually decreased further on optimizing different concentration of 8-HQC and SNP which improves fresh weight as it improves the carbohydrate rate and its metabolism in leaves and decrease the rate of microorganism as (Ag-NPs) by nature is a enhancer which alleviate xylem vessels blockage and is responsible for increasing vase life of flower and welldefined in the previous studies as per the reports of Solgi *et al.* (2009) in Orchid, Rahman *et al.* (2019) in Orchid and Kazemi and Ameri (2012) in Carnation and Koushesh *et al.* (2017) in Gerbera.

Table 1: Influence of various vase solutions on fresh weight change at different duration in (days) in Chrysanthemum (*Chrysanthemum morifolium* Ramat) Cv. White Star.

Sr. No.	Treatments	Fresh weight (g) change of plant dipped in Vase solution at different duration in (days)								
		1st day		Pooled Mean	3rd day		Pooled Mean	5th day		Pooled Mean
		2021-22	2022-23		2021-22	2022-23		2021-22	2022-23	
T_0	Control (de-ionized water)	11.04	11.45	11.24	10.35	10.58	10.47	9.77	9.44	9.60
T_1	AgNP 5µl	13.24	13.74	13.49	12.09	12.30	12.20	11.18	11.68	11.43
T_2	AgNP 10µl	13.97	13.98	13.98	12.99	13.25	13.12	11.79	11.85	11.82
T_3	AgNP 15µl	14.30	14.64	14.47	13.23	13.49	13.36	12.17	12.52	12.35
T_4	AgNP 20µl	19.40	21.45	20.43	18.12	18.75	18.43	17.13	17.48	17.30
T_5	AgNP 25µl	13.09	14.01	13.55	12.13	12.70	12.42	11.13	11.65	11.39
T_6	SNP 5ppm	13.38	13.72	13.55	12.19	12.69	12.44	11.31	12.10	11.70
T_7	SNP 10ppm	13.26	13.27	13.27	12.07	12.47	12.27	11.10	11.68	11.39
T_8	SNP 15ppm	15.32	15.99	15.65	14.18	14.81	14.50	13.35	13.92	13.63
T_9	SNP 20ppm	12.65	12.66	12.65	11.26	11.62	11.44	10.45	11.15	10.80
T_{10}	SNP 25ppm	12.43	13.44	12.94	11.23	11.29	11.26	10.09	11.08	10.58
T_{11}	8-HQC 50ppm	12.74	13.36	13.05	11.12	11.40	11.26	10.11	10.84	10.47
T_{12}	8-HQC 100ppm	12.50	12.88	12.69	11.03	11.14	11.08	10.11	11.06	10.59
T_{13}	8-HQC 150ppm	14.09	14.10	14.09	13.14	13.62	13.38	12.31	12.98	12.64
T_{14}	8-HQC 200ppm	17.37	18.79	18.08	16.17	16.77	16.47	15.03	16.17	15.60
T_{15}	8-HQC 250ppm	13.26	13.27	13.26	12.15	12.49	12.32	11.03	11.81	11.42
	SEm (±)	0.143	0.213		0.106	0.213		0.050	0.308	
	C.D.(*p=0.05%*)	0.414	0.620		0.308	0.620		0.146	0.895	

AgNP = Silver nano particles, SNP = Sodium nitroprusside and 8-HQC = 8-Hydroxyquinoline.

Table 1a: Influence of various vase solutions on fresh weight change at different duration in (days) in Chrysanthemum (*Chrysanthemum morifolium* Ramat) Cv. White Star.

Sr. No.	Treatments	Fresh weight (g) change of plant dipped in Vase solution at different duration in (days)					
		7th day		Pooled Mean	9th day		Pooled Mean
		2021-22	2022-23		2021-22	2022-23	
T_0	Control	7.94	8.00	7.97	6.72	6.89	6.80
T_1	AgNP 5µl	10.08	10.26	10.17	9.08	9.09	9.08
T_2	AgNP 10µl	11.10	11.29	11.19	9.92	9.93	9.92
T_3	AgNP 15µl	11.12	11.30	11.21	10.02	10.39	10.20
T_4	AgNP 20µl	16.02	16.56	16.29	14.50	15.28	14.89
T_5	AgNP 25µl	10.12	10.34	10.23	8.94	9.11	9.03
T_6	SNP 5ppm	10.13	10.19	10.16	9.00	9.10	9.05
T_7	SNP 10ppm	10.06	10.12	10.09	9.08	9.15	9.12
T_8	SNP 15ppm	12.22	12.41	12.31	11.01	11.14	11.07
T_9	SNP 20ppm	9.40	9.45	9.43	8.84	8.93	8.88
T_{10}	SNP 25ppm	9.20	9.24	9.22	8.09	8.16	8.12
T_{11}	8-HQC 50ppm	8.92	8.97	8.94	8.06	8.10	8.08
T_{12}	8-HQC 100ppm	9.04	9.28	9.16	7.95	8.10	8.03
T_{13}	8-HQC 150ppm	11.13	11.17	11.15	10.01	10.11	10.06
T_{14}	8-HQC 200ppm	13.91	14.32	14.11	12.70	13.46	13.08
T_{15}	8-HQC 250ppm	10.04	10.37	10.20	8.82	9.13	8.98
	SEm (±)	0.078	0.183		0.127	0.092	
	C.D.*(p=0.05%)*	0.226	0.531		0.370	0.266	

B. Days to bud opening (%)

The data presented in Table 2 and 2a for bud opening (%) during the (2021-2022 & 2022-2023) followed by the Pooled data for both year *viz.*, at 1st day (22.31, 24.93 and 23.62) , 3rd day (35.17, 39.66 and 37.41) 5th day (56.51, 57.55 and 57.03) 7th day (76.85, 79.63 and 78.24) and 9th day (94.11, 95.44 and 94.78) were recorded under the treatment T4 (AgNP 20µl) followed by at 1st day (19.08, 19.96 and 19.52) , 3rd day (30.67, 31.78 and 31.22) 5th day (52.57, 53.64 and 53.11) 7th day (73.72, 79.56 and 76.64) and 9th day (87.44, 91.76 and 89.60) under the treatment T14 (8-HQC 200ppm) and at 1st day (17.27, 18.60 and 17.93), 3rd day (26.02, 30.04 and 28.03) 5th day (47.40, 49.06 and 48.23) 7th day (63.70, 70.46 and 67.08) and 9th day (76.99, 81.16 and 79.08) under the treatment T8 (SNP 15ppm) respectively, while minimum was observed at 1st day *viz.*, (10.07, 11.38 and 10.72) , 3rd day (19.33, 19.38 and 19.36) 5th day (31.33, 30.71 and 31.02) 7th day (42.74, 48.18 and 45.46) and 9th day (62.33, 67.87 and 65.10) under the treatment T0. The present results are best derived under the above treatments as optimum dose of Silver nano particles are known for enhancing the vase

life of cut flowers which might have improved the minimum days for the bud opening. The present findings are corroborated with the findings of Ansari *et al.* (2011) in Gerbera, Hashembadi *et al.* (2014) in Carnation, (Jain *et al.,* 2014; Amin, 2017) in Chrysanthemum.

Table 2: Influence of various vase solutions on days to bud opening (%) at different duration in (days) in Chrysanthemum (*Chrysanthemum morifolium* Ramat) Cv. White Star.

Sr. No.	Treatments	Days to bud opening (%) at different duration in (days)								
		1st day		Pooled Mean	3rd day		Pooled Mean	5th day		Pooled Mean
		2021-22	2022-23		2021-22	2022-23		2021-22	2022-23	
T_0	Control (de-ionized water)	10.07	11.38	10.72	19.33	19.38	19.36	31.33	30.71	31.02
T_1	AgNP 5µl	14.41	16.10	15.26	21.15	24.81	22.98	38.38	38.19	38.29
T_2	AgNP 10µl	15.61	16.42	16.01	22.34	26.95	24.65	41.52	41.74	41.63
T_3	AgNP 15µl	15.58	16.28	15.93	23.35	27.39	25.37	42.14	42.36	42.25
T_4	AgNP 20µl	22.31	24.93	23.62	35.17	39.66	37.41	56.51	57.55	57.03
T_5	AgNP 25µl	15.71	16.62	16.17	25.34	28.73	27.03	43.60	44.12	43.86
T_6	SNP 5ppm	15.73	17.73	16.73	25.65	29.68	27.67	43.12	45.25	44.18
T_7	SNP 10ppm	15.68	17.74	16.71	24.70	28.43	26.57	44.77	45.81	45.29
T_8	SNP 15ppm	17.27	18.60	17.93	26.02	30.04	28.03	47.40	49.06	48.23
T_9	SNP 20ppm	14.44	17.16	15.80	24.36	28.99	26.67	42.79	43.91	43.35
T_{10}	SNP 25ppm	15.79	19.82	17.80	22.57	27.07	24.82	43.41	44.02	43.71
T_{11}	8-HQC 50ppm	15.86	17.14	16.50	23.26	27.62	25.44	41.43	42.38	41.90
T_{12}	8-HQC 100ppm	16.21	17.68	16.94	23.35	27.56	25.46	42.32	42.68	42.50
T_{13}	8-HQC 150ppm	16.41	17.88	17.15	24.33	26.96	25.64	44.94	45.54	45.24
T_{14}	8-HQC 200ppm	19.08	19.96	19.52	30.67	31.78	31.22	52.57	53.64	53.11
T_{15}	8-HQC 250ppm	15.91	17.85	16.88	24.00	30.73	27.36	42.41	44.90	43.65
	SEm (±)	0.126	0.637		0.291	0.639		0.693	0.443	
	C.D.(*p=0.05%*)	0.365	1.850		0.844	1.855		2.012	1.285	

Table 2a: Influence of various vase solutions on fresh weight change at different duration in (days) in Chrysanthemum (*Chrysanthemum morifolium* Ramat) Cv. White Star.

Sr. No.	Treatments	Days to bud opening (%) at different duration in (days)					
		7th day		Pooled Mean	9th day		Pooled Mean
		2021-22	2022-23		2021-22	2022-23	
T_0	Control (de-ionized water)	42.74	48.18	45.46	62.33	67.87	65.10
T_1	AgNP 5µl	53.14	58.07	55.61	72.11	79.66	75.88
T_2	AgNP 10µl	54.66	57.33	56.00	73.13	79.00	76.07
T_3	AgNP 15µl	55.27	58.42	56.84	70.55	76.57	73.56
T_4	AgNP 20µl	76.85	79.63	78.24	94.11	95.44	94.78
T_5	AgNP 25µl	56.19	59.40	57.79	72.37	75.53	73.95
T_6	SNP 5ppm	55.78	60.44	58.11	72.75	78.73	75.74
T_7	SNP 10ppm	56.66	61.03	58.84	74.62	77.76	76.19
T_8	SNP 15ppm	63.70	70.46	67.08	76.99	81.16	79.08
T_9	SNP 20ppm	56.47	60.55	58.51	75.59	81.00	78.30
T_{10}	SNP 25ppm	57.84	61.32	59.58	73.28	78.69	75.99
T_{11}	8-HQC 50ppm	57.51	63.50	60.50	71.84	75.85	73.84
T_{12}	8-HQC 100ppm	61.00	65.52	63.26	71.85	75.39	73.62
T_{13}	8-HQC 150ppm	62.37	67.58	64.98	73.85	80.44	77.14
T_{14}	8-HQC 200ppm	73.72	79.56	76.64	87.44	91.76	89.60
T_{15}	8-HQC 250ppm	61.37	68.49	64.93	71.51	76.58	74.05
	SEm (±)	0.723	0.435		0.539	0.418	
	C.D.(*p=0.05%*)	2.097	1.262		1.563	1.213	

C. Solution uptake by plant at different duration in (days)

The data presented in Table 3 and 3a for solution uptake (ml) during the (2021-2022 & 2022-2023) followed by the Pooled data for both year *viz.*, at 1st day (46.84, 47.18 and 47.01) , 3rd day (44.71, 44.98 and 44.85) 5th day (42.81, 42.04 and 42.42) 7th day (40.08, 40.42 and 40.25) and 9th day (38.82, 38.46 and 38.64) were recorded under the treatment T4 (AgNP 20µl) followed by at 1st day (44.30, 44.64 and 44.47) , 3rd day (42.36, 43.69 and 43.02) 5th day (40.13, 38.80 and 39.47) 7th day (38.05, 38.39 and 38.22) and 9th day (36.52, 36.93 and 36.72) under the treatment T14 (8-HQC 200ppm) and at 1st day (42.12, 42.45 and 42.28) , 3rd day (40.14, 41.33 and 40.73) 5th day (38.11,38.00 and 38.05) 7th day (36.60, 36.94 and 36.77) and 9th day (34.13, 33.82 and 33.98) under the treatment T8 (SNP 15ppm) respectively, while minimum was observed at 1st day *viz.*, (21.11, 21.45 and 21.28) , 3rd day (19.21, 19.58 and 19.39) 5th day (17.11, 17.38 and 17.24) 7th day (15.12, 15.46 and 15.29) and 9th day (13.83, 12.17 and 13.00) under the treatment T0. The present results were reported under the above treatments as optimum dose

of Silver nano particles, 8-HQC and SNP's with their recommended dose are better known for removal of blockage from xylem vessel as this might have improved the solution uptake (ml). The present findings are similar with the findings of Marousky (1973); Rogers, 1973; Gladon and Staby (1976); Meman and Dabhi (2006); (Gupta *et al.*, 2006; Jain *et al.*, 2014; Amin, 2017) in Chrysanthemum, Amin (2017) in Carnation.

Table 3: Influence of various vase solutions on solution uptake by plant at different duration in (days) in Chrysanthemum (*Chrysanthemum morifolium* Ramat) Cv. White Star.

Sr. No.	Treatments	Solution uptake by plant at different duration in (days)								
		1st day		Pooled Mean	3rd day		Pooled Mean	5th day		Pooled Mean
		2021-22	2022-23		2021-22	2022-23		2021-22	2022-23	
T_0	Control (de-ionized water)	21.11	21.45	21.28	19.21	19.58	19.39	17.11	17.38	17.24
T_1	AgNP 5µl	32.26	32.60	32.43	30.15	30.85	30.50	28.08	27.96	28.02
T_2	AgNP 10µl	33.21	33.55	33.38	31.20	31.57	31.39	29.25	28.65	28.95
T_3	AgNP 15µl	34.51	34.84	34.67	32.54	32.88	32.71	30.73	30.07	30.40
T_4	AgNP 20µl	46.84	47.18	47.01	44.71	44.98	44.85	42.81	42.04	42.42
T_5	AgNP 25µl	36.51	36.85	36.68	34.41	34.75	34.58	32.25	31.63	31.94
T_6	SNP 5ppm	34.52	34.86	34.69	32.46	32.90	32.68	30.51	30.13	30.32
T_7	SNP 10ppm	33.84	34.18	34.01	31.48	31.99	31.73	29.56	29.20	29.38
T_8	SNP 15ppm	42.12	42.45	42.28	40.14	41.33	40.73	38.11	38.00	38.05
T_9	SNP 20ppm	36.52	36.86	36.69	34.40	34.76	34.58	32.30	31.95	32.13
T_{10}	SNP 25ppm	37.15	37.48	37.31	35.22	35.57	35.40	33.42	32.98	33.20
T_{11}	8-HQC 50ppm	33.44	33.78	33.61	31.39	31.67	31.53	29.87	29.39	29.63
T_{12}	8-HQC 100ppm	35.16	35.50	35.33	33.45	33.84	33.64	31.27	30.91	31.09
T_{13}	8-HQC 150ppm	37.45	37.78	37.61	35.42	35.93	35.68	33.49	32.72	33.10
T_{14}	8-HQC 200ppm	44.30	44.64	44.47	42.36	43.69	43.02	40.13	38.80	39.47
T_{15}	8-HQC 250ppm	39.85	40.19	40.02	37.84	38.07	37.95	35.48	34.15	34.81
	SEm (±)	0.027	0.306		0.027	0.379		0.033	0.322	
	C.D.(*p=0.05%*)	0.077	0.889		0.077	1.100		0.096	0.935	

Table 3a: Influence of various vase solutions on solution uptake by plant at different duration in (days) in Chrysanthemum (*Chrysanthemum morifolium* Ramat) Cv. White Star.

Sr. No.	Treatments	Solution uptake by plant at different duration in (days)					
		7th day		Pooled Mean	9th day		Pooled Mean
		2021-22	2022-23		2021-22	2022-23	
T_0	Control (de-ionized water)	15.12	15.46	15.29	13.83	12.17	13.00
T_1	AgNP 5µl	26.12	26.46	26.29	24.09	23.92	24.00
T_2	AgNP 10µl	27.20	27.54	27.37	26.27	26.06	26.16
T_3	AgNP 15µl	28.43	28.76	28.59	26.49	26.09	26.29
T_4	AgNP 20µl	40.08	40.42	40.25	38.82	38.46	38.64
T_5	AgNP 25µl	30.51	30.85	30.68	28.42	28.49	28.45
T_6	SNP 5ppm	28.37	28.70	28.53	26.12	26.04	26.08
T_7	SNP 10ppm	27.39	27.72	27.55	25.39	24.94	25.17
T_8	SNP 15ppm	36.60	36.94	36.77	34.13	33.82	33.98
T_9	SNP 20ppm	30.18	30.52	30.35	28.21	28.16	28.18
T_{10}	SNP 25ppm	30.22	30.56	30.39	28.25	28.04	28.15
T_{11}	8-HQC 50ppm	27.18	27.52	27.35	25.27	25.78	25.53
T_{12}	8-HQC 100ppm	29.18	29.52	29.35	27.58	28.00	27.79
T_{13}	8-HQC 150ppm	31.48	31.82	31.65	29.59	30.01	29.80
T_{14}	8-HQC 200ppm	38.05	38.39	38.22	36.52	36.93	36.72
T_{15}	8-HQC 250ppm	34.84	35.18	35.01	31.62	32.01	31.81
	SEm (±)	0.164	0.313		0.022	0.329	
	C.D.(*p=0.05%*)	0.477	0.908		0.063	0.954	

D. Days of determination of Chlorophyll (Chl.a and Chl.b) in Chrysanthemum

The data presented in Table 4 for determination of chlorophyll during (2021-2022 & 2022-2023) followed by the Pooled data for both year *viz.*, at the day of treatment was observed maximum for Chl.a µg/ml, Chl.b µg/ml with total chlorophyll µg/ml for 2021-2022 (0.873±0.003), (0.440±0.000) and (1.31) for 2022-2023 (0.923±0.009) µg/ml, (0.497±0.007) µg/ml and (1.42) µg/ml under the treatment T4 (AgNP 20µl) followed by for 2021-2022 (0.767±0.003) µg/ml, (0.380±0.003) µg/ml and (1.14) µg/ml and for 2022-2023 (0.833±0.009) µg/ml, (0.467±0.003) µg/ml and (1.30) µg/mlunder treatment T14 (8-HQC 200ppm) and for 2021-2022 (0.687±0.003) µg/ml, (0.340±0.000) µg/ml and (1.02) µg/ml similarly 2022-2023 (0.740±0.012) µg/ml, (0.420±0.007) µg/ml and (1.16) µg/ml under treatment T8 (SNP 15ppm) respectively. However, minimum chlorophyll was estimation for 2021-2022 (0.443±0.003) µg/ml, (0.217±0.003) µg/ml and (0.66)

µg/ml and for 2022-2023 (0.470±0.010) µg/ml, (0.253±0.003) µg/ml and (0.72) µg/ml under treatment under T_0 Control (de-ionized water). The present results were reported under the above treatments as optimum dose of Silver nano particles, 8-HQC and SNP's with their recommended dose are better known for removal of blockage from xylem vessel by inhibiting the bacterial blockages this might have improved and preserved the Chlorophyll content in the Chrysanthemum. The present findings are in accordance with the findings of (Banijamali *et al.*, 2019; Tung *et al.*, 2020; Pavasupree *et al.*, 2023) in *Chrysanthemum indicum* and *Chrysanthemum morifolium*.

Table 4: Determination of Chlorophyll in leaves in Chrysanthemum (*Chrysanthemum morifolium* Ramat) Cv. White Star.

Sr. No.	Treatments	Determination of Chlorophyll					
		Chlorophyll					
		2021-22			2022-23		
		Chl.a (µg/ml)	Chl.b (µg/ml)	Total Chlorophyll (µg/ml)	Chl.a (µg/ml)	Chl.b (µg/ml)	Total Chlorophyll(µg/ml)
T_0	Control (de-ionized water)	0.443±0.003	0.217±0.003	0.66	0.470±0.010	0.253±0.003	0.72
T_1	AgNP 5µl	0.527±0.003	0.250±0.000	0.77	0.553±0.013	0.303±0.012	0.85
T_2	AgNP 10µl	0.650±0.000	0.310±0.000	0.96	0.670±0.012	0.343±0.009	1.01
T_3	AgNP 15µl	0.670±0.000	0.323±0.003	0.99	0.693±0.023	0.357±0.005	1.05
T_4	AgNP 20µl	0.873±0.003	0.440±0.000	1.31	0.923±0.009	0.497±0.007	1.42
T_5	AgNP 25µl	0.577±0.003	0.283±0.003	0.86	0.597±0.009	0.317±0.009	0.91
T_6	SNP 5ppm	0.567±0.003	0.287±0.000	0.85	0.577±0.007	0.327±0.019	0.90
T_7	SNP 10ppm	0.583±0.003	0.280±0.003	0.86	0.600±0.006	0.310±0.015	0.91
T_8	SNP 15ppm	0.687±0.003	0.340±0.000	1.02	0.740±0.012	0.420±0.007	1.16
T_9	SNP 20ppm	0.583±0.003	0.280±0.003	0.86	0.590±0.010	0.327±0.019	0.91
T_{10}	SNP 25ppm	0.580±0.003	0.290±0.003	0.87	0.597±0.017	0.317±0.015	0.91
T_{11}	8-HQC 50ppm	0.587±0.000	0.293±0.000	0.88	0.607±0.009	0.300±0.006	0.90
T_{12}	8-HQC 100ppm	0.653±0.003	0.313±0.000	0.96	0.667±0.017	0.343±0.009	1.01
T_{13}	8-HQC 150ppm	0.657±0.000	0.317±0.000	0.97	0.687±0.018	0.343±0.006	1.03
T_{14}	8-HQC 200ppm	0.767±0.003	0.380±0.003	1.14	0.833±0.009	0.467±0.003	1.30
T_{15}	8-HQC 250ppm	0.680±0.003	0.327±0.003	1.00	0.697±0.009	0.377±0.012	1.07
	SEm (±)	0.003	0.002		0.009	0.010	
	C.D.(*p=0.05%*)	0.007	0.006		0.025	0.027	

CONCLUSIONS

Results of the present study suggest the overall best treatment for different parameters for improving the vase life of chrysanthemum during the consecutive seasons (2021-2022 & 2022-2023) were recorded under the treatment T_4 (AgNP 20µl) followed by the treatment T_{14} (8-HQC 200ppm) and T_8 (SNP 15ppm) while, vase solution with T_0 Control (de-ionized water) did not improve the different vase life parameters in Chrysanthemum. The various vase solutions significantly improved the different post harvest parameters in Chrysanthemum *viz.*, Fresh weight (g) change at different interval (days), days to bud opening (%), solution uptake by plant at different duration in (days) and days of determination of Chlorophyll (Chl.a and Chl.b) in Chrysanthemum however, minimum response was noted under Control. Overall, the current investigation was carried out and resulted in the successful development of a complete mechanism in improving the vase life of Chrysanthemum 'White Star'.

FUTURE SCOPE

The future scope of research on the influence of Silver nanoparticles (AgNP), Sodium nitroprusside (SNP), and 8-hydroxyquinoline citrate (8-HQC) on the vase life of Chrysanthemum (Chrysanthemum morifolium) cv. 'White Star' holds tremendous potential in both horticultural and biotechnological domains. As we continue to explore the synergistic effects of these compounds, we may unlock novel strategies to extend the post-harvest longevity of Chrysanthemum flowers. AgNP's antimicrobial properties could help combat pathogenic threats in vase water, while SNP might trigger stress-resistance mechanisms in the flowers, delaying senescence. Furthermore, 8-HQC's antioxidant capabilities may play a pivotal role in preserving the freshness and quality of the blooms. By harnessing these emerging technologies, we can not only bolster the ornamental flower industry but also contribute to sustainable floral production practices, ensuring that Chrysanthemum 'White Star' and similar cultivars remain vibrant and marketable for an extended period.

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Conflict of Interest. None.

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