Effect of Wrapping Materials and Storage Time on Shelf Life of Tuberose (Polianthes tuberosa L.)

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ABSTRACT

Background: The use of wrapping material during storage of cut flowers creates a modified atmosphere which reduces flower metabolism during storage, thereby slowing carbohydrate consumption as respiratory substrate. The main problem related to dry storage is moisture loss or desiccation. Keeping in view the above aspects, the present study was conducted to enhance the shelf life of tuberose.

Methods: The experiment was carried out at Post-Harvest Laboratory of Department of Horticulture, COA, CCS HAU, Hisar during the cropping season (March to September) of year 2019. It was laid out in CRD (factorial) with three replications and twenty-four treatment combinations, comprising of six wrapping materials (newspaper, butter paper, chart sheet, low density polyethylene of 100µ, high density polyethylene of 200µ and control as without wrapping) and four storage time (1, 4, 7 and 10 days), were tested. After harvesting, cut spikes were wrapped in wrapping materials and kept in cold-store at low temperature (less than 5°C), thereafter cut spikes were placed in vase solution (4% sucrose plus 300 ppm 8-HQC) for recording observations on floral parameters.

Result: Among different wrapping materials, the butter paper wrapped cut spikes observed better in most of the parameters followed by LDPE (100µ) wrapped cut spikes. Among the storage time, storage of cut spikes for 1 day observed better in most of the parameters except time taken up to opening of first pair of florets and total post-harvest life. Overall, butter paper wrapped cut spikes stored for 1 day performed better in term of floret diameter (46.73 mm), floret length (56.10 mm), floret longevity (2.89 days), appearance (3.70/5.0 scale), florets opened at a time (32.30%), total opened florets (54.32%), marketable vase life (6.53 days), total vase life (11.17 days), weight loss (17.08%) and solution consumed (135.33 ml) by the spikes. However, the cut spikes wrapped in butter paper stored for 10 days were found better with early opening of first pair of florets (0.95 days) and maximum post-harvest life (20.10 days).

Key words: Cut spike, Floret, Storage time, Tuberose, Wrapping material, µ (micron).

INTRODUCTION

With the availability of varied agro-climatic conditions, cheap labour and steady increase in the demand for flowers, floriculture is strengthening its strong roots in India. At present, the area in India under floriculture is 3.2 lakh hectares with a production of 19.6 lakh tonnes of loose flowers and 8.2 lakh tonnes of cut flowers (Anonymous, 2018a). The cut flowers like rose, gladiolus, tuberose, chrysanthemum etc. are commonly and frequently demanded both in the local as well as international market. Among these, tuberose is also an important cut flower crop which is commercially cultivated for cut and loose flower trade and also for the extraction of its highly valued natural flower oil that is used in high-value perfumes and other cosmetic products. The concrete yield from fresh florets is 0.08 to 0.11 per cent, of which 18.0 to 23.0 per cent is alcohol soluble absolute. Tuberose is popular among flower loving people, because of its sweet and pleasant fragrance and extended keeping quality and grown for garden decoration in pots, beds and borders. It is also a preferred cut flower, not just for use in arrangements, but also for the individual floret that can provide fragrance to bouquets and boutonnieres.

Tuberose is commercially cultivated in India, Kenya, South Africa, Morocco, France, North Carolina, Hawaii, Mexico, Taiwan, Italy, USA, Egypt, China and several other tropical and subtropical countries around the world. In India, it is majorly grown in West Bengal, Karnataka andhra Pradesh, Tamil Nadu, Maharashtra and Haryana. Presently, the area under tuberose cultivations in Haryana is about 167 hectares with a production of 32.6 lakh sticks mainly grown in Faridabad, Palwal, Gurugram, Sonipat, Panchkula and Karnal districts (Anonymous, 2018b).

Tuberose (Polianthes tuberosa L.) commonly known as ‘Rajni’ is a bulbous flowering perennial ornamental plant which belongs to the family Amaryllidaceae. Its flowers have funnel shaped white florets about 25.0 mm long, single
or double which emit an exquisite fragrance. ‘Single’ type varieties are more fragrant than ‘Double’ type. Tuberose spike bears 10-20 pairs of florets that open acropetally. Commercially, 60 -90 cm long spikes are harvested when two or three basal florets are open.

The quality of cut spikes is very important from the marketing point of view in domestic as well as export. Prices of cut flowers increase up to 9-10 times by post-harvest management and value addition. Therefore, proper packing of cut flowers is an important factor in deciding the vase life and quality of the cut spikes. Packaging play a key role in extending freshness, value addition and reducing damage (Ghildiyal et al., 2012). Sub-standard packaging and storage practices lead to deterioration in quality of the products with shorter vase life and ultimately poor market value. Tuberose flowers are highly perishable in nature unlike other horticultural or agricultural crops.

The use of different wrapping materials during storage creates a modified atmosphere which reduces flower/floret metabolism during storage, thereby slowing carbohydrate consumption as the respiratory substrate.

Dry storage of flowers includes keeping the flowers in package boxes and store them at room temperature or under controlled conditions by maintaining relative humidity, temperature and air circulation without keeping them in water or some other preservative solutions. The main problem related to dry storage is moisture loss or desiccation. Keeping in view the above facts and the paucity of research on these aspects, the present study was conducted.

**MATERIALS AND METHODS**

The present investigation was carried out at Post Harvest Laboratory of Dept. of Horticulture, COA, CCS HAU, Hisar during the cropping season (March to September) of year 2019 with a view to enhancing the quality and post-harvest life of tuberose cut spikes. Hisar has a semi-arid subtropical climate with hot, dry and desiccating winds during summer season and severe cold during winter season. The mean monthly maximum temperature during summer (May to July) is around 42 to 45°C, while the minimum temperature during winter months of December and January which sometimes goes as low as 0°C or less than that. As per requirement, average sized bulbs of tuberose cv. Prajwal were obtained from the Departmental Research Farm and the crop was grown at Agro-Tourism Centre of the University. Uniform sized bulbs of tuberose were planted on dated 29th March 2019 with spacing of 20 X 20 cm and at 4-5 cm depth. Various agronomical practices like irrigation, fertilization, weed management and plant protection measures were adopted according to the “package of practices for horticultural crops” as recommended by the University. The experiment was laid out in CRD (Factorial) with three replications and 24 treatment combinations, comprising of six wrapping materials [W₁: Newspaper, W₂: Butter paper, W₃: Chart sheet, W₄: Low density polyethylene (LDPE 100μ), W₅: High density polyethylene (HDPE 200μ) and W₆: Control as without wrapping] and four storage time (S₁: 1 day, S₂: 4 days, S₃: 7 days and S₄: 10 days), were tested. After harvesting at tight bud stage, first of all, fresh weight of five cut spikes in each treatment was recorded and then the cut spikes were wrapped in wrapping materials individually and kept in Cold-store in plastic crates for dry storage at low temperature in a Solar-based Cold-store at a low temperature (less than 5°C) for different storage time at COAE & T, CCS HAU, Hisar. After removing from cold storage, the cut spikes were weighed to calculate the loss in weight during the cold storage. The basal end of each spike was cut up to 1-2 cm to control the microbial growth. These spikes were then placed in vase solution (4% sucrose plus 300 ppm 8-HQC) individually in 500 ml conical flask for recording observations on floral parameters for each treatment (Murry, 2014).

Days to open first pair of florets were determined by the time taken in between the keeping of cut spike in vase solution and the opening of first pair of florets. Floret diameter and length (mm) was observed on four well opened florets selected in each spike and diameter of opened face and length (from base to top) of each floret was measured with measuring scale and then averaged. For floret longevity, three florets from each spike were selected randomly and the number of days taken in fading of each floret from the date of cut spike placed in vase solution were counted and then averaged.

Appearance of cut spikes was measured in scale (based on freshness and colour of florets and bending of spike) by visually observing the spike every day from the time of end of marketable vase life up to the full opening of 50 percent florets on each spike (depending upon the shelf life of cut spikes) and graded as A (5 points), B (3 points) and C (1 point) and then averaged. Further, the maximum number of opened floral buds per spike at a time were also counted and then the percentage of opened florets at a time was calculated by using the mathematical formula. Similarly, at the end of vase life the total number of opened floral buds on each spike were counted and then converted into percentage of opened florets by using the same formula. Days taken to open 50% florets in each spike were counted by recording total number of opened buds per spike regularly and then averaged. Marketable vase life was calculated in number of days in between the keeping spike in vase solution and the fading of lower 25% florets in each spike and then averaged. Total vase life was calculated by counting the number of days from the time when cut spikes were placed in vase solution up to the fading of last opened floret in all five spikes and then averaged. Total post-harvest life was determined by counting the number of days from the harvesting date of spike to the fading of last opened floret in each spike and then averaged. After the harvesting of spikes, initial weight of each spike was recorded before the wrapping and at the end of vase life the final weight of each spike was also recorded and then the initial and final weights of five spikes were averaged and then the percentage of
loss in weight was calculated by using the mathematical formula. Amount of solution consumed (g) by the spike was calculated by subtracting final weight of solution at the end of vase life from the initial weight of solution in 500 ml conical flask.

The recorded data on different parameters was analyzed statistically using OPSTAT statistical software developed by CCShAU, Hisar to find out the significance of variation resulting from the experimental treatments.

**RESULTS AND DISCUSSION**

**Effect of wrapping materials on floral parameters of cut spike**

The wrapping materials significantly influenced all the floral parameters as observed in this study (Table 1 and 2). The minimum days to open the first pair of florets (1.40 days), maximum floret diameter (45.10 mm) and length (53.99 mm) was recorded in butter paper wrapped cut spikes and it was followed by LDPE wrapping, whereas the maximum days to open the first pair of florets, minimum floret diameter and length was recorded in unwrapped cut spikes. This might be based on the fact that wrapping materials decrease the rate of respiration by generating a modified atmosphere (MA) with limited oxygen and higher carbon dioxide concentration which slow down the rate of respiration and reduces the loss of stored food and helped to provide adequate energy to the spike for the successful opening of florets to a larger diameter and length (Kumar et al., 2010). The present findings also got support from the results of Roychowdhury et al. (2011) in tuberose cv. ‘Calcutta Double’.

The spikes wrapped with butter paper showed the maximum floret longevity (2.71 days) and the highest scoring (3.54/5.0) of spike appearance and followed by LDPE wrapping, whereas unwrapped cut spikes showed the minimum floret longevity and the lowest scoring of spike appearance in vase solution. It might be due to that butter paper, as a wrapping material, possesses low air diffusion rate with limited oxygen and higher concentration of carbon dioxide as compared to other wrapping materials. High CO₂ concentration (5-10%) has been reported to delay the senescence of vegetative tissue (Meir et al., 1995), possibly due to its inhibitive ethylene activity and/or its effect on the preservation of high levels of polyamines in tissues. This finding also got support from other findings of Varu and Barad (2008); Roychowdary et al. (2011) in tuberose.

The cut spikes wrapped in butter paper (W₅) resulted in minimum weight loss (21.60%) and LDPE wrapped spikes were found at par (22.48%) with W₅, whereas unwrapped cut spikes resulted in maximum weight loss (28.42%). Similar effect of wrapping on loose flowers of tuberose was also observed by Archana et al. (2019). The maximum amount of solution consumed (127.73 ml) was observed with butter paper wrapped cut spikes, while the minimum amount of solution consumed (95.53 ml) was observed with unwrapped cut spikes. The reason for maximum solution consumed by butter paper wrapped cut spikes might be the maintaining higher level of carbohydrates and cell turgidity in spike, for which cut spikes required more carbohydrates in the form of sugar which was dissolved in vase solution. Similar results were also reported by Varu and Barad (2008); Baidya and Chakrabarty (2020) in cut spikes of tuberose.

**Effect of storage time on floral parameters of cut spike**

The data recorded on all the floral parameters were significantly influenced by the duration of storage (Table 1 and 2). The cut spikes stored for 10 days took the minimum number of days (1.47) to open the first pair of florets, whereas cut spikes stored for 1 day took the maximum number of days (1.90). This might be due to long time storage of spike at low temperatures gradually leads towards the metabolic activities that enhanced their ageing and become on the verge of opening when kept in vase solution as compared to short time storage. The cut spikes stored for 1 day recorded the maximum floret diameter (44.56 mm) as well as length (53.71 mm) and it was followed by 4 days storage, while cut spikes stored for 10 days recorded the minimum floret diameter (39.96 mm) as well as length (49.01 mm) when kept in vase solution. Although at low temperature, it was possible to store the cut spikes for longer period (10
### Table 1: Effect of wrapping materials and storage duration on quantity parameters of tuberose spikes.

| Treatments              | Days taken to open first pair of florets | Days taken to open 50% florets | Percentage of florets opened at a time | Percentage of opened florets | Percentage loss in weight of spikes | Amount of solution consumed (ml) |
|-------------------------|------------------------------------------|-------------------------------|----------------------------------------|-------------------------------|-------------------------------------|---------------------------------|
| **A : Wrapping materials** |                                           |                               |                                        |                               |                                     |                                 |
| W₁ : Newspaper          | 1.77                                     | 7.26                          | 30.68                                  | 49.70                         | 26.89                               | 114.82                          |
| W₂ : Butter paper       | 1.40                                     | 6.97                          | 31.53                                  | 52.52                         | 21.60                               | 127.73                          |
| W₃ : Chart sheet        | 1.75                                     | 7.26                          | 30.19                                  | 48.90                         | 27.66                               | 108.80                          |
| W₄ : LDPE (100 µ)       | 1.73                                     | 7.18                          | 31.17                                  | 50.37                         | 22.48                               | 125.70                          |
| W₅ : HDPE (200 µ)       | 1.80                                     | 7.28                          | 30.83                                  | 49.61                         | 25.63                               | 113.00                          |
| W₆ : Control (without wrapping) | 1.88                                    | 7.35                          | 30.15                                  | 47.92                         | 28.42                               | 95.53                           |
| **CD at 5 %**           | 0.20                                     | 0.13                          | 0.17                                   | 0.72                          | 0.82                                | 2.01                            |
| **B : Storage time**    |                                           |                               |                                        |                               |                                     |                                 |
| S₁ : 1 day              | 1.90                                     | 6.99                          | 31.67                                  | 53.13                         | 22.15                               | 120.61                          |
| S₂ : 4 days             | 1.84                                     | 7.24                          | 30.92                                  | 50.75                         | 23.85                               | 117.67                          |
| S₃ : 7 days             | 1.68                                     | 7.31                          | 30.51                                  | 48.58                         | 26.42                               | 111.82                          |
| S₄ : 10 days            | 1.47                                     | 7.33                          | 29.94                                  | 46.90                         | 29.38                               | 106.94                          |
| **CD at 5 %**           | 0.16                                     | 0.11                          | 0.14                                   | 0.56                          | 0.67                                | 1.64                            |
| **Wrapping materials x Storage time (A x B)** |                                     |                               |                                        |                               |                                     |                                 |
| W₁S₁                    | 1.94                                     | 7.00                          | 31.40                                  | 53.23                         | 24.71                               | 120.00                          |
|                         |                                          |                               | (27.16)                                | (64.20)                        | (17.49)                             |                                 |
| W₂S₁                    | 1.80                                     | 6.83                          | 32.30                                  | 54.32                         | 17.08                               | 135.33                          |
|                         |                                          |                               | (28.57)                                | (66.01)                        | (8.67)                              |                                 |
| W₃S₁                    | 1.90                                     | 7.13                          | 31.03                                  | 52.61                         | 25.76                               | 114.00                          |
|                         |                                          |                               | (26.59)                                | (63.16)                        | (18.90)                             |                                 |
| W₄S₁                    | 1.83                                     | 6.93                          | 32.18                                  | 53.26                         | 18.19                               | 132.00                          |
|                         |                                          |                               | (28.38)                                | (64.26)                        | (9.75)                              |                                 |
| W₅S₁                    | 1.92                                     | 6.97                          | 31.75                                  | 52.94                         | 20.78                               | 119.67                          |
|                         |                                          |                               | (27.72)                                | (63.72)                        | (12.64)                             |                                 |
| W₆S₁                    | 2.03                                     | 7.07                          | 31.36                                  | 52.39                         | 26.37                               | 102.67                          |
|                         |                                          |                               | (27.10)                                | (62.79)                        | (19.75)                             |                                 |
| W₁S₂                    | 1.93                                     | 7.27                          | 30.97                                  | 50.93                         | 25.15                               | 118.50                          |
|                         |                                          |                               | (26.50)                                | (60.30)                        | (18.10)                             |                                 |
| W₂S₂                    | 1.60                                     | 6.93                          | 31.83                                  | 53.38                         | 19.84                               | 133.47                          |
|                         |                                          |                               | (27.84)                                | (64.46)                        | (11.53)                             |                                 |
| W₃S₂                    | 1.85                                     | 7.30                          | 30.46                                  | 50.05                         | 26.15                               | 111.43                          |
|                         |                                          |                               | (25.72)                                | (58.79)                        | (19.45)                             |                                 |
| W₄S₂                    | 1.75                                     | 7.20                          | 30.99                                  | 51.59                         | 20.45                               | 132.97                          |
|                         |                                          |                               | (26.53)                                | (61.44)                        | (12.22)                             |                                 |
| W₅S₂                    | 1.87                                     | 7.40                          | 30.98                                  | 49.88                         | 24.87                               | 113.33                          |
|                         |                                          |                               | (26.51)                                | (58.50)                        | (17.70)                             |                                 |
| W₆S₂                    | 2.02                                     | 7.33                          | 30.28                                  | 48.65                         | 26.63                               | 96.32                           |
|                         |                                          |                               | (25.44)                                | (56.38)                        | (20.11)                             |                                 |
| W₁S₃                    | 1.75                                     | 7.40                          | 30.55                                  | 48.32                         | 27.90                               | 111.53                          |
|                         |                                          |                               | (25.86)                                | (55.81)                        | (21.93)                             |                                 |
| W₂S₃                    | 1.27                                     | 7.03                          | 31.18                                  | 52.32                         | 22.18                               | 125.67                          |
|                         |                                          |                               | (26.83)                                | (62.67)                        | (14.27)                             |                                 |
| W₃S₃                    | 1.77                                     | 7.33                          | 29.87                                  | 47.08                         | 29.17                               | 106.33                          |
|                         |                                          |                               | (24.83)                                | (53.65)                        | (23.77)                             |                                 |
| W₄S₃                    | 1.71                                     | 7.27                          | 30.97                                  | 49.28                         | 23.18                               | 124.40                          |

Table 1: Continue.....
Effect of Wrapping Materials and Storage Time on Shelf Life of Tuberose (Polianthes tuberosa L.)

Table 1: contineu.....

| Wrapping Material | Storage Time | Floret Longevity (days) | Spike Appearance | Vase Life | Post-Harvest Life |
|-------------------|--------------|-------------------------|------------------|----------|-------------------|
| W₂S₁              | 1.73         | 30.58                   | 48.62            | 27.34    | 110.47            |
|                   |              | (25.90)                 | (56.33)          | (21.11)  |                   |
| W₂S₃              | 1.83         | 29.84                   | 45.88            | 28.76    | 92.53             |
|                   |              | (24.78)                 | (51.57)          | (23.17)  |                   |
| W₃S₄              | 1.47         | 29.79                   | 46.32            | 29.81    | 109.23            |
|                   |              | (24.71)                 | (52.34)          | (24.73)  |                   |
| W₄S₄              | 0.95         | 30.81                   | 50.08            | 27.32    | 116.43            |
|                   |              | (26.26)                 | (58.85)          | (21.08)  |                   |
| W₅S₄              | 1.47         | 29.41                   | 45.88            | 29.57    | 103.43            |
|                   |              | (24.14)                 | (51.56)          | (24.43)  |                   |
| W₆S₄              | 1.63         | 30.48                   | 47.34            | 28.10    | 113.43            |
|                   |              | (25.75)                 | (51.11)          | (22.20)  |                   |
| W₇S₄              | 1.67         | 30.02                   | 47.01            | 29.52    | 108.53            |
|                   |              | (25.05)                 | (53.54)          | (24.30)  |                   |
| W₈S₄              | 1.62         | 29.14                   | 44.77            | 31.94    | 90.60             |
|                   |              | (23.72)                 | (49.63)          | (28.02)  |                   |
| CD at 5 %         | NS           | NS                      | 0.35             | 1.43     | 1.65              |

days), yet the diameter and length of floret were reduced in comparison to shorter period (1 day). Wathaka et al. (2001) also reported that shorter storage duration of spikes increased diameter, length and opening of florets as compared to longer storage duration in tuberose. Similar results were also obtained by Murry (2014) and Mahawer et al. (2019) in tuberose and Khan et al. (2007) in tulip.

The floret longevity and score of spike appearance decreased with an increase in storage time. The cut spikes stored for 1 day recorded the maximum floret longevity (2.75 days) and score for appearance (3.30) and it was followed by 4 days storage, whereas cut spikes stored for 10 days recorded the minimum floret longevity (2.30 days) and score for appearance (2.96). It might be due to cellular senescence processes of cut spike which proceeded even during cold storage and such senescence activities were carried out at the expense of the stored food in spike. Although at low temperature, it was possible to store the cut spikes for longer period (10 days), the floret longevity and spike appearance were reduced as compared to shorter period (1 day).

The cut spikes stored for 1 day recorded the maximum florets opened at a time (31.67 %), total opened florets (53.13 %) and minimum number of days taken to open 50 % florets (6.99 days), whereas cut spikes stored for 10 days recorded the minimum florets opened at a time (29.94 %), total opened florets (46.90 %) and the maximum number of days to open 50 % florets (7.33 days). Similar results were also reported by Kumar et al. (2003), Murry (2014) and Gawde et al. (2018) in tuberose.

The cut spikes stored for 1 day showed the maximum marketable (5.87 days) as well as total (10.77 days) vase life and minimum post-harvest life (11.77 days), whereas spikes stored for 10 days showed the minimum marketable (5.23 days) as well total (9.31 days) vase life and maximum post-harvest life (19.31 days). Mahawer et al. (2019) also reported that increased in the storage duration decreased the florets opening in tuberose cv. Suvasini. These results were also in accordance with Wathaka et al. (2001) in tuberose, Singh et al. (2003) in gladiolus and Khan et al. (2004) in rose.

The cut spikes stored for 1 day recorded the minimum percentage of weight loss (22.15 %) and maximum amount of solution consumed (120.61 ml) and it was followed by storage for 4 days, while cut spikes stored for 10 days recorded the maximum percentage of weight loss (29.38 %) and the minimum amount of solution consumed (106.94 ml). Shil et al. (2014) also reported that total water absorption decreased and the physiological loss in weight increased with the increase in storage duration of cut spikes in tuberose.

Interaction effect of wrapping materials and storage time on floral parameters of cut spike

Interaction effect of wrapping materials and storage time was found the non-significant in respect of time taken to opening of first pair of florets and opening of 50% florets and the significant with respect to diameter, length and longevity of floret, spike appearance, percentage of florets opened at a time and total percentage of opened florets (Table 1 and 2). The minimum number of days (0.95) taken to open the first pair of florets were recorded in butter paper wrapped cut spikes stored for 10 days, whereas the maximum number of days (2.03) were recorded in unwrapped cut spikes stored for 1 day. The floret diameter (46.73 mm) was observed maximum in butter paper wrapped cut spikes stored for 1 day (W₂S₁) and it was followed by
### Table 2: Effect of wrapping materials and storage duration on quality and vase life parameters of tuberose spikes.

| Treatments                  | Florets diameter (mm) | Florets length (mm) | Floret longevity (days) | Appearance (freshness, color and bending) | Marketable vase life (Days) | Total vase life (days) | Total post-harvest life (days) |
|-----------------------------|-----------------------|---------------------|-------------------------|---------------------------------------------|-----------------------------|------------------------|-----------------------------|
|                            | W<sub>1</sub>         | W<sub>2</sub>       | W<sub>3</sub>           | W<sub>4</sub>                                |                             |                        |                             |
|                            | 41.72                 | 43.22               | 39.18                   | 43.98                                       | 5.39                        | 9.88                   | 15.38                       |

#### A : Wrapping materials

| CD at 5 %                  | 0.65                  | 0.65                | 0.05                    | 0.05                                       | 0.06                        | 0.08                   | 0.12                        |

#### B : Storage time

| S<sub>1</sub> 1 day       | 44.56                 | 43.25               | 39.18                   | 43.98                                       | 5.87                        | 10.77                  | 11.77                       |
| S<sub>2</sub> 4 days      | 44.67                 | 43.25               | 39.18                   | 43.98                                       | 5.64                        | 10.40                  | 14.40                       |
| S<sub>3</sub> 7 days      | 44.77                 | 43.25               | 39.18                   | 43.98                                       | 5.53                        | 10.63                  | 16.63                       |
| S<sub>4</sub> 10 days     | 44.87                 | 43.25               | 39.18                   | 43.98                                       | 5.23                        | 9.31                   | 19.31                       |
| CD at 5 %                  | 0.65                  | 0.65                | 0.05                    | 0.05                                       | 0.06                        | 0.10                   | 0.10                        |

#### Wrapping materials x Storage time (A x B)

| W<sub>1</sub>S<sub>1</sub> | 43.80                 | 43.73               | 39.70                   | 43.98                                       | 5.67                        | 10.70                  | 11.70                       |
| W<sub>1</sub>S<sub>2</sub> | 44.70                 | 43.73               | 39.70                   | 43.98                                       | 5.53                        | 10.63                  | 16.63                       |
| W<sub>1</sub>S<sub>3</sub> | 45.77                 | 43.73               | 39.70                   | 43.98                                       | 5.23                        | 9.31                   | 19.31                       |
| W<sub>1</sub>S<sub>4</sub> | 44.10                 | 43.73               | 39.70                   | 43.98                                       | 5.23                        | 9.31                   | 19.31                       |

LDPE wrapped cut spikes (45.77 mm) stored for 1 day. Although the length of floret (56.10 mm) was recorded maximum with treatment W<sub>2</sub>S<sub>1</sub>, but the spikes wrapped in butter paper and stored for 4 days (55.43 mm) were also observed at par with treatment W<sub>2</sub>S<sub>1</sub> while the minimum floret diameter (35.83 mm) and length (47.80 mm) were recorded in unwrapped cut spikes stored for 10 days. Murry (2014) also reported that the keeping quality of tuberose cut spikes was better when stored for shorter period (0 and 3 days) and wrapped either with cellophane or butter paper. The cut spikes wrapped in butter paper stored for 1 day (W<sub>2</sub>S<sub>1</sub>) resulted in maximum floret longevity (2.89 days) and LDPE wrapped cut spikes stored for 1 day were observed at par (2.79 days) with W<sub>2</sub>S<sub>1</sub> and the maximum scoring (3.70) for spike appearance was also recorded in treatment W<sub>2</sub>S<sub>1</sub> and the butter paper wrapped spikes stored for 4 days were...
found at par (3.64) with treatment $W_2S_1$, whereas the minimum floret longevity (2.04 days) and scoring for spike appearance (2.72) were recorded in unwrapped cut spikes stored for 10 days. These results might be due to that the wrapping material and low temperature slowed down the respiration and transpiration loss of moisture and less use of carbohydrates in metabolic activities in stored cut flowers. Similar results were also obtained by Mahawer et al. (2019) in tuberose and Dastagiri et al. (2014) in ornithogalum.

The maximum percentage of florets opened at a time (32.30%) was recorded in cut spikes wrapped with butter paper and stored for 1 day ($W_1S_1$). The treatments $W_1S_1$ (32.18%) and $W_2S_1$ (31.83%) were also found at par with treatment $W_1S_1$, while the minimum percentage of florets opened at a time (29.14%) was recorded in unwrapped cut spikes stored for 10 days ($W_2S_4$). The maximum percentage of opened florets (54.32%) was also observed in treatment $W_4S_1$ and the treatment $W_2S_1$ (53.23%), $W_1S_1$ (53.26%), $W_4S_1$ (52.94%) and $W_2S_1$ (53.38%) were observed at par with treatment $W_1S_1$, while the minimum percentage of opened florets (44.77%) was observed with $W_2S_4$. Furthermore, the treatment $W_2S_4$ took minimum days (6.83 days) to open 50% florets and it was followed by treatment $W_1S_4$ (6.93 days), whereas the maximum number of days (7.53 days) were taken by treatment $W_4S_4$. The cut spikes wrapped in butter paper or LDPE and stored for shorter duration resulted in earliest as well as better opening of florets as compared to spikes wrapped in other material and stored for longer duration. Singh et al. (2007) also reported that the quality of packaged cold stored cut spikes of gladiolus was significantly degraded with an increase in storage duration.

The maximum marketable vase life (6.53 days) was recorded in butter paper wrapped cut spikes stored for 1 day ($W_1S_1$) and it was followed by butter paper wrapped spikes stored for 4 days (6.37 days), whereas the minimum marketable vase life (4.87 days) was recorded in unwrapped cut spikes stored for 10 days ($W_2S_4$). Similarly, the total vase life was also recorded maximum (11.17 days) in treatment $W_2S_1$ and the treatment $W_1S_1$ was observed at par (10.93 days) with treatment $W_1S_1$, while it was recorded minimum (8.10 days) in treatment $W_1S_4$. The total post-harvest life of cut spikes was observed maximum (20.10 days) in butter paper wrapped cut spikes stored for 10 days ($W_2S_4$) and the treatment $W_2S_3$ (19.93 days) was found at par with treatment $W_4S_3$, whereas the minimum post-harvest life (11.50 days) was recorded in unwrapped cut spikes stored for 1 day. Similar findings were also reported by Kumar et al. (2003) in tuberose, Singh et al. (2003) in gladiolus, khan et al. (2004) in rose and Dastagiri et al. (2014) in ornithogalum.

Among the various treatments, the minimum weight loss (17.08 %) was observed in butter paper wrapped cut spikes stored for 1 day ($W_1S_1$) and treatment $W_1S_1$ (18.19 %) was found at par with treatment $W_1S_1$, whereas unwrapped cut spikes stored for 10 days ($W_4S_2$) resulted in maximum weight loss (31.94 %). The maximum amount of solution (135.33 ml) was also consumed by treatment $W_2S_1$, but the treatments $W_1S_1$ (132.00 ml), $W_2S_2$ (133.47 ml) and $W_2S_2$ (132.97 ml) were also observed statistically at par with treatment $W_2S_1$, while the minimum amount of solution (90.60 ml) was consumed by treatment $W_1S_4$. Such results might be due that the shorter storage durations did not reduce the quantity of stored food and the modified atmosphere created by wrapping materials retarded metabolic processes such as respiration and moisture loss. Similar results were also reported by Murry (2014) in tuberose.

**CONCLUSION**

From the present investigation it may be concluded that the butter paper wrapped cut spikes showed their superiority in terms of early opening of first pair of florets and the opening of 50% florets, maximum diameter, length and longevity of florets, highest scoring of spike appearance, maximum percentage of florets opened at a time and total opened florets, maximum marketable as well as total vase life and post-harvest life, minimum loss in weight of spike and maximum vase solution consumed by the spike and it was followed by LDPE (100µ) wrapped cut spikes in most of the above mentioned parameters.

Among the storage time, 1 day stored cut spikes performed better in terms of early opening of 50% florets, maximum diameter, length and longevity of florets, highest scoring of spike appearance, maximum percentage of florets opened at a time and total opened florets, maximum marketable as well as total vase life, minimum loss in weight of spike and maximum vase solution consumed by the spike. However, earlier opening of first pair of florets (1.47 days) and maximum post-harvest life (19.31 days) were obtained in cut spikes stored for 10 days.

Overall, the butter paper wrapped cut spikes stored for 1 day performed better in most of the floral parameters and it was followed by LDPE wrapped cut spikes stored for the same period (i.e 1 day). However, earlier opening of first pair of florets and the maximum post-harvest life was observed in butter paper wrapped cut spikes stored for 10 days. From this study it may also be concluded that if required cold storage of tuberose cut spikes is possible for 7 to 10 days by wrapping in butter paper or LDPE (100µ) without much losses in their quality parameters.

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