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STANDARDIZATION OF DIFFERENT DRYING TECHNIQUES IN LIMONIUM (*LIMONIUM SINUATUM*)

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ABSTRACT

The investigation on the “Standardization of different drying techniques in Limonium (*Limonium sinuatum*)” was conducted at the Department of Floriculture and Landscaping, College of Horticulture, Bengaluru, during 2023-2024. The experiment, using a Factorial Complete Block Design (FCBD), involved three varieties—Shooting Star (V_1), Silver Pink (V_2), and Sky Light (V_3)—and three drying methods: Air drying (D_1), hot air oven drying (D_2) and heat pump drying (D_3), replicated thrice. Among varieties, Sky Light (V_3) recorded the highest dry weight (27.38 g) and the highest consumer acceptance scores for appearance (3.86) and overall acceptability (4.03). Shooting Star (V_1) had the quickest drying time (54.22 hours) and the highest score for colour (3.92). In drying methods, Air drying (D_1) yielded the highest dry weight (25.78 g) and the best scores for colour (4.08), shape (3.65), appearance (4.02) and overall acceptability (4.14). Hot air oven drying (D_2) had the shortest drying time (2.87 hours). The combination of Sky Light and Air drying (V_3D_1) produced the highest dry weight (39.56 g) and superior acceptance scores, while Shooting Star with hot air oven drying (V_1D_2) was the fastest (2.00 hours). This study recommends V_3D_1 for optimal quality and V_1D_2 for rapid drying.

Key words : Limonium, Air drying, Hot air oven drying, Heat pump drying, Consumer acceptance.

Introduction

Limonium (*Limonium sinuatum*), from the Plumbaginaceae family, originates in the Canary Islands and Mediterranean regions. The name *limonium* is derived from the Greek “leimon,” meaning “meadow.” The inflorescences of limonium form a panicle with small, funnel-shaped true flowers surrounded by vibrant trumpet-shaped calyces in colours such as purple, pink, yellow and white. Though fresh flowers are attractive but are more expensive, shorter lived and available only during a particular season. Despite using the best chemical and botanicals for improving of keeping quality and enhancement of vase life, the fresh flowers cannot be stored for long time. In the present era of eco-consciousness, use of natural products has become a premier choice of the masses in their lifestyle. This is where dry flower takes advantage, cause a flower once

dried through right technique it will remain same as it is up to six months to a year. The demand for dry flowers is increasing at rate of 8-10 per cent per annum. Offering a lot of opportunities for the Indian entrepreneurs to enter in the global floriculture trade. More than 10,000 tonnes of dried flowers are exported annually from India valued around 100 crores and exports 500 varieties of flowers to 20 nations. Important floriculture dried products include: Lotus pods, poppy seed heads, camellias, straw flower, limonium, delphinium, lavender, dahlia, african marigold, jute flowers, roses, etc. Export destinations for Indian dry flower products are United states, Malaysia, Singapore, United Kingdom etc. The major dry flower industry in India is located in Tuticorin and Kolkata and raw material for these industries comes from Pune, Bangalore, Nasik, Madya Pradesh, Bihar and North- eastern states. Given the high demand for flower fillers and the recent

introduction of a few new cut flower varieties to the floriculture market limonium is not yet grown commercially in Bengaluru. Therefore, this will open new dimension and opportunities for farmers to produce high-quality flowers as well as for women entrepreneurs to produce high quality everlasting flowers (Ranjan and Misra, 2002).

Materials and Methods

The investigation was carried out at Department of Floriculture and Landscape Architecture, College of Horticulture, Bengaluru, during 2023-2024. Three varieties i.e, Shooting Star (V_1), Silver Pink (V_2) and Sky Light (V_3) were used in this investigation and were dried through three drying method viz., Air drying (D_1), hot air oven drying (D_2) and heat pump drying (D_3). The dried flower panicles were evaluated for quality parameters, such as fresh weight, dry panicle weight, drying duration, colour retention (Acc to RHS chart), storage studies and consumer acceptance for colour, texture, shape, appearance and overall acceptability, as per the standard procedures. The experimental design followed was Factorial Randomized Complete Block Design (FRCBD) with nine treatments replicated thrice and statistically analysed.

Methodology

Experiment was carried out to find the best drying method among, Air drying, Hot air oven drying and Heat pump drying. In Air drying a sample of three panicles per treatment of three varieties replicated three times were hanged upside down in the room with good ventilation and flowers were left for drying until the dry weight becomes constant for two consecutive days. In hot air oven at 40°C the panicles were placed on trays inside the oven for uniform drying. Here a sample of three panicles per treatment replicated three times of three varieties, were kept for drying until the dry weight becomes constant for two consecutive hours and feel papery texture of panicles. In a heat pump dryer, a steady increase in temperature was applied, reaching a maximum of 40°C. A sample of three panicles per treatment, replicated three times for each of the three varieties were kept for drying until the dry weight becomes constant for two consecutive hours and feel papery texture of panicles. The storage observation for dried flower panicles were covered with newspaper and stored in the cardboard boxes in an ambient room condition, and monthly observation was recorded for weight loss and colour over a period of three months.

Results and Discussion

Dry weight

Significant effects on dry weight was observed in three varieties that were dried through different drying methods. Out of the three varieties maximum (27.38 g) dry weight was observed in Sky Light (V_3), whereas Shooting Star (V_1) had the minimum dry weight (7.47 g). Among three different drying methods, air drying (D_1) had the highest dry weight (25.78 g), whereas lowest dry weight (16.76 g) was noticed in hot air oven drying (D_2). The results of the interaction between varieties and drying showed that V3D1 (Sky Light + air drying) had the maximum dry weight (39.56 g) followed by V2D1 (Silver Pink + air drying) (31.11 g), while V1D1 (Shooting Star + air drying) had the minimum dry weight (6.67 g) (Table 1).

Drying duration

Among three varieties the earliest drying (54.22 hrs) was observed in Shooting Star (V_1). Whereas, longest duration for drying (78.22 hrs) was observed in Silver Pink (V_2). Out of the three different drying methods, hot air oven drying (D_2) recorded the earliest drying duration (2.87 hrs) and air drying (D_1) took the longer period for drying (185.78 hrs). The results of the interaction between varieties and drying showed earliest drying (2.00 hrs) in V1D2 (Shooting Star + hot air oven drying) and longer period for drying (210.67 hrs) was observed in V2D1 (Silver Pink + air drying) (Table 1). This might be due to hot air produced by hot air oven, might have removed the moisture excessively from plant samples and get dried Raghupathi *et al.* (2020). This also holds good for those flowers dried at 40°C for long duration and at higher temperature. Where air drying helps in slow and steadily removal of moisture hence has more dry weight. Similar observations were reported by Yadlod *et al.* (2016); Safeena and Patil (2007) in ornamental plants and Patil and Karale (2003) in drying of gerbera flowers.

Storage observations

Upon assessing the drying quality of the three varieties, Sky Light (V_3) had the highest dry weight (26.63, 26.45, and 26.28 g) at 30, 60, and 90 days after drying respectively, whereas Shooting Star (V_1) had the lowest dry weight (7.51, 7.36, and 7.15 g respectively) at the same intervals. Among different drying methods at 30, 60 and 90 days after drying, Air drying (D_1) had the highest dry weight (24.73, 24.25 and 24.28 g respectively), whereas hot air oven drying (D_2) had the lowest dry weight (16.45, 16.24 and 16.10 g respectively) at same intervals. The interaction between varieties and drying

Table 1 : Fresh weight (g), Dry weight (g) and Drying duration (hrs) of panicles of limonium varieties with different drying methods.

Treatment	Fresh weight (g)	Dry weight (g)	Drying duration (hrs)
Varieties (V)			
V1: Shooting Star	20.55 ^b	7.47 ^b	54.22 ^a
V2: Silver Pink	62.93 ^a	25.44 ^a	78.27 ^a
V3: Sky Light	72.87 ^a	27.38 ^a	73.82 ^a
S. Em. ±	3.74	1.37	5.668
CD @ 1%	11.12	4.06	16.842
Drying (D)			
D1: Air drying	73.08 ^a	25.78 ^a	185.78 ^a
D2: Hot air oven drying	39.91 ^b	16.76 ^b	2.87 ^b
D3: Heat pump drying	43.36 ^b	17.76 ^b	17.67 ^b
S. Em. ±	3.74	1.37	5.668
CD @ 1%	11.12	4.06	16.842
Interaction (V × D)			
V1D1 (Shooting Star + Air drying)	22.32 ^e	6.67 ^e	146.67 ^b
V1D2 (Shooting Star + Hot air oven drying)	20.76 ^e	7.93 ^e	2.00 ^c
V1D3 (Shooting Star + Heat pump drying)	18.56 ^e	7.81 ^{de}	14.00 ^c
V2D1 (Silver Pink + Air drying)	87.47 ^b	31.11 ^b	210.67 ^a
V2D2 (Silver Pink + Hot air oven drying)	31.78 ^{de}	15.56 ^{cd}	3.15 ^c
V2D3 (Silver Pink + Heat pump drying)	69.55 ^{bc}	29.67 ^b	21.00 ^c
V3D1 (Sky Light + Air drying)	109.46 ^a	39.56 ^a	200.00 ^a
V3D2 (Sky Light + Hot air oven drying)	67.18 ^c	26.78 ^b	3.45 ^c
V3D3 (Sky Light + Heat pump drying)	41.98 ^d	15.80 ^c	18.00 ^c
S. Em. ±	6.48	2.37	9.818
CD @ 1%	19.26	7.03	29.171

Table 2 : Colour retention quality of panicles of limonium varieties with different drying methods.

Colour (According to RHS colour chart)	Before drying	D1 (Air drying)	D2 (Hot air oven drying)	D3 (Heat pump drying)
V1 (Shooting Star)	FAN-2, Violet group, N87-B, Strong purple	FAN-2, Violet group, N87-D, Brilliant purple	FAN-2, Violet group, N87-D, Brilliant purple	FAN-2, Violet group, N87-D, Brilliant purple
V2 (Silver Pink)	FAN-2, Purple group, 76-B, very light purple	FAN-2, Purple group, 76-C, very pale purple	FAN-2, Purple group, 76-D, very pale purple	FAN-2, Purple group, 76-B, very light purple
V3 (Sky Light)	FAN-2, Violet blue, group 91-A, light violet	FAN-2, Violet blue group, 91-B, light violet	FAN-2, Violet blue group, 91-B, light violet	FAN-2, Violet blue group, 91-B, light violet

at 30, 60, and 90 days after drying indicated that V3D1 (Sky Light + air drying) had the highest dry weight (37.70, 37.48, and 37.28 g respectively) followed by V2D1 (Silver Pink + air drying) (29.91, 28.80, and 29.48 g respectively) and V1D1 (Shooting Star + air drying) had the lowest dry weight (6.57, 6.48, and 6.09 g, respectively) (Tables 3 and 4). There was no significant reduction in the panicle weight and colour retention over three-month period, as panicles were stored in cardboard boxes so less moisture loss occurred.

Consumer acceptance

The qualitative characteristics of dried flowers such as colour, texture, shape, appearance and overall appearance were significantly influenced by various drying treatments (Table 5).

Colour : Significant difference in score for colour among the varieties dried with three drying methods was observed in the present study. Out of the three varieties the maximum consumer acceptance score (3.92) for colour was obtained by Shooting Star (V_1), whereas Silver Pink (V_2) had the lowest score (3.53) for colour. Within three different drying methods, air drying (D_1) had the maximum consumer acceptance score for colour (4.08), whereas hot air oven drying (D_2) had the minimum score (3.42) for colour. The results of the interaction between varieties and drying showed that V3D1 (Sky Light + air drying) had the maximum consumer acceptance score (4.22) for colour which was on par with V2D1 (Silver Pink + air drying), V1D2 (Shooting Star + hot air oven drying), V1D1 (Shooting Star + air drying) and V1D3 (Shooting Star + heat pump drying) (4.20, 4.16, 3.81, 3.78 respectively). While, V2D2 (Silver Pink + hot air oven drying) had the lowest score (2.91). Colour in particular is crucial for achieving good aesthetic quality in dried flower products

Bharati *et al.* (2007). During dehydration, plant materials often lose their vibrant colours due to oxidative reactions and the breakdown of cellular compartmentation, which occurs as water is removed from the plant tissues. This loss of colour can impact the final appearance and quality of dried flowers, highlighting the importance of selecting appropriate drying methods to preserve their aesthetic appeal Meman and Barad (2009). Significant differences were observed for flower colour with respect to different methods of drying. Good colour retention was recorded

Table 3 : Change in weight of panicles during storage of limonium varieties with different drying methods.

Treatment	Dried weight(g)		
	30 DAD	60 DAD	90 DAD
Varieties (V)			
V1: Shooting Star	7.51 ^b	7.36 ^b	7.15 ^b
V2: Silver Pink	24.84 ^a	24.37 ^a	24.50 ^a
V3: Sky Light	26.63 ^a	26.45 ^a	26.28 ^a
S. Em. ±	1.33	1.32	1.31
CD @ 1 %	3.96	3.93	3.90
Drying (D)			
D1: Air drying	24.73 ^a	24.25 ^a	24.28 ^a
D2: Hot air oven drying	16.45 ^b	16.24 ^b	16.10 ^b
D3: Heat pump drying	17.80 ^b	17.69 ^b	17.55 ^b
S. Em. ±	1.33	1.32	1.31
CD @ 1%	3.96	3.93	3.90
Interaction (V × D)			
V1D1 (Shooting Star + Air drying)	6.57 ^e	6.48 ^e	6.09 ^d
V1D2 (Shooting Star + Hot air oven drying)	7.87 ^e	7.61 ^e	7.49 ^d
V1D3 (Shooting Star + Heat pump drying)	8.09 ^{de}	7.99 ^{de}	7.88 ^d
V2D1 (Silver Pink+Air drying)	29.91 ^b	28.80 ^b	29.48 ^b
V2D2 (Silver Pink + Hot air oven drying)	14.91 ^{cd}	14.73 ^{cd}	14.64 ^c
V2D3 (Silver Pink + Heat pump drying)	29.71 ^b	29.57 ^b	29.39 ^b
V3D1 (Sky Light + Air drying)	37.70 ^a	37.48 ^a	37.28 ^a
V3D2 (Sky Light + Hot air oven drying)	26.59 ^b	26.37 ^b	26.17 ^b
V3D3 (Sky Light+Heat pump drying)	15.61 ^c	15.52 ^c	15.39 ^c
S. Em. ±	2.31	2.29	2.27
CD @ 1%	6.87	6.81	6.75

DAD – Days after drying

in air dried flowers, since this had obtained maximum score by sensory evaluation might be because of shade, which did not cause any colour fading of flowers, whereas hot air oven dried flowers had poorer petals this might be because of excessive dehydration effected on colouring pigments in flower petals Raghu pathi *et al.* (2020).

Shape and Appearance : Score for shape showed

significant difference among the different drying method. Within three different drying methods, air drying (D₁) had the maximum consumer acceptance score for shape (3.95), whereas heat pump drying (D₃) had the lowest score (3.44) for shape. The results of the interaction between varieties and drying showed that V3D1 (Sky Light + air drying) had the maximum consumer acceptance score (4.29) for shape, which was on par with V2D1 (Silver Pink + air drying) (4.06), while V2D2 (Silver Pink + hot air oven drying) had the lowest score (3.08) shape.

Significant difference in score for appearance among the varieties dried with three drying methods was found in the present study. Out of the three varieties the maximum consumer acceptance score (3.86) for appearance was obtained by Sky Light (V₃), whereas Silver Pink (V₂) had the minimum score (3.57) for appearance. Out of the three different drying methods, air drying (D₁) had the highest consumer acceptance score for appearance (4.02), whereas hot air oven drying (D₂) had the lowest score (3.51) for appearance. The results of the interaction between varieties and drying showed that V3D1 (Sky Light + air drying) had the maximum consumer acceptance score (4.36) for appearance, which was on par with V2D1 (Silver Pink + air drying) (4.10), while V2D2 (Silver Pink + hot air oven drying) had the lowest score (3.14) for appearance. With respect to shape and appearance of dried flowers, significant differences were observed. Better shape and appearance of dried flower were obtained in air drying flowers were of poor quality after drying in oven drying. This might be due to gradual removal of moisture from flower panicles in shade drying due to room temperature and also flowers were dried by hanging them upside down, which resulted in somewhat natural effect on flower panicles. Whereas in oven drying method, due to high temperature there was sudden removal of moisture which might be responsible for poorer quality of dried flowers. The observations were in accordance with the findings of Padmavathamma (1999); Gill *et al.* (2002) and Dilita *et al.* (2011).

Overall acceptance

Overall acceptance score was significantly varied among the varieties and different drying methods. Out of the three varieties the maximum consumer acceptance score (4.03) for overall acceptance was obtained by Sky Light (V₃), whereas Silver Pink (V₂) had the lowest score (3.58). Out of the three different drying methods, air drying (D₁) had the highest overall acceptance (4.14), whereas hot air oven drying (D₂) had the lowest score (3.39). The results of the interaction between varieties



Plate 1 : Flower colour of fresh and dried flowers of limonium varieties with different drying methods (According to RHS colour chart).

Table 4 : Colour retention of panicles during storage of limonium varieties with different drying methods.

Colour (RHS colour chart)	D1 (Air drying)			D2 (Hot air oven drying)			D3 (Heat pump drying)		
	30 DAD	60 DAD	90 DAD	30 DAD	60 DAD	90 DAD	30 DAD	60 DAD	90 DAD
V1 (Shooting Star)	FAN-2, Violet group, N87-D, light purple	FAN-2, Violet group, N87-D, light purple	FAN-2, Violet group, N87-D, light purple	FAN-2, Violet group, N87-D, light purple	FAN-2, Violet group, N87-D, light purple	FAN-2, Violet group, N87-D, light purple	FAN-2, Violet group, N87-D, light purple	FAN-2, Violet group, N87-D, light purple	FAN-2, Violet group, N87-D, light purple
V2 (Silver Pink)	FAN-2, Purple group, 76-D, very pale purple	FAN-2, Purple group, 76-D, very pale purple	FAN-2, Purple group, 76-D, very pale purple	FAN-2, Purple group, 76-D, very pale purple	FAN-2, Purple group, 76-D, very pale purple	FAN-2, Purple group, 76-D, very pale purple	FAN-2, Purple group, 76-D, very pale purple	FAN-2, Purple group, 76-D, very pale purple	FAN-2, Purple group, 76-D, very pale purple
V3 (Sky Light)	FAN-2, Violet blue group, 91-C, pale violet	FAN-2, Violet blue group, 91-C, pale violet	FAN-2, Violet blue group, 91-C, pale violet	FAN-2, Violet blue group, 91-C, pale violet	FAN-2, Violet blue group, 91-C, pale violet	FAN-2, Violet blue group, 91-C, pale violet	FAN-2, Violet blue group, 91-C, pale violet	FAN-2, Violet blue group, 91-C, pale violet	FAN-2, Violet blue group, 91-C, pale violet

and drying showed that V3D1 (Sky Light + air drying) had the maximum consumer acceptance score (4.43) for overall acceptance, which was on par with V2D1 (Silver Pink + air drying) and V3D3 (Sky Light + heat pump drying) (4.25 and 4.22) respectively, while V2D2 (Silver

Pink + hot air oven drying) had the least score (3.02). Air dried spikes obtained maximum score for texture the reason might be the slower drying process *i. e.*, air drying minimizes brittleness and helps retain the delicate structures of the blooms Raghupathi *et al.* (2020).

Table 5 : Consumer acceptance scores of dried limonium varieties after drying with different drying methods.

Treatment	Colour	Texture	Shape	Appearance	Overall acceptance
Varieties (V)					
V1: Shooting Star	3.92 ^a	3.63	3.53	3.75 ^{ab}	3.67 ^b
V2: Silver Pink	3.53 ^b	4.03	3.54	3.57 ^b	3.58 ^b
V3: Sky Light	3.57 ^b	3.68	3.78	3.86 ^a	4.03 ^a
S. Em. ±	0.09	0.26	0.08	0.08	0.06
CD @ 1 %	0.26	NS	NS	0.23	0.16
Drying (D)					
D1: Air drying	4.08 ^a	4.02	3.95 ^a	4.02 ^a	4.14 ^a
D2: Hot air oven drying	3.42 ^b	3.77	3.47 ^b	3.51 ^b	3.39 ^c
D3: Heat pump drying	3.51 ^b	3.55	3.44 ^b	3.65 ^b	3.76 ^b
S. Em. ±	0.09	0.26	0.08	0.08	0.06
CD @ 1%	0.26	NS	0.22	0.23	0.16
Interaction (V × D)					
V1D1 (Shooting Star + Air drying)	3.81 ^{ab}	3.62	3.49 ^c	3.60 ^{cd}	3.73 ^b
V1D2 (Shooting Star + Hot air oven drying)	4.16 ^a	3.56	3.69 ^{bc}	3.93 ^{bc}	3.71 ^{bc}
V1D3 (Shooting Star + Heat pump drying)	3.78 ^{ab}	3.70	3.42 ^{cd}	3.72 ^{bcd}	3.58 ^{bc}
V2D1 (Silver Pink + Air drying)	4.20 ^a	4.07	4.06 ^{ab}	4.10 ^{ab}	4.25 ^a
V2D2 (Silver Pink + Hot air oven drying)	2.91 ^d	4.54	3.08 ^d	3.14 ^e	3.02 ^d
V2D3 (Silver Pink + Heat pump drying)	3.47 ^{bc}	3.48	3.49 ^c	3.47 ^{de}	3.47 ^{bc}
V3D1 (Sky Light + Air drying)	4.22 ^a	4.37	4.29 ^a	4.36 ^a	4.43 ^a
V3D2 (Sky Light + Hot air oven drying)	3.21 ^{cd}	3.20	3.65 ^c	3.46 ^{de}	3.43 ^c
V3D3 (Sky Light + Heat pump drying)	3.28 ^{cd}	3.48	3.40 ^{cd}	3.77 ^{bcd}	4.22 ^a
S. Em. ±	0.15	0.45	0.131	0.14	0.10
CD @ 1%	0.45	NS	0.388	0.40	0.28

NS- Non-significant.

Whereas, heat pump drying in terms of texture might lead to increased brittleness due to rapid moisture removal may cause the cell walls to collapse, resulting in a more fragile structure. This could diminish the aesthetic quality. The results were in accordance with the findings of Mishra *et al.* (2014) and Nair and Singh (2011). Overall acceptability of dried limonium spikes also showed significant differences with respect to different methods of drying. Acceptability was high in air dried flowers and low in hot air oven dried flowers. Since all the quality parameters like colour, texture, size and shape of dried flowers were good in air dried flowers compared to other methods of drying.

Conclusion

In terms of drying quality, the variety Sky Light was found superior in most of the quality parameters. Among different drying methods air drying was found to be more effective as it performed best in most of the quality parameters. Based on the performance of different limonium varieties and drying techniques, that limonium variety 'Sky Light' can be recommended for drying

through 'Air drying' for production of high-quality dried blooms.

Future Scope

Based on the results of this study, the following areas of research can be considered for further exploration of Standardization of drying techniques in limonium by using different desiccants for drying and evaluating drying of more limonium varieties.

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