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Drying of Flowers and Other Ornamental Plant Parts in India

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ABSTRACT

With the increasing awareness for natural ecofriendly products, dried flowers have attained prime importance in the floriculture industry. Future prospects of the dry flower industry are expected to contribute a lot to the country's economy in comparison to the fresh cut flowers and other live plants. Dry flowers and plant materials have tremendous potential as substitute for fresh flowers and foliage for interior decoration as well as for a variety of other aesthetic and commercial uses. In this review the scattered information and data on drying of flowers and other ornamental plant parts are being tried to put together. This could eventually be helpful in drawing the attention of the researchers and scientists to work on it, besides the entrepreneurs would be directly benefitted by utilizing the knowledge review in this paper.

Keywords: dehydration, dry flowers, drying techniques

INTRODUCTION

Flowers have always remained an integral part of mankind and love for natural flowers is an inherent instinct. Fresh flowers are quite attractive, but very expensive and short lived as well as available only during a particular season. Dried flower products on the other hand are long lasting and retained their aesthetic value irrespective of the season (Hiller 1994). The art of flower drying is a very age old practice. Earlier dried flowers were used in the form of herbarium by botanists for the purpose of identification of various species (Prasad *et al.* 1997). In 'The Florist' Published in 1860, author describes the techniques of drying red roses, pansies, stock and other single flowers in sand. Though drying of flowers is well known even in the past but for the first time the flowers were dried commercially in Germany (Louis and Gibson 1982).

Dried and preserved ornamental products offer a wide range of qualities like; novelty, longevity, aesthetic properties, flexibility and year round availability (Joyce 1998). Dried ornamental plant parts are generally less expensive and are sought for their everlasting and attractive appearance (Smith 2000). Very little research and development projects have been undertaken on the flower drying industry across the globe in contrast to other areas of floriculture**.** Numerous workers have described varied approaches/ methods to dehydrate flowers and other ornamental plant parts (Dubois and Joyce 1989; Bhutani 1995; Westland 1995). Drying of flowers and foliage by various methods like air drying, sun drying, oven and microwave oven drying, freeze drying and embedded drying can be used for making decorative floral crafts items like cards, floral segments, wall hangings, landscapes, calendars, potpourris etc. for various purposes (Bhutani 1990; Bhalla and Sharma 2002) with potpourris being the major segment of dry flower industry valuing at Rs. 550 million in India alone (Murugan *et al*. 2007). Dried flowers are a good standby for the florist's, since designs can be made up during the slack periods and arrangement can be displayed where fresh flowers are unsuitable from the grower's point of view and the price is less than for equivalent fresh flowers (Salinger 1987). The demand for dry flowers and attractive plant parts, dried floral arrangements and floral crafts has increased manifold during the last decade. In the recent floriculture trade, the exports from India during grew from Rs. 2660 million during 2002-2003 to Rs. 2730 million during 2004-2005 to achieve a growth rate of 2.66% (Singh 2009). The Indian export basket comprise of 71% of dry flowers which are exported to USA, Europe, Japan, Australia, far East and Russia. Dry flowers constitute more than two-thirds of the total floriculture exports. The demand for dry flowers is increasing at an impressive rate of 8-10% annually thus offering a lot of opportunities for the Indian entrepreneurs to enter into the global floricultural trade (Singh 2009). The range of dried flowers and other attractive plant parts is quite extensive, namely; stems, roots, shoots, buds, flowers, inflorescences, fruits, fruiting shoots, cones, seeds, foliage, bracts, thorns, barks, lichens, fleshy fungi, mosses, sellaginellas, etc. (Desh Raj 2001). A number of flowers respond well to drying such as anemone, zinnia, allium, sweet william, carnation, stock, freesia, narcissus, chrysanthemum, pansy, daffodils, marigold, rose, lilies, etc. (Rogers 1988) and foliages like ferns, aspidistra, eucalyptus, ivy, laurel, magnolia and mahonia, etc. (Rogers 1967; Healy 1986). Dehydrated plant parts may be arranged aesthetically and covered with plastic or transparent glass to protect them from atmospheric humidity, wind and dust (Datta 1997; Bhattacharjee and De 2003). Saleable articles like paper weights, pendants and table pieces can be made by embedding the dry flowers in transparent blocks or sheets (Kher and Bhutani 1979). Therefore dry flowers score over the cut flowers that often decorate homes and offices because of their ability to remain decorative for longer periods almost definitely with less care (Zizzo and Foscella 1999).

TYPE OF CROP AND VARIETY

Selection of a suitable crop for drying purpose is very important for the success of the industry (Mishra *et al*. 2003). Some of the flowers lose its ornamental value after drying. Sweet pea flowers when pressed dried looses their colour and become dark brown which is not suitable for further use (Louis and Gibson 1982). The quality of dry flower also varies with cultivar of a particular crop. In *Helichrysum*, although, its petals are hard but lose its shape after drying, petals reflex downward and centre disc florets shed. This

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characteristic is encountered more with yellow cultivars than the rest (Sangama 2004).

STAGE OF HARVESTING

The stage of harvesting for different flowers varies according to the species and the form of flower desired (Paul and Shylla 2002). However, usually flowers are harvested just before they are fully open and the colour has not yet faded (Padmavathamma 1999). Flowers harvested at fully open stage took lesser time for drying than those harvested at tight bud and half open stage of Helichrysum (Sangama 2004). Safeena *et al*. (2006a) reported that flowers harvested at half bloom stage took minimum time for drying. Faster dehydration may be due to the fact that flowers loose moisture as harvesting time is delayed due to sensitivity of the flower tissues to ethylene, or other hydrolyzing enzymes and senescence also (Kofranek and Halevy 1972; reviewed by Teixeira da Silva 2006). Lourduswamy *et al*. (2003) reported that full bloom stage of *Gomphrena* and both half as well as full bloom stages of French marigold and Zinnia are the ideal harvesting stages for dry flower production.

MOISTURE CONTENT AFTER DRYING

Moisture content in the flowers after drying influences flower shape. The lower moisture content provides rigidity and results in uniform cell contraction in the flowers while the higher moisture content in dried flowers lead to flaccid flowers. Chen *et al*. (2000) reported stronger and stiffer petals in dried flowers having low moisture content. Mechanical support provided by the media throughout the drying process ensured well maintained flower shape provided that the moisture content remains below 11.55%. In addition, the moisture content in the dried flowers also influences its longevity which is inversely proportional (Pandey 2001). A range of 8-11.5% moisture content in the dried flowers will ensure good quality, firmness and maintained keeping quality for more than six months. Excessive drying of flowers resulted into petal shedding during handling (Singh 2004). Drying below 8% moisture content showed shedding effect which may be attributed to excessive loss in moisture that may have resulted into weakened adhesion and cohesion forces in flower tissue and might have caused softening of the middle lamella leading to abscission. Paparozzi and McCallister (1988) observed rapid tissue desiccation in microwave dried statice flowers. Similarly, Wilkins and Desborough (1986) observed vulnerability of flowers to breakage in vacuum-dried flowers.

TECHNIQUES OF DRYING

The quality and appearance of dried flowers and other ornamental plant parts is greatly influenced by the method of drying being used. Different techniques involved for the production of dried ornamental plant material includes air drying, press drying, embedded drying, oven drying and freeze drying etc. The NBRI, Lucknow is a pioneer institute in India where works on the dehydration of flowers, foliage and floral crafts is being carried out. Various dehydration techniques have been developed by which flowers, twigs, branches, foliage etc. retain their fresh look for several months or years (Mishra *et al*. 2003).

Air drying

Air drying is a very common method of drying where plant materials are tie up with a rope/wire and are kept in hanging position either in dark or in the sun for quick drying. Air drying requires a warm clean dark and well ventilated area with low humidity (Raghupathy *et al*. 2000). Flowers may also be spread over blotting sheets/news papers and kept in dark or in the sun (Datta 1997). Bryan (1992) reported air drying as the earliest method to dry rose, larkspur, statice and straw flower. For air drying flowers of good quality at slightly immature stage should be selected and there after stripped of the foliage and hung upside down in a warm dark area. The weak flowers if any are to be wired before drying (Perry 1996). Evelyn (1997) carried out air drying in dusty rooms by placing the flowers inside a perforated paper bag to promote air circulation. Crisp textured flowers of *Helichrysum* (straw flower) and *Limonium* (statice) can be easily dried either by hanging them in an inverted position or by keeping them in a container positioned erect till they get desiccated (Susan 1990; Bhutani 1995). Kumar and Parmar (1998) found that air drying in shade is applicable during dry season and summer particularly for flowers such as *Acroclinum*, *Helichrysum* and *Limonium*. Other crisp-textured flowers like *Anaphilis*, *Delphinium*, *Oregano*, *Rumex* and *Holmskioldia*, etc. can also be dried by air drying (Deshraj 2006). Flowers hung in a dark area took 8-10 days for drying when there is sufficient ventilation (Champoux 1999). Out of the 16 plant species tested for drying, only gypsophilla, gomphrena and statice flowers dried well by hang drying method in a dark room (MacPhail 1997). Rose bunches could be hung dried in shade within 5-10 days (Seaberg 1997). Lourduswamy (1998) reported that gomphrena flowers from half to full maturity took 7-9 days for air drying while roses took 5-10 days. Smith (1993) reported that flowers like strawflower, globe amaranth, salvia, chrysanthemum and many other of the everlastings can be picked up for air drying in the bud stage or partially opened, as they continue to open while drying and some other are picked when they are fully mature. Sell (1993) suggested various rooms/areas for drying the flowers and reported that rooms with 75% or more relative humidity should be avoided as they encourage the mould growth which spoils the flowers. Flower heads of *Hydrangea* and *Gypsophilla* can be dried by putting their stems in a little water (Westland 1995). Water drying, which usually seems like a contradiction in terms, gives fairly good results with flowers, e.g. hydrangeas, cornflower, Baby's Breath and a few others (Deshraj 2006). Alpertuit (2000) observed that flowers dried by air drying are extremely stiff once it dried. Blue and yellow flowers retain their colour when air dried but pink flowers fade. According to White *et al*. (2002) more fleshy flowers and foliage took more time for drying.

Press drying

Press drying thought to have been first reported in 1820. Later it was used by the herbalists or botanists for the preparation of herbarium (Lawrence 1969). In press drying, the flowers and foliage are placed between the folds of newspaper sheets or blotting papers giving some space among flowers. These sheets are kept one above the other and corrugated boards of the same size are placed in between the folded sheets so as to allow the water vapour to escape (Bhutani 1990). The drying time can be reduced if the sheets are kept in oven at an appropriate temperature (Datta 1997). However, Prasad *et al.* (1997) added that shapes of the material cannot be maintained as it becomes flattened because the fresh material after pressing within the iron or wooden frame tends to stick to the paper used. Further, the microbial attack is a common feature because the moisture and cellulose of the paper serve as the potential substrate for the sporulation and growth of these organisms. Though the flowers and foliages that become flat after press drying, yet this material can be used for composing floral-craft items like; greeting cards, floral designs and other art creations which may be framed for wall pin-ups (Bhutani 1990). Gill *et al*. (2002b) reported the time required for press drying of different flower crops and they concluded that rose, carnation and helichrysum required 120, 132 and 72 h, respectively for press drying. Kher and Bhutani (1979) found that press drying in oven at 35-39°C for 48 h was optimum for pansy, whereas 24 h for the leaves of *Grevillea*, *Thuja*, *Adiantum*, *Nephrolepis* and flowers of *Hibiscus*, *Haemotoxylon*, *Cassia biflora*, *Calliandra* and marigold. A temperature of 40-44°C for 24 h was optimum for *Euphor-*

bia leucocephala, *Galphinia nitida*, *Lantana camara*, *Lantana depressa* and *Lantana montevidensis* while it was 45-49°C for flowers of *Ixora* and *Mussaenda*. Lourdusamy *et al*. (2001) described press drying as the earliest method of preserving flowers and suggested that flowers like candytuft, chrysanthemum, lantana, rose, verbena, euphorbia and leaves like thuja, ferns, silver-oaks, etc. are suitable for press drying. Datta (1997) reported that original shape of the material cannot be maintained by this method but the original colour is maintained. Lissy (1999) suggested the application of water based varnish over the entire pressed picture to avoid fading of original colour.

Embedded drying

Sand, borax, silica gel, sawdust, perlite and a combination of these are used as media for embedding. Among these, sand and borax are cheaper but it takes more time for drying. For delicate flowers like roses, dahlia, carnation etc., silica gel is the ideal drying agent (Prasad *et al*. 1997). Desiccant method is the useful method for delicate flowers that may fall apart when air dried as recommended by Thomler (1997). Among the dessicants like sand, cornmeal, borax and silica gel used, silica gel has been found to be the best. Champoux (1997) reported silica gel as the best medium for getting excellent dried flowers that retain colour and shape. Desh Raj (2006) found that it is difficult to avoid shrinkage and changes in morphology of the dehydrated ornamental plant material during hang-drying mainly due to loss of moisture from the cells. The flowers and foliage are to be embedded very carefully in various desiccants such as sand or silica gel in a suitable container during air drying to avoid shrinkage and other morphological changes (Datta 1997). Embedding in deep containers can accommodate the plant material without disturbing its shape and form in plant materials like bougainvillea, candytuft, chrysanthemum, dahlia (pompon), gerbera, marigold, roses, etc. (Bhutani 1990; Bhutani 1995). Singh *et al.* (2004) found that drying of zinnia flowers in sand resulted in good quality of dried flowers with attractive flower colour and smooth petal texture. Orduno and Baltazar (1995) mentioned that silica gel is not actually a gel but is granular in shape like sugar. It is called gel only because it is a xerogel of silicic acid. Bhutani (1993) reported that embedding in silica gel is perhaps the easiest and the best method of embedded drying. Silica gel is composed of a vast network of interconnecting microscopic pores which attract and hold moisture by a phenomenon known as physical adsorption and capillary condensation. Through this phenomenon, it acts as a dehydrating agent (Safeena *et al.* 2006b). Silica gel has also been reported to be the fastest acting desiccant (Neave 1996). Trinklein (2000) reported that since silica gel dries flowers quickly and so more flowers can be moved in and out of the mixture during a single season. Paul and Shylla (2002) while reviewing the efficacy of different desiccants for flower drying concluded that though silica gel is an expensive desiccant but can be recycled for reuse. The crystals are blue when dry and turn pink after absorbing moisture. If silica gel is to be reused again, it should be warmed up in an oven till the crystals turn blue. Deshraj and Gupta (2003) reported that silica gel (60-120 mesh) is the best absorbent for removing moisture from flowers and foliage followed by boric acid (granules). Pertuit (2002) reported that silica gel is appropriate for drying flowers with closely packed petals such as rose. Sandhu (2002) described and recommended silica gel embedding as the more appropriate method for proper colour retention of helichrysum and statice. Gill *et al.* (2002) found that embedding of rose, carnation, fern and silver-oak in silica gel produced good results, while, embedding helichrysum in silica gel and sand combination was also satisfactory. Drying was found much faster with silica gel and borax in comparison to sand due to the strong hygroscopic nature which leads to rapid removal of moisture from flowers (Singh *et al*. 2003). Sell (1993) reported that a mixture of borax and corn meal (1: 1, v/v) for embedding and drying of chrysanthemum and dahlia flowers produced good results. Effect of different media on dehydration of zinnia was studied by Singh *et al.* (2004) who reported that drying in silica gel was faster without any deterioration in quality; however, there was slight roughness in petal texture which was aesthetically accepted. Bhalla *et al.* (2006) studied the different methods of drying of chrysanthemum (*Dendranthema grandiflora* Tzvelev) and reported that flowers dried in microwave oven after embedding in silica gel gave the best results in terms of retention of colour and shape. Dhatt *et al.* (2007) studied the methods of drying of rose buds and found that silica gel embedding of rose buds had the best quality with respect to colour and shape. Bhattacharjee and De (2003) suggested that borax and alum being light in weight can be used for dehydration of flowers. Borax being hygroscopic in nature and may bleach flower petals if embedded for a long time (Datta 1997). Smith (1993) reported that flowers like rose, aster, carnation, marigold, dahlia, larkspur, geranium, zinnia, chrysanthemum and delphinium can be dried well in borax. Orduno and Baltazar (1995) studied the effects of river or sea sand in combination with borax on drying of rose, carnation and gerbera and reported that rose and carnation dried well in river sand containing a high proportion of borax within 15- 20 days period, while sea sand with a low proportion of borax for 10-15 days resulted in better dried gerberas. Mixing of silica gel crystals or dry river sand to 2 or 3 parts alum or borax to overcome the problems of sticking of the media, when either of them was used alone (Westland 1995). Singh *et al.* (2003) found that drying of zinnia flowers was much faster with silica gel and borax. Paul and Shylla (2002) reviewed that both borax and alum are best suited for delicate flowers such as anemones, cosmos, larkspur, ornithogalum, etc. Singh *et al.* (2004) reported that media influence both flower colour as well as texture. Drying with sand provides smooth petal texture while with silica gel, a slight roughness and while with borax more roughness was recorded. Alleman (1994) reported that silica gel crystals could be used for drying roses. The self indicating nature of silica gel ensures the moisture content by exhibiting blue colour when dry and pink/white, when it regains moisture from flowers. Sujatha *et al*. (2001) reported that borax crystals and sand in the ratio of 1: 1 volume by volume basis was the best combination as it helps to regain brightness and colour. Among the various dessicants used to dry Indian blue water lily flowers, fine sand was the best (Geetha *et al*. 2002). Fine sand has been found to be the best material for embedding because it is easy to handle, heavy and does not react with water vapour (Datta 2001). Behera (2009) conducted an experiment to find out suitable drying technique, media, temperature and duration for rose cut flowers at half bloom stage with 10 cm long stem embedded in five drying media namely; sand, silica gel, borax, mixture of sand and silica gel (50: 50, v/v) and mixture of sand and borax (50: 50, v/v). After embedding, flowers were given different temperature and exposure duration treatments in hot air oven and microwave oven. The anthocyanin content was maximum when flowers were embedded in borax and were dried for 3.30 minutes in microwave oven. The maximum presentability till 120 days was recorded in flowers embedded in the mixture of sand and borax and kept in microwave oven for 3.30 minutes compared to other treatments.

Oven drying

Nowadays hot air and microwave ovens are also being used for faster drying and to improve the quality of dry flowers. In these methods, plant material is kept at controlled temperature for a specified time typical of the plant species. Temperature plays an important role in the drying of flowers and other ornamental plant parts by influencing both qualitative and quantitative parameters. At higher temperature, as proposed by Mayak and Halevy (1980) the rate of transpiration is comparatively much higher. With the increase in temperature, diffusion pressure deficit of air increases which stimulates diffusion of internal moisture surface and further increases its vaporization rate, thus leading to high moisture loss at higher temperature. Singh *et al.* (2004) studied the effect of different temperature treatments on drying of zinnia (*Zinnia elegans*) and reported that higher the temperature, more faster will be the dehydration process but drying of flowers at higher temperature will accelerate degradation of all pigments viz; chlorophylls, carotenes, xanthophylls and anthocyanins. Similar reports of rapid drying at higher temperature have been documented by Chen *et al*. (2000). Khafaga and Kock (1980) in *Hibiscus sabdariffa* var. Sabdariffa recorded higher degradation of anthocyanins at higher temperature. Prasad *et al.* (1997) observed that fully opened flowers are not suitable for oven drying. Parker (2000) gave the description of vacuum press dryer to dry any type of wood. Oven drying of China aster flowers using white sand as the medium is best for retention of original colour, shape and texture of dried flowers (Raju and Jayanthi 2002). At 45-49°C, French marigold took 72 h and African marigold 96 h for drying (Ranjan and Misra 2002). Kher and Bhutani (1979) advocated 35-39°C as optimum temperature for bougainvillea (48 h), pompon dahlias and narcissi (72 h). A temperature of 40-44°C for *Aerva javanica*, China aster, *Euphorbia leucocephala*, *Delphinium ajacis*, *Mina lobata*, rose buds and *Zinnia linearis* (48 h, *Tagetes patula* and medium and large rose flowers (72 h), gladiolus and very large rose flower (96 h) and 45-49°C for *Helipterum roseum*, small flowered perennial chrysanthemum, candytuft, dombeya, gerbera, gomphrena, helichrysum and statice (48 h), *Tagetes erecta* (96 h) and for water lily (120 h). Pandya *et al*. (2001) studied the effects of drying on chrysanthemum flowers in a hot air oven at 40°C for 35-50 h in sand as an embedding medium. They reported that the colour and structure of the floral parts showed no change, whereas total chlorophyll content was significantly reduced in the dehydrated parts as compared to control without any change in length and diameter of floral parts. Safeena *et al.* (2006) studied the response of drying in hot air oven at different temperatures (30, 40 and 50°C) on the quality of rose ('Skyline', 'Lambada', 'Ravel' and 'First Red') and found that drying of Dutch rose flowers at 40°C by embedding in silica gel gave the best results for colour, texture and appearance. Dahiya (2003) reported that the best quality dried flowers of chrysanthemum can be obtained by embedding them in silica gel and keeping at 50°C for 48 h in the hot air oven. Bassapa *et al.* (1991) found that *Helichrysum* flowers dried in a room and in open sun retained their colour intensity for longer duration as compared to 40 and 50°C oven-dried flowers. Venugopal and Patil (2000) observed that helichrysum flowers when dried at room temperature under shade and subsequently oven-dried at 50°C retained the colour intensity for 150-180 days. Dahiya (2003) found that the weight and moisture content of dried flowers decreased significantly with an increase in the temperature of the hot air oven and duration of drying. They also reported that the carotenoids content of chrysanthemum decreased with the increase in the temperature and duration in the hot air oven. Singh *et al.* (2002) reported minimum degradation of zinnia flower pigments (chlorophyll, carotenes, xanthophylls and anthocyanins) in room dried flowers, whereas it was maximum at 50°C in a hot air oven. Bhutani (1990) advocated the use of microwave oven for drying of plant material.

The principle of drying is based on liberation of moisture by agitating water molecules present in organic substances with the help of electronically produced microwaves. Drying is unbelievably fast in microwave oven, when flowers and foliages are embedded in fine silica gel contained in non-metallic earthenware or glassware (Bhutani 1995). Datta (1997) observed microwave oven drying is the most suitable method to dehydrate the white flowers of 'Jubilee' cultivar of chrysanthemum. Paprozzi and McCallister (1988) concluded that fresh cut statice stems up to 34 cm long preserved well by soaking in a 1: 2 or 1: 3 glycerol: water for 48 h, followed by drying for 1 min at 34°C. Zhang (2000), while comparing the mechanism of microwave, airflow and microwave-air flow mechanism on drying of chrysanthemum, found that microwave-airflow combined drying was effective in reducing the drying time and improving the quality of the dried flowers, thereby enhancing the selling price by 5-10 times higher as compared to traditional drying. Aravinda and Jayanthi (2004) standardized the drying techniques like microwave drying, oven drying and sun drying for chrysanthemum (Button type local) flowers. Microwave drying with silica gel gave the best results for shape while oven drying with white sand was found best for colour and overall acceptability. Thomler (1997) reported that microwave oven drying is more suited for cluster of florets such as golden rod, gypsophilla and corn flower. Anemones, chrysanthemum, marigold, roses, pansies, paeonies are best suited to this method (Bull 1999). According to Miller (1997) large roses require two and a half minutes to dry. Dhatt *et al.* (2007) dried rose buds in microwave oven for 3, 4 and 5 min, respectively and found that microwave drying of rose buds for 4 min exhibited good colour and good shape retention. Rothemberger (2000) advocated a cup of water in the oven before starting helps to prevent excessive drying. Microwave oven dried flower petals should be sprayed with hair spray or lacquer to prevent absorption of air moisture. White *et al.* (2002) reported that microvwave oven dried flowers looked fresh and more colourful than obtained by other methods.

Glycerine drying

Glycerine drying has been used by several workers especially to preserve foliage. It is comparatively less expensive and has a high water attracting capacity (Joyce 1998). Many types of foliage have been successfully preserved by either immersing leaves or placing crushed stems in a 33% glycerol solution. The resultant leaves are soft and flexible (Dana 1983). Westland (1995) reported that preserving foliage and berries in glycerine and hot water solution brings them into almost everlasting category. In glycerine drying, the quality of the product was good as moisture in flower was replaced by a mixture of water and glycerine (Paul and Shylla 2002).

The use of glycerine in drying is reported to be successful with most foliage. Semant *et al*. (1993) observed that one part of glycerine mixed with 2 parts of hot water was the ideal mixture for twigs of 26 plant species to absorb at room temperature. The material should remain in solution until full absorption has taken place. Glycerine serves as a good source for micro-organisms, so a pinch of antibiotic is necessary to prevent microbial growth in the dried specimens (Prasad *et al*. 1997). Sell (1993) used glycerine: hot water (1: 2, v/v) to preserve Magnolia stems. He reported that mature leaves respond well to this treatment as they translocate the solution readily to stems. Verey (1994) found that glycerinizing replaced the water content of leaves giving them a strong and pliable nature. This method is found more suitable for eucalyptus, hydrangea, ivy and magnolia. Paparozzi and McCallister (1988) reported that glycerol and microwave preservation of annual statice maintained flexibility of the flower without the greasy feeling which is generally observed in glycerol preservation. Healey (1986) preserved the foliages of different ornamental plants for different intervals and reported that *Aspidistra* spp. took 12 weeks followed by *Fatsia japonica* (7-10 weeks), *Mahonia* spp. (3-6 weeks), *Magnolia* spp. (3-4 weeks) and minimum 2-weeks by *Eucalyptus* spp.

Freeze drying

The most effective method of flower preservation is freeze drying. Freeze drying relies on the principle of sublimation, whereby ice held under conditions of partial vacuum (less than 4.58 torr) and low temperature (< 0°C) will evaporate on heating without going through a liquid phase. The absence of liquid water during the dehydration process means that undesirable chemical reactions will not occur. Hence, colour and even fragrance are retained in the dried article (Dubois and Joyce 2005). In this process, the flowers are placed into a refrigerated chamber and the temperature of the chamber is lowered to below freezing. A vacuum is then created in the chamber, causing the moisture in the flowers to sublimate, or change from solid to gaseous form. The water vapour is then collected in a separate chamber and the dried flowers are allowed to slowly warm to room temperature. This process takes several days (Trinklein 2006). Brown (1999) has conducted freeze drying with different varieties of roses and carnation and determined the freezing time and temperature at which drying is perfect to keep the quality of flowers. Shannel (1999) reported that light extension to freeze dried arrangements should be avoided to prevent colour fading. Bridal bouquets could be preserved without any damage by the technique of flower drying (Ruth 2000). Chen *et al.* (2000) evaluated the effect of different freezing time (2 and 4 h), freezing temperature (-35°C) and vacuum drying temperature (27, 37, 47°C) on colour, moisture content and stem and petal strength of roses and carnations. Lower vacuum drying temperatures resulted in flowers with colour closer to fresh flowers. Bhattacharjee and De (2003) reported that several cultivars of carnation flowers were successfully cryo-dried and remained naturalistic in appearance after being placed in freeze drier (-20°C) for 7 days. Liang *et al.* (2005) studied the application of freeze drying and microwave drying to China rose flowers. The flowers dried by freeze drying and pre-treated with tartaric acid solution before microwave drying had a good colour and appearance. Wilkins and Desborough (1986) compared the effect of different pre-treatments (glycerine, clove oil, ethylene glycol, glycerine + dimethylsulfoxide, clove oil + dimethylsulfoxside, ethylene glycol + dimethylsulfoxside) on carnation flowers at a cryo-drying temperature of -80°C for 12 h. After that the flowers were kept in freeze drier for 7 days. It was found that untreated flowers remained naturalistic in appearance while the pre-treated ones had lower aesthetic value. Sohn *et al.* (2003) studied the effect of freeze drying for 14 days on the shape and colour of *Rosa hybrida* (cvs. 'Tineke', 'Golden Gate', 'Saphire', 'Roulette', 'Rote Rose'). Shrinkage was observed in freeze drying but the colour remained similar to a fresh rose. The colour of 'Tineke' and 'Golden Gate' remained closest to fresh rose whereas dried 'Rote Rose' was the farthest. In another experiment, flowers were dried in lyophilizer (freeze drier) in a temperature sequence where, the temperature of the flower chamber of freeze drier was increased from -5°F to 25°F with an interval of 5°F each. Maximum moisture loss and maximum total sugars content was obtained in the flowers which were dried in freeze drier (Behera 2009).

FUTURE PERSPECTIVES

Dehydration is an important post harvest technology for enhancing the ornamental keeping quality of flowers. India has a diverse agroclimatic condition and rich flora resources and offers a varied range of value added products which include the dried ornamentals. With such great potentialities, exploration of suitable technology is required. For boosting the floriculture industry and to earn more foreign exchange, more research on dehydration of flower should be undertaken and standardized for commercial exploitation. Dry flowers are hygroscopic and tend to reabsorb moisture from atmosphere. So, there is a need to investigate and work out some proper chemical treatment on dried flowers to enhance the hardening of dried ornamentals and to avoid reabsorption of moisture. Dry flowers are less flexible and need to be handled with care. So, proper packaging technology for long lasting use of dry flower should be evaluated. Thus, a complete package to evaluate on petal pigment level and flower tissue integrity, the aftercare treatment with packaging and ready to use articles are the areas to be investigated and standardized.

Appendix Common and botanical names of cut flower species mentioned in this review.

Common name	Botanical Latin name	Family
African marigold	*Tagetus erecta*	Asteraceae
Allium	*Allium aflatunense*	Alliaceae
Anemone	*Anemone rivularia*	Ranunculaceae
Aspidistera	*Aspidistera laurida*	Liliaceae
Aster	*Aster percoides*	Asteraceae
Baby's Breath	*Gypsophilla elegans*	Caryophyllaceae
Barberry	*Mahonia aquifolium*	Berberidaceae
Bougainvillea	*Bougainvellia spectabilis*	Nytaginaceae
Candytuft	*Iberis iberidifolia*	Cruciferae
Carnation	*Dianthus caryophyllus*	Caryophllaceae
China Aster	*Callistephus chinensis*	Asteraceae
China Rose	*Hibiscus rosa sinensis*	Malvaceae
Chrysanthemum	*Dandranthema grandiflora*	Asteraceae
Cornflower	*Centuria cyanus*	Asteraceae
Cosmos	*Cosmos sulphurius*	Asteraceae
Cup and Saucer	*Holmskoildia sanguine*	Verbenaceae
Daffodils	*Narcissus pseudonarcissus*	Amaryllidaceae
Dahlia	*Dahlia variabilis*	Asteraceae
Dombeya	*Dombeya elegans*	Sterculiaceae
Eucalyptus	*Eucalyptus citriodora*	Myrtaceae
Euphorbia	*Euphobia leucocephala*	Euphorbiaceae
Fatsia	*Fatsia japonica*	Araliaceae
Freesia	*Freesia refracta*	Iridaceae
French Marigold	*Tagetes patula*	Asteraceae
Galphimia	*Galphimia nitida*	Malpighiaceae
Geranium	*Geranium hortorum*	Geraniaceae
Gerbera	*Gerbera jamesonii*	Asteraceae
Gladiolus	*Gladiolus grandiflorus*	Iridaceae
Globe Amaranth	*Gomphrena globosa*	Amarantheceae
Golden Rod	*Solidago Canadensis*	Asteraceae
Rosalin	*Hibiscus sabdariffa*	Malvaceae
Hydrangea	*Hydrangea macrophylla*	Hydrangeaceae
Ivy	*Hedera helix*	Araliaceae
Ixora	*Ixora coccinea*	Rubiaceae
Lantana	*Lantana camara*	Verbenaceae
Lantana	*Lantana depressa*	Verbenaceae
Lantana	*Lantana montevidensis*	Verbenaceae
Larkspur	*Delphinium ejacis*	Ranunculaceae
Laurel	*Laurus nobilis*	Lauraceae
Lilies	*Lilium* spp	Liliaceae
Madian Hair Fern	*Adiantum macrophylla*	Polypodiaceae
Magnolia	*Magnolia grandiflora*	Magnoliaceae
Mussaenda	*Mussaenda phillipica*	Rubiaceae
Narcissus	*Narcissus tegetta*	Amaryllidaceae
Oregano	*Oreganum vulgare*	Lamiaceae
Ornithogallum	*Ornithogallum thyrsoides*	Liliaceae
Paeonies	*Paeonia suffroticosa*	Asteraceae
Pansy	*Viola odorata*	Violaceae
Paper flower/Acroclinum	*Helipterum rosaeum*	Asteraceae
Pearly Everlasting	*Anaphilis margaritacea*	Asteraceae
Powder Puff tree	*Calliandra emerginata*	Leguminosae
Rose	*Rosa* spp	Rosaceae
Rumex	*Rumex hastatus*	Polygoniaceae
Salvia	*Salvia splendens*	Lamiaceae
Silver Oak	*Grevellia robusta*	Proteaceae
Star glory	*Mina lobata*	Convolvulaceae
Statice	*Limonium sinuatum*	Plumbaginaceae
Stock	*Mathiola incana*	Cruciferae
Straw flower	*Helichrysum bracteatum*	Asteraceae
Sweet pea	*Lathyrus odoratus*	Leguminosae
Sweet William	*Dianthus barbetus*	Caryophyllaceae
Sword Fern	*Nephrolepsis exaltata*	Polypodiaceae
Thuja	*Thuja compacta*	Cupressaceae
Verbena	*Verbena x hybrid*	Verbenaceae
Water lily	*Nymphea odorata*	Nympheaceae
Zinnia	*Zinnia elegans*	Asteraceae

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