Bedding Plants and Seedlings

Hyeon-Hye Kim, Kevin Kern and William H. Carlson
Department of Horticulture, Michigan State University, East Lansing, MI

Introduction: Storage of vegetable and flower bedding plants may be necessary in situations where adverse weather conditions, seasonal availability, or extension of the time of availability makes it essential. There are two stages of plants in bedding plant production and storage: plugs and finished plants. Generally, finished bedding plants are hardier and can withstand greater environmental changes than the plug stage of the same plant. However, storage is easier when the plant is in the more compact plug stage.

Plug Storage: Most bedding plants are produced as plugs. Research on plug storage is mainly limited to that published in recent years. Heins et al. (1995) found that the duration a species could be stored without plant death or flowering delay was influenced by storage temperature and irradiance. Plant quality improved with the addition of light compared to that of plants in dark storage, especially as the duration of storage and storage temperature increased (Heins and Lang, 1992a, 1992c, 1992d; Heins and Wallace, 1993a, 1993b). Shipping plugs in boxes or trucks is in fact a form of short-term storage. As the duration of shipping increases, cooling plugs prior to shipping becomes more important, and will improve their postharvest condition when they reach their final destination (Heins et al. 1994b; Kaczperski et al., 1996; Lang et al., 1991a). The impact of storage on plugs may vary depending on the specific storage conditions, age, species, cultivar, and physiological state of the plugs. The optimum storage temperatures and maximum storage durations for selected species are shown in Table 1.

Growers who only have one or two coolers may need to store plugs of several species at one time. Researchers in Michigan (Heins and Lange, 1992d,; Heins et al., 1992) showed how to identify a compromise temperature, one that is collectively acceptable, although maybe not individually optimal. If only short-term storage is necessary, a temperature warmer than the optimum may be more economical (Heins et al., 1994b). Also, the environmental conditions before and after storage can influence the growth of the plugs following storage (Heins et al., 1991, 1994b; Heins and Lange, 1992a; Kaczperski et al., 1996).

A major disease problem associated with plug storage is Botrytis (Heins et al., 1992, 1994b, 1995; Lang et al., 1991a, 1991b). Maintaining a high RH in a cooler decreases the frequency of watering, but also favors the growth of Botrytis. The disease is generally not a problem on pansies, but does affect many species including impatiens, geraniums, and petunias. Those crops should be stored under low RH conditions and irrigated if plugs are stored longer than 1 week (Heins et al., 1991).

Growers should be aware that low RH in coolers with significant air velocity causes plugs to dry out quickly. The frequency of irrigations will vary, depending on the temperature and RH of the cooler. Contact between the foliage and water should be minimized to avoid fungal infection. Plugs can be sub-irrigated with clear water as needed during storage because the plants' nutritional needs are minimal under low temperatures (Heins and Lange, 1992a; Heins et al., 1994b). Heins et al. (1994a) recommend applications of certain fungicide tank mixtures for controlling Botrytis blight and sporulation during plug storage.

Plugs grown with high fertility, resulting in lush, soft growth preceding storage, are more susceptible to Botrytis during storage (Heins et al., 1994b; Kaczperski et al., 1996). These plants are more likely to weaken under the stress of storage than hardened plants, allowing invasion by the pathogen. Plugs in a toned or hardened condition because of reductions in fertility prior to storage are more resistant to Botrytis (Heins et al., 1995). In addition, hardening of these plugs will aid in the plugs resistance to drought stress. A hardened plug will resist drought damage better than a plug grown with high levels of phosphorus (Borch et al., 1999).

Plug storage has the potential to become a viable grower management tool (Heins and Lange, 1992b) if cooler space is available. However, as with any new technique, growers should experiment with just a few plug trays before they commit a large volume to storage (Heins et al., 1991; Heins and Lange, 1992a;

Heins and Wallace, 1993c; Lange et al., 1991a, 1991b). See Table 1 for specific species storage temperatures and light levels.

Table 1. Optimal storage temperatures and maximum storage durations for plugs of selected bedding plant species and cultivars either in the dark or under a minimum of 5 footcandles of light.

Species	Cultivars evaluated	Optimal storage temperature		Maximum weeks storage		Literature
		ºC	ºF	in the dark	in the light	references
Ageratum	'Blue Danube'	7.5	45.0	6	6	Heins et al., 1992 Heins et al., 1994b Heins et al., 1995 Heins and Lange, 1992a
Alyssum	'New Carpet of Snow'	2.5	36.0	5	6	Heins et al., 1994b Heins et al., 1995
Begonia, fibrous	'Vodka'	5.0	41.0	6	6	Heins et al., 1994b Heins et al., 1995
		5.0 - 7.5	41.0 - 45.0			Heins et al., 1992 Heins and Lange, 1992c
Begonia, tuberous	'Nonstop Scarlet'	5.0	41.0	3	6	Heins et al., 1994b Heins et al., 1995
		5.0 - 7.5	41.0 - 45.0			Heins & Wallace, 1993d
Celosia	'Cherry Red'	10.0	50.0	2	3	Heins et al., 1994b Heins et al., 1995
Dahlia	'Amore / Figaro'	5.0	41.0	2	5	Heins et al., 1994b Heins et al., 1995
		5.0 - 7.5	41.0 - 45.0			Heins and Wallace, 1993c
Geranium	'Pinto Red'	3.0	37.5			Heins et al., 1991 Lange et al., 1991b
		2.5	36.0	4	4	Heins et al., 1994b Heins et al., 1995
Impatiens	'Accent Orange'	7.5	45.0	6	6	Heins et al., 1991 Heins et al., 1994b Heins et al., 1995 Lange et al., 1991a
Lobelia	'Blue Moon'	5.0	41.0	6	6	Heins et al., 1994b Heins et al., 1995 Heins and Wallace, 1993e
Marigold, French	'Hero Yellow'	5.0	41.0	3	6	Heins et al., 1992 Heins et al., 1994b, Heins and Lange, 1992c Heins et al., 1995
New Guniea impatiens	'Kientzler Agua', 'Kientzler Anaea', 'Kientzler Apollon', 'Kientzler Celerio', 'Kientzler Celsia', 'Kientzler Eurema', 'Kientzler Marpesia', 'Kientzler Melissa', 'Kientzler Octavia', 'Kientzler Saturnia', 'Kientzler Sesia', 'Paradise Antigua', 'Paradise Aruba', 'Paradise Barbados', 'Paradise Bora-Bora', 'Paradise Lanai', 'Paradise Maui', 'Paradise Papete', 'Paradise Samoa', 'Paradise Tahiti', 'Paradise Tobago', 'Paradise Tonga', 'Paradise Trinidad'	12.5	55.0	2	3	Heins et al., 1994b Heins et al., 1995
Pansy	'Majestic Yellow'	2.5	36.0	6	6	Heins et al., 1991 Heins et al., 1994b Heins et al., 1995
		0 - 2.5	32.0 - 36.5			Heins and Lang, 1992d Lange et al., 1991a

Petunia	'Ultra Red'	3.0	37.5			Heins et al., 1991 Lange et al., 1991b
		2.5	36.0	6	6	Heins et al., 1994b Heins et al., 1995
Portulaca	'Fuchsia'	7.5	45.0	5	5	Heins et al., 1994b Heins et al., 1995
		5.0 - 7.5	41.0 - 45.0			Heins & Wallace, 1993e
Salvia	'Red Hot Sally'	5.0	41.0	6	6	Heins et al., 1994b Heins et al., 1995
		7.5	45.0			Heins et al.,, 1992 Heins and Lang, 1992a
Tomato	'Rutgers'	7.5	45.0	3	3	Heins et al., 1994b Heins et al., 1995 Heins and Wallace, 1992
Verbena	'Romance Mix'	7.5	45.0	1	1	Heins et al., 1994b Heins et al., 1995
Vinca	'Peppermint Cooler'	10.0	50.0	5	6	Heins et al., 1994b Heins et al., 1995

Table 2: Short-term greenhouse-holding temperatures for finished bedding plants. The temperatures in Table 2 are the lowest recommended growth temperatures after transplant. At lower temperatures, plant quality may be adversely affected by chilling injury. Refer to the plug storage table for temperatures and lengths of time the plants may be stored without damage.

Hold at or above 15 °C (60 °F)	**Reference**
Balsam	Aldrich et al., 1976
Begonia (fibrous)	Aldrich et al., 1976
Celosia	Aldrich et al., 1976
Celery	Aldrich et al., 1976 Arent et al., 1994 Barrett et al., 1999
Coleus	Aldrich et al., 1976
Cucumber	Aldrich et al., 1976 Arent et al., 1994 Barrett et al., 1999
Eggplant	Arent et al., 1994 Barrett et al., 1999
Kochia	Aldrich et al., 1976
Muskmelon	Aldrich et al., 1976 Arent et al., 1994 Barrett et al., 1999
Pepper	Aldrich et al., 1976 Arent et al., 1994 Barrett et al., 1999
Pumpkin	Aldrich et al., 1976 Arent et al., 1994 Barrett et al., 1999
Squash	Aldrich et al., 1976 Arent et al., 1994
Tomato	Aldrich et al., 1976 Arent et al., 1994 Barrett et al., 1999
Vinca rosea	Aldrich et al., 1976
Watermelon	Aldrich et al., 1976 Arent et al., 1994 Barrett et al., 1999
Zinnia (dwarf & tall)	Aldrich et al., 1976

Hold at 7-10 °C (45-50 °F)	**Reference**
Alyssum	Aldrich et al., 1976
Calendula	Aldrich et al., 1976
Carnation	Aldrich et al., 1976
Larkspur	Aldrich et al., 1976
Lobelia	Aldrich et al., 1976
Pansy	Aldrich et al., 1976
Snapdragon (tall & dwarf)	Aldrich et al., 1976

Hold at 10-13 °C (50-55 °F)	**Reference**
Ageratum	Aldrich et al., 1976
Aster	Aldrich et al., 1976
Broccoli	Aldrich et al., 1976 Arent et al., 1994 Barrett et al., 1999
Browallia	Aldrich et al., 1976
Brussels Sprouts	Arent et al., 1994 Barrett et al., 1999
Cabbage	Aldrich et al., 1976 Arent et al., 1994 Barrett et al., 1999
Cauliflower	Aldrich et al., 1976 Arent et al., 1994 Barrett et al., 1999
Collards	Arent et al., 1994 Barrett et al., 1999
Centaurea cyanus	Aldrich et al., 1976
Dahlia	Aldrich et al., 1976
Dianthus	Aldrich et al., 1976
Dusty Miller	Aldrich et al., 1976
Geranium	Aldrich et al., 1976
Impatiens	Aldrich et al., 1976
Lettuce	Aldrich et al., 1976 Arent et al., 1994 Barrett et al., 1999
Marigold	Aldrich et al., 1976
Nierembergia	Aldrich et al., 1976
Onion	Arent et al., 1994 Barrett et al., 1999
Petunia	Aldrich et al., 1976
Phlox	Aldrich et al., 1976
Portulaca	Aldrich et al., 1976
Salvia	Aldrich et al., 1976
Verbena	Aldrich et al., 1976

Finished Plant Storage: Finished bedding plants are those that are in a state ready for sale to the general public. Generally, finished plants are not stored in coolers because of the difficulty of moving large quantities of plants from greenhouse to cooler. To reduce plant growth, greenhouse temperatures are dropped while waiting for the crop to sell. Finished plants should be held at temperatures low enough to reduce growth, but not to cause damage or impair future growth. The following table lists certain cultivars of popular bedding and vegetable plants, and suggested holding temperatures.

According to Nelson (1983), a general greenhouse holding temperature of 13 °C (55 °F) is applicable for many of the common types of bedding and vegetable plants. Alyssum, begonia, geranium, impatiens, marigold, petunia, salvia, pepper, and tomato all kept well at this temperature. Impatiens plants were still marketable after 36 days at this temperature. Bedding plants hold better at a higher light level (7500 lux) than at a lower light level (500 to 2700 lux).

Conifer and Hardwood Seedling Storage: Storage of conifer and hardwood forest seedlings is possible at a low temperature and high RH (Aldhous, 1964; Camm et al., 1994; Duffield and Eide, 1959). Loosely tied bundles of seedlings, as well as containerized seedlings may be stored in conditions that lower the metabolic activity of the plants. However, for most species, temperatures should be kept above freezing to avoid injury (Camm et al., 1994; Lantz et al., 1989). Top and root growth capacity are affected by the cold storage of certain seedlings, and these are dependent on seed source and lifting date of the seedlings (Jenkinson et al., 1993). A cold hardened seedling will store more successfully and for a longer period of time than a non-hardened seedling. Maximum stress resistance occurs in late Fall to early Winter. Therefore, lifting dates for seedlings being put into cold storage should be delayed as long as possible (Camm et al., 1994).

Warehouses or sheds can be used for storage of seedlings at a variety of temperatures. Refrigerated storage rooms or coolers are also used for storing seedlings at cooler temperatures (1 to 4 °C; 34 to 40 °F). High RH and good air circulation, as well as daily photoperiod control where possible, are important factors that influence the success of seedling storage (Camm et al., 1994; Lantz et al., 1989).

Storage of seedlings may be done in polyethylene bags to facilitate high RH, but spacing between the bags must be enough to allow for adequate air movement in order to avoid fungal pathogens. Loosely tied bundles of seedlings may be packed with slightly wet peat surrounding the roots and then wrapped in film-coated paper with the tops exposed and placed in a container for storage. With prolonged storage, root growth capacity can decline (> 6 mo), as well as lead to a disruption of naturally occurring seasonal progression events. The following chart lists several species which may be stored for up to 3 mo at 1 to 4 °C (34 to 40 °F).

Species:

Norway Spruce	Western Hemlock	Yellow Poplar
Sitka Spruce	Lawson Cypress	Hybrid Poplar*
Douglas Fir	Sycamore	Eastern Cottonwood*
Lodgepole Pine	Sweetgum	
Scotch Pine	Green ash	
Loblolly Pine	Oak	
Ponderosa Pine	Birch	* hardwood cuttings

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