Crop: Chrysanthemum
Scientific Name: Dendranthem grandiflora
(Chrysanthemum morifolium Ramat).

I. Introduction

A. *Dendranthem grandiflora* (*Chrysanthemum morifolium Ramat*). is a complex hybrid of several species that grow wild in China and Japan. Two species are important contributors.

1. *C. indicum*, a native of China and Southern Japan with small yellow ray inflorescences.

2. *C. sinense*, a species with white ray and orange disc flowers

B. Other species such as *C. coreanum*, *C. articum*, and *C. nipponicum* have also contributed flowering types and extended flowering time.

C. In 1987, the pot chrysanthemum was the number two flowering pot crop in total sales, second only to Poinsettia.

1. In 1989, 32.5 million pots of chrysanthemums were produced with a value of $95.8 million.

2. Michigan chrysanthemum production for 1989 was valued at $4.3 million.

3. Based on dollar value of the crop , the leading producers in 1987 were California (26%), New York (6.2%), Ohio (3.6%), Texas (6.5%), Florida (11.4%), Michigan (4.5%), Illinois (4.4%), and North Carolina (6.2%).

D. Gus Poesch, Alex Laurie and Ken Post, while at Michigan State University, made the first contributions in photoperiodic response of chrysanthemums by observing flower delay due to light.

E. Year round production started in the late 1940's because of:

1. Daylength - lighting research work.

2. Breeding of new varieties and increased commercial cutting production.

F. The pot chrysanthemum is a popular crop all year round but also has large holiday sales.

G. Pot production primarily includes pinched plants, but some single flower plants are also grown.

1. Production by pot size nationally is estimated at:

a. 4 in. pots 10%

b. 5 in. pots 5%

c. 6 in. pots 80%

d. Miscellaneous sizes 5%

II. Cultivars

A. Chrysanthemum cultivar development in the U.S. initially centered around Elmer D. Smith of Michigan who exhibited his first seedling in 1889. Eventually, he introduced over 500 varieties.

B. Many cultivars are commercially available in the commercial market. New cultivars are introduced yearly.

C. Current breeding objectives include:

1. Uniform development under a wide temperature range (high and low temperature tolerance).

2. Faster flowering from the start of short days.

3. New colors and flower types.

4. Resistance to insects and diseases.

D. Summary of cultivar characteristics:

1. Greatest production in the U.S. during 1988 was of the following cultivars.

a. Surf (white decorative)

b. Irridon (yellow decorative)

c. Bright Golden Anne (yellow decorative)

d. Deep Luv

2. Color (1988)

a. yellow 40%

b. white 27%

c. pink 23%

d. bronze 10%

3. Flower type (1988)

a. decorative 70%

b. daisy and other 30%

4. Response group

a. 8 week 30%

b. 9 week 40%

c. 10 week 30%

E. Flower shapes vary. Flowers can be classified as single (daisy), anemone, pompon, decorative, or under some miscellaneous classification based on petal shape (Spider, Fuji, Quill, or Spoon).

III. Flowering requirements.

√ A. The chrysanthemum is classified as a short day plant, i.e., plants require a long dark period for both induction and development.

√ B. The chrysanthemum has two critical photoperiods, one for flower initiation and one for flower development. Flower development requires a longer night period than initiation. The exact length of critical photoperiods for initiation and development depends on cultivar and temperature.

C. In general, the longer the response group, the longer the required dark span (night length) for both initiation and development. Some short response group varieties will initiate and develop a flower under a photoperiod unsuitable for initiation in a long response group variety. Examples of how critical photoperiods vary for chrysanthemum varieties grown at 60°F night temperature are shown below.

Variety (weeks)	Response Group	Initiation		Development	
		hr light	**hr dark**	**hr light**	**hr dark**
White Wonder	6	16.00	8.00	13.75	10.25
Pristine	8	15.25	8.75	12.00	12.00
Encore	10	14.50	9.50	12.00	12.00
Fortune	12	13.00	11.00	12.00	12.00
Snow	15	11.00	13.00	10.00	14.00

D. The critical photoperiods are also temperature dependent. In general, as temperature increases or decreases from an optimum, the number of dark hours (night length) increases for initiation and further development. The effect of temperature on critical photoperiods in chrysanthemum is shown below.

Variety (weeks)	Response Group (°F)	Night Temp (°F)	Initiation		Development	
			hr light	hr dark	hr light	hr dark
White Wonder	6	50	13.75	10.25	*	*
		60	16.00	8.00	13.75	10.25
		80	16.00	8.00	12.00	12.00
Encore	10	50	13.75	10.25	13.75	10.25
		60	14.50	9.50	13.00	11.00
		80	15.25	8.75	12.00	12.00
Snow	15	50	12.00	12.00	12.00	12.00
		60	11.00	13.00	10.00	14.00
		80	10.00	14.00	9.00	15.00

* No flower development occurred at this temperature.

E. Under short day conditions, temperature and light levels influence time to flower.

1. Response to temperature is cultivar dependent. Flowering in certain cultivars is delayed more when the temperature is lowered from 65°F than when it is raised from 65°F. Likewise, flowers of certain cultivars are delayed more when temperature is raised above 65°F than when it is lowered below 65°F.

2. Day temperature, night temperature and light level interact to influence the time to flower of a chrysanthemum cultivar. Under the same temperature regime, the required time for flowering will decrease as the light level increases.

F. When the flower buds show color, short day treatment can be discontinued. From this stage of development, the flowers will open normally under either long or short days.

G. Regardless of photoperiod and temperature, a chrysanthemum shoot will eventually initiate a flower. The longer the photoperiod or higher the temperature, the longer it will take to initiate the flower (i.e. more leaves will be formed before the flower initiates). If conditions are not proper for development after initiation, the bud will develop into a crown bud. Unintentional initiation under long days is normally not a problem under commercial conditions except in certain cultivars. Shown below is the number of leaves initiated before the flower on five varieties of chrysanthemum grown under long days (natural day length plus 5 hr night break) (3).

Cultivar	Number of Leaves on Main Plant Shoot		
	Date of Planting		
	June 13	October 10	May 29
Tuneful	45	90	60
Gold Crystal	44	69	50
Polaris	34	56	41
Bluechip	30	48	34
Bright Golden Anne	20	34	18

H. During the long nights of fall, winter, and early spring, plants can be maintained in a vegetative state through the use of low intensity night lighting.

1. Traditionally, incandescent lights have been used as a night interruption for 4 hr from 2200-0200 at 10 fc. Light from fluorescent and high pressure sodium lamps at the same intensity and duration can also be used.

2. Cyclic lighting is also effective in preventing flowering under short day conditions as well. Six minutes of lighting per 30 minutes during the 4 hr period from 2200-0200 is as effective as continuous lighting. Cyclic lighting would normally not be used with high pressure sodium lamps due to the long "warm up" times of the lamps and reduction in lamp life due to repeated starts.

IV. Environmental Requirements

A. Light duration -- The following recommendations apply to northern U.S. latitudes.

1. Vegetative growth

a. To keep plants vegetative, night interruption lighting should be provided using the following schedule:

Time Period	**Duration of night interruptions (hr)**
June-July	2
August - September	3
October - March	4
April - May	3

2. Reproductive growth

a. Short days (long nights) must be supplied to the plant either from natural short days or from artificial short days. Artificial short days ~~created by a blackout curtain~~ are recommended from March 15 through ~~September 15.~~ Crops started under the natural short days of January and finished in late March normally do not require any artificial short day treatment.

B. Light intensity

1. Full sunlight is required for maximum growth, especially during the winter.

   a. Some shade may be used from May 15 to Sept 15 -- mainly to reduce temperature.

   b. Shading of plants in flower is necessary during the summer to prevent petal burn, especially on disbud varieties.

2. Uniformity of flowering is greatly reduced under low light intensities.

3. Supplemental light (500 to 1,000 fc) under low natural light conditions results in a higher quality plant and reduced time to flower.

   a. Supplemental lighting is most beneficial on crops started during the period from early October through early March. Lighting time and duration depends on stage of crop development.

      1) Long day period -- light 20 hr per day (0200-2200 hour).

      2) Short day period (first 2 to 3 weeks) -- light 10 hr per day (0700 to 1700 hour).

      3) Short day period (last 5 to 8 weeks) -- normally not lighted due to spacing of plants and reduced plant response.

C. Temperature

1. During vegetative growth (long days), maintain 68°F night temperatures.

2. Maintain 68 to 70°F night temperatures during flower initiation and up through visible bud for fastest development. A temperature of 68°F for the first 2 weeks of short days followed by 65°F until visible bud is also acceptable. Temperatures below 63°F affect bud set and delay the crop.

3. High temperatures, especially above 70°F, cause heat delay in flower bud development.

4. After plants have reached visible bud, force at 65-68°F for fastest development until color. Temperature of 60-62°F are acceptable although growth is slowed a few days. Night temperature can then be lowered to 56 to 58°F after plants show color, although faster development occurs at 65°F.

5. The relationship between day and night temperature is the primary factor influencing shoot length. A large difference between day and night temperatures, with day temperature being the higher temperature, will result in longer internodes. High day and night temperatures at the start of short days results in more leaves beneath the flower (delayed flower initiation), producing more internodes and taller plants. (See section IV. C. 3. above).

6. The relationship between day temperature and night temperature can be used to control the rate of stem elongation. Increasing DT relative to NT promotes stem elongation. In contrast, as DT is reduced below the NT, stem elongation is progressively reduced.

D. Water

1. Chrysanthemums require large amounts of water, especially during the summer.

2. Avoid overwatering new plants during the winter.

3. Allow the soil to dry somewhat between waterings. Plants have traditionally been watered so some leaching occurs. This requires about 12 oz (350 ml) per 6 in. pot, 4 to 5 fl oz (120 to 150 ml) per 4 in. pot.

4. Subirrigation systems result in no leaching. Fertilizer concentration must be adjusted to avoid toxic soluble salt accumulations.

E. Fertilizer

1. The fertilizer concentration necessary to produce a high quality plant is dependent on the initial soil fertility level and the amount of leaching at each irrigation. Chrysanthemum plants have a high nutrient requirement immediately after rooting and during early

reproductive growth. Therefore, initial fertilization concentrations will depend on the nutrient charge in the media.Very low nutrient levels in the media can occur when cuttings are direct stuck and rooted under mist. Leaching during mist propagation can reduce media nutrients to very low levels. Under such circumstances, one or two applications of 600 ppm N and K may be necessary to adequately increase nutrient levels. Magnesium, phosphorous, and minor nutrients may also be necessary as they also leach readily.After adequate nutrient levels are achieved early in crop development, subsequent fertilizer concentrations depend on the amount of leaching at each irrigation. If irrigations result in heavy leaching (40-60%; not uncommon with emitter tube systems), nutrient concentrations of 300-400 ppm N and K may be necessary to maintain adequate media nutritional levels. If leaching is low or nonexistent (subirrigation systems), nutrient concentrations of 150 ppm N and K will likely be adequate to maintain nutrient levels. Media nutrient levels should be monitored by soluble salt readings so fertilizer concentrations can be adjusted accordingly.

2. An application of 500-600 ppm nitrogen and potassium is often recommended immediately after planting rooted cuttings or 7 to 10 days after sticking unrooted cuttings.

3. Phosphorus is normally added in the form of superphosphate prior to planting, 2 1/2 lb per cu yd. Phosphorus readily leaches in a soilless medium. Therefore, add phosphorus at 100 ppm to the fertilizer at least every 4 to 5 weeks.

4. A mixture of ammonium and nitrate nitrogen is preferred during most growth. Use mainly nitrate nitrogen (60% or more) during late fall and winter due to slow conversion of ammonium to nitrate and potential ammonium toxicity during low light periods.

5. In soilless mixes, include a source of trace elements.

6. Finish off crops with KNO_3 or terminate fertilization when flowers first color to improve postharvest quality unless nutrient levels are very low at that time.

F. Carbon dioxide

1. CO_2 is most valuable during vegetative and early reproductive growth.

2. CO_2 levels of about 1,000 ppm early in the crop can result in heavier

stems, larger flowers, and quicker flowering compared with plants not receiving additional CO_2.

3. Increased CO_2 levels in combination with high temperatures can result in excessive stem elongation.

V. Cultivation

A. Propagation

1. Propagation is entirely by cuttings and growth of cuttings from stock are normally done by specialists.

2. These specialists use culture-indexed, disease-free stock plants. Culture indexing has been used to obtain plants free of *Verticillium*, bacterial wilt, stunt virus and other viruses.

3. Rooted and unrooted cuttings are available.

   a. Unrooted cuttings are easier and faster to plant than rooted cuttings due to the lack of roots. They are also cheaper to purchase.

   b. Unrooted cuttings require a special environment and extra time as compared to rooted cuttings to allow for the formation of roots.

4. Propagation procedure

   a. Terminal cuttings 2 to 3 inches in length are normally rooted under intermittent mist. Cuttings can also be rooted under plastic without mist as long as high temperatures are avoided under the plastic. Cuttings can be sprayed with a wetting agent to improve initial wetting under mist.

   b. Long photoperiods are used to maintain cuttings in the vegetative state.

   c. Under low light conditions, high intensity discharge (HID) lighting accelerates rooting and a sturdier rooted cutting will develop.

d. Dipping cutting ends in 2500 to 1500 ppm IBA speeds rooting. Rooting occurs in 7 to 10 days with moderate temperatures (70 to 75°F). Use of bottom heat is suggested to maintain adequate media temperature. ✓

e. Cuttings can be rooted in a peat-lite medium and transplanted or rooted directly in the pot.

f. Rooted cuttings can be stored at 31 to 33°F for 2 to 3 weeks if kept moist, but not excessively wet. ✓

B. Media and planting

1. A coarse and porous medium is preferred.

2. A pH of 6.2 to 6.4 is ideal. Above 6.8, foliar problems can occur due to micronutrient deficiencies. ✓

a. Adjust pH if needed -- 2 1/2 lb ground limestone per cubic yard raises pH 1/2 to 1 unit.

b. Check pH every week throughout the life of the crop.

3. Pasteurize soil based media at 180°F for 30 minutes with steam or at 140 to 160°F for 30 minutes with aerated steam.

4. Sort cuttings by size. Plant shallow with cuttings slanted towards the outside of the pot when planting more than one cutting per pot.

5. Four to six cuttings are planted per 5 1/2 in. or 6 in. pot, depending on the market.

6. Freely breaking cultivars may require only 4 plants per pot, especially from Easter to Thanksgiving.

C. Spacing. Several spacing techniques can be used. Listed below are spacings commonly used for chrysanthemum production.

1. Two climate zero move system (2C0M).

a. Climate 1: 65°F -- long days

b. Climate 2: 60 to 62°F – short days

c. In this system, the plants are placed at final spacing immediately after potting. The temperature and photoperiod are changed in the production area to achieve the second climate. This system has a low labor requirement but uses space inefficiently.

2. Traditional - two climate one move system, (2C1M).

   a. Climate 1: 65°F - long days

   b. Climate 2: 60 to 62°F - short days

   c. One production area is used for the long day environment. The plants are then moved to final spacing in a second production area. This system uses space more efficiently than the 2C0M system.

3. Unit spacing -- two climate, two move system (2C2M).

   a. Climate 1: 65°F - long days

   b. Climate 2: 60 to 62°F - short days

   c. Each unit consists of 3 benches in the short day area kept at 60 to 62°F. At the first move, the plants are placed on the middle bench of each unit. After 5 weeks (for a 10 week variety), the plants are spaced to the 2 outer benches of each unit.

      1) Compared to the 2C1M system, this system is more space efficient.

      2) It requires one additional spacing compared to the 2C1M system.

      3) The system is designed for uniform year around production of plants.

      4) It does not easily allow for production of a holiday crop.

4. Zone system -- 3 climate, 2 move system, (3C2M).

    a. Climate 1: 65°F -- Long days

    b. Climate 2: 65 to 67°F -- Short days (first 5-6 weeks)

    c. Climate 3: 58 to 60°F -- Short days (to finish)

    d. In this system, the plants are finished at a lower temperature to improve quality.

        1) Compared to the 2C1M system, this system is more space efficient.

        2) It requires two separate production areas during short days.

        3) It also requires one additional moving of plants compared to the 2C1M system.

        4) It is easier to fit holiday scheduling into production.

        5) It may improve quality.

        6) It saves energy through lower fuel costs.

D. Support

1. No support is required unless stems are weak. Plants are then often wrapped with a string or a plastic hoop.

E. Pinching

1. The main purpose of pinching is to increase the number of flowers per plant.

2. The pinching schedule depends on time of year, cultivar, pot size and final plant height desired.

3. Time to pinch is based on growth of the plant.

    a. Before pinching, establish a good root system (roots grown to the bottom of the pot).

    b. Allow 1 - 1/2 to 1 - 3/4 in. of new top growth.

4. In order to achieve desired plant height, it is necessary to pinch in relation to the beginning of short days according to each variety.

   a. The following pinching schedule may be used as a guide for rooted cuttings (5):

Season and treatment	Days from planting rooted cuttings to pinching NORTH	SOUTH
LATE SPRING-EARLY FALL PLANTINGS:		
Tall treatment	7-10	7-10
Medium treatment	8-11	8-11
Short treatment	10-14	10-14
EARLY SPRING-LATE FALL PLANTINGS:		
Tall treatment	10-14	10-14
Medium treatment	11-14	11-15
Short treatment	14-17	14-17
MIDWINTER PLANTINGS:		
Tall treatment	14-17	10-14
Medium treatment	15-18	11-15
Short treatment	17-21	14-17

   b. The above schedule is modified (shortened) when HID lighting is used.

5. A soft pinch produces the best results. Remove the top 1/2 in. of the growing point leaving 6 to 8 leaves.

6. With short cultivars, the pinch is sometimes given 7 days before the start of SD while medium and tall cultivars are normally pinched at the start of SD.

7. Normally, one wishes to avoid a delayed pinch. A delayed pinch is one made after the start of SD. Breaks from a delayed pinch come from reproductive buds and produce sparse and narrow foliage. The resulting plants will appear very loose and open. However, delayed pinch (1-3 days) can be helpful when excessive plant height is a problem, especially on plants produced in 4 or 4 1/2 inch pots. A 3 to 5 delay pinch is then useful.

F. Disbudding

1. Disbudding is used to modify the number of flower buds per shoot.

2. Standard Disbudding - All lateral flower buds are removed, leaving only the terminal bud. It is done as soon as lateral flower buds are large enough to handle without damage to the terminal flower bud.

3. Center Bud Removal - The terminal flower bud is removed. It is done on many daisy varieties and on plants in small pots. Normally plants require one additional week to flower from planting.

4. Multiple Bud Removal (MBR) - Tip pinch each branch that develops from the first pinch when a minimum of 4 to a maximum of 6 leaves have developed on the breaks, or when you can feel the bud, but not see it yet.

   a. Delays flowering.

   b. Benefits of MBR:

      1) Eliminates "clubbiness" on winter grown plants.
      2) Increases headsize.
      3) Can grow disbud varieties as spray.
      4) Reduces height and eliminates need for a B-9 application.

G. Growth regulators

1. The quantity and timing of growth regulators is dependent on the season, the cultivar, the desired final plant height, and the greenhouse structure itself. General guidelines are listed below.

2. Spray 10 to 14 days after pinch or when shoots are 1 to 1 1/2 in. long. A second application may be needed 2 to 3 weeks later.

3. The rate of stem elongation varies with stage of plant development. Apply growth regulators before the stem elongates most rapidly, within 4 weeks after start of short days.

4. Cultivars are classified according to treatment necessary to achieve a plant of desired height. Classifications of short, medium, and tall are based on the following criteria:

a. How quickly the variety forms roots.

b. Potential of plant for stem elongation.

c. Response of plant to growth regulators.

5. Most commonly used growth regulators in chrysanthemum production are B-Nine-SP (daminozide, SADH) and A-Rest (ancymidol).

6. B-9 application is based on cultivar response:

   a. Tall treatment varieties: 2 applications are often suggested.

   b. Medium treatment varieties: normally only 1 early application.

   c. Short treatment varieties: 1 late application, if any.

7. Suggested concentration of B-9 applications:

   a. 2,500 ppm in winter

   b. 3,750 ppm in spring and fall

   c. 5,000 ppm in summer

8. To control height on extra-tall cultivars, a pre-plant dip or post-planting spray of B-Nine can be used in addition to recommended applications.

   a. Dip plants in 1,250 ppm B-Nine just long enough to wet the stems and foliage. After planting let the foliage dry before watering.

   b. Sprayed plants can also be 1,250-2,500 ppm 3 to 5 days after planting.

9. A-Rest sprays of 25 to 100 ppm give good height control.

   a. Spray immediately after pinch to just wet the foliage.

   b. Varieties requiring 2,500 ppm B-Nine typically require 25 ppm A-Rest.

c. Drench: 0.125 to 0.5 mg of A-Rest in 8 oz (240 ml) of water per 6 in. pot.

10. The response to B-Nine varies with cultivar and time of year. The cultivars in the figure below received one 2500 ppm application of B-Nine.

11. B-Nine requirements are reduced when plants are grown under negative DIF.

VI. Problems

A. Diseases

1. Most diseases are eliminated by using culture indexed plants and growing in a pasteurized, well-drained soil.

2. Stem rot can be caused by *Pythium*, *Rhizoctonia*, and *Sclerotinia*. Control with fungicidal drenches.

3. *Botrytis* can be a problem especially on petals under conditions of high humidity.

B. Insects

1. Although there are potentially numerous insect problems, a preventive schedule of spraying and fumigation is often less costly than the losses that occur with infestation.

2. Common insect pests include aphids, spider mites, leaf miners, thrips and caterpillars. The control chemicals are constantly changing due to introductions of new chemicals, labeling changes and the development of insect resistance. See Extension Bulletins E-1750 The Glasshouse Ornamental Disease Control Handbook and E-2014 Insect and Mite Management in Commercial Greenhouses or consult The Spartan Ornamental Network plant problem control program.

C. Physiological

1. Crown bud formation occurs when a bud is set under correct initiation conditions but the plant is not provided with correct developmental conditions. Vegetative shoots often surround the bud. Crown buds are caused by:

a. Light leaks or failure to apply black cloth consistently.

b. Insufficient light intensity during lighting period to keep plants vegetative.

c. Cuttings taken from shoots that were too long and thus initiated.

d. Too high temperature during short days.

2. Neckiness is a problem in which the flower stem below the bud is elongated and devoid of foliage. It can be prevented by an application of B-9 within 1 to 3 days after disbudding. A later application may be ineffective.

3. Uneven flowering can be caused by several factors.

a. Light leaks in the black cloth.

b. Insufficient number of short days.

c. High temperatures.

d. Low temperatures (lower than 60°F) during flower initiation (first 3 to 4 weeks of short days).

e. Low light during development.

f. Ethylene pollution.

4) HEAT DELAY

VII. Harvesting, Handling, and Marketing

A. Maximize production light levels for good postharvest longevity. Low light levels during the final 3 to 4 weeks of production decreases longevity.

B. Highest plant and flower quality occurs when temperatures are lowered to 56°F the last couple of weeks before sale.

C. Termination of fertilizer (especially ammonium forms) on well fertilized plants at time of disbudding (approximately 3 to 4 weeks prior to marketing) extends longevity 10 to 14 days and acclimatized plants are more tolerant of shipping conditions. Fertilization should continue later into development on plants growing with low nutrient levels.

D. Maintenance of a good root system is critical for a long decorative life. Monitor watering closely to prevent overwatering.

E. Leaf yellowing in some cultivars may be a direct result of over fertilization (especially with ammonium forms of nitrogen) rather than crowding.

F. Flowers fail to open properly if plants are removed from the greenhouse tooo soon, i.e., when just showing color.

G. A flower grows very rapidly during the last 10 days of development, often gaining 90% of its final dry weight. Inadequate light conditions during this period may result in black centers.

H. In one experiment, flowering chrysanthemums shipped for 7 days at 70°F lasted 23 days under interior conditions while plants shipped at 75°F lasted for only 10 days. Plants shipped at 75°F were of poor quality after shipping.

I. Maintaining potted chrysanthemums under interior conditions at 65°F increased longevity by 13 days compared to an interior temperature of 80°F.