METHODS OF PRODUCING FIELD-GROWN SPECIALTY CUT FLOWERS

By

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METHODS OF PRODUCING FIELD-GROWN

SPECIALTY CUT FLOWERS

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PREFACE

The purpose of this study was to determine production methods for specialty cut flower production in Oklahoma. The work was composed of three aspects—seed germination, spacing requirements, and annual production.

Without the aid and guidance of my major advisor, Dr. John Dole, I would not be completing my Master's degree. I want to thank him for the many roles he has played: advisor, teacher, and friend. I would especially like to thank him for believing in me.

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Other faculty members in the department were also helpful to me in different ways. I want to thank Dr. Janet Cole for her assistance with the seed germination study, her support during my term as president of the Horticulture Club, and for being a role model. I learned a great deal about horticulture from Dr. Mike Smith, and would like to thank him for all his help.

It would have been difficult to do all the field work alone. However, Randall Smith spent many hours helping with planting, harvesting, and data collection. I want

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To my husband Gary, thank you is not quite adequate. Thanks for being so supportive, understanding, and patient. Most of all thanks for just being yourself and for giving me the confidence and courage to succeed. I want to thank my mother, Marylois King, for her love and support and for being a mom all over again. Special thanks go to my grandmother, Carlma Telle, for her love and encouragement. All the letters, phone calls and care packages will long be remembered. I would like to thank my brother and sister for their support. Special thanks to Jason, Joshua, Erica, and Courtney for the joy they bring to life and for just being themselves.

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CHAPTER I

INTRODUCTION

The specialty cut flower industry has been growing steadily for the past several years producing new or rediscovered species. While the wholesale value of standard cut flowers (roses, carnation, chrysanthemums, etc.) remained constant or declined slightly from 1987 to 1990, the specialty cut flower market increased 56% (U.S. Department of Agriculture, 1989, 1991). The increase occurred despite continued pressure from imported cut flowers which reduced the growth of the domestic cut flower industry in the 1970s and 1980s. Wholesale cut flower and green purchases in Oklahoma for 1989 were $9.3 million with only $207 thousand produced within the state. Imported cut flowers pass through a lengthy marketing chain before they reach the consumer, and as a result quality and longevity of the flowers suffer. However, this is balanced with low economic prices in response to large scale production and marketing.

Leading the resurgence in specialty cut flower production are growers who produce high quality crops and specialize in unusual species. In addition, the potential market for Oklahoma-grown cut flowers could be expanded to other states because of the close proximity (one day shipping time) of large metropolitan areas such as Dallas, Ft. Worth, Houston, Kansas City, Denver, and Little Rock. Also, the development of new cut flower species could create greater demand for cut flowers in Oklahoma and surrounding areas.

New cut flower species could possibly be developed from non-cultivated native species or from species being cultivated in areas other than Oklahoma. Currently many species are being grown in the field: *Liatris, Gypsophila, Limonium,* and *Gladiolus* in such states as California and Florida (Kelly, 1991). Native wildflowers are increasingly popular and many species could be used as cut flowers. The National Wildflower Research Center in Austin, Texas was established to encourage people to incorporate wildflowers into their landscapes and to serve as an information center on wildflowers. However, the center states that wildflower research is limited and more work needs to be done (Gilbert, 1987).

Agricultural producers are currently interested in alternative crops to diversify their operations and increase profit margins (Kelly, 1991). Field production of cut flowers requires intensive management, but the high value of the crop could be profitable for the grower and the overhead expense of a greenhouse operation would be avoided. The goals of this research were to evaluate dormancy and seed germination of wildflowers with potential for use as cut flowers, to determine the optimum spacing in the field for increased yield, to determine a cost analysis of the different spacings, and to evaluate the effect of multiple planting dates on season long production of annuals.

Dormancy and Seed Germination

Direct planting of seed is the most economical method of establishment for native wildflowers. While conditions for maximum seed germination and optimum mechanism of dormancy involved are unknown for many wildflowers, some species have been studied. Storage conditions and germination requirements for *Liatris aspera* Michx., *Liatris pycnostachya* Michx., *Asclepias tuberosa* L., and *Penstemon grandiflorus* Nutt. were evaluated by Salac and Hesse (1975). Seeds were placed under three storage conditions, dry, warm storage, 20±4C; dry, cold storage, 4C; and moist, cold storage, 4C (stratification), and six storage periods, 0, 21, 42, 63, 84, or 105 days. Seeds were then germinated under four different combinations of temperatures and photoperiods used to simulate mean soil temperature and day lengths for early spring, late spring or early fall, or midsummer in Nebraska. For *Asclepias*, germination rate increased with the length of storage time. However, after 105 days only 52.5% of the seeds had germinated, which suggested that *Asclepias* required a storage period longer than 105 days. While length of storage for *L. aspera* showed no influence on germination, *L. pycnostachya* seeds stored for 63 and 105 days germinated better than the non-stored seeds. Germination of *P. grandiflorus* benefitted from only 21 days of storage. Optimum germination for all species occurred when seeds were stratified at 4C, and grown under long photoperiods at 33/19C (day/night).

Allen and Meyer (1990) also evaluated the optimum germination temperature and dormancy-breaking procedures of three wildflowers. Viability tests were performed using the triphenyl tetrazolium chloride (TTC) staining technique. Two weeks of stratification did not break dormancy of 'Cedar' Palmer penstemon (*Penstemon palmeri* Gray) or firecracker penstemon (*Penstemon eatonii* Gray), whereas germination was increased following eight weeks of stratification. Incubation above 20C decreased germination, and optimum germination occurred at 15C. Salac, et al. (1982) determined that purple coneflower (*Echinacea purpurea* (L.) Moensch.) needed to be planted in November, while good emergence of Maximilian sunflower (*Helianthus maximiliani* Schrad.) resulted with both November and April seeding. Possibly, purple coneflower had a low temperature requirement to overcome dormancy and Maximilian sunflower had either no dormancy or a limited dormancy requirement. Smith-Jochum and Albrecht (1987) determined that germination rate was highest when seeds were placed in moist sand or peat at 0C for one month for purple coneflower.

Samfield, et al. (1990) also evaluated purple coneflower to determine methods of improving germination using seeds primed with aerated solutions of a potassium phosphate buffer at 16C (pH=7.0), and vacuum-stored for two months after priming. Storing the seeds at a low moisture level under a partial vacuum improved germination. The storage condition may have reduced respiratory activity and prolonged seed viability. Owens and Call (1985) studied the effect of moisture stress levels and temperature on germination of Maximilian sunflower. Cumulative germination was highest at water potentials of 0 and -0.25 MPa in the 25/15C (day/night) temperature regime.

Most wildflower seeds are dormant and require manipulation to overcome dormancy and germinate. A moist, cold storage period, which varied by species, significantly increased germination (Salac and Hesse, 1975; Allen and Meyer, 1990; and Smith-Jochum and Albrecht, 1987). Therefore, this study focused on dormancy-breaking procedures using stratification.

Spacing

General recommendations by Armitage (1992a) indicated that cut flowers are typically spaced in the field at 22.5 x 22.5-cm, 22.5 x 30-cm, 30 x 30-cm, or 30 x 32.5-cm. Although some species may be spaced at 15 x 15-cm to increase yield per square foot, the stems are usually weaker because of lack of air movement and reduced light. Armitage (1987) studied the following species planted on 30-, 60-, 90-, or 120-cm centers—*Achillea filipendulina* Lam. 'Coronation Gold', *Achillea millefolium* L. 'Rose Beauty', *Physostegia virginiana* L., *Liatris pycnostachya* Michx., and *Salvia leucantha* Cav. He found the number of flowering stems per plant increased with the increased spacing, but the number of stems per square meter decreased over time. Increased spacing significantly increased yield per plant, but the yield per square meter declined possibly because of greater non-productive space per unit area.

Armitage (1992b) further examined different species of *Achillea* to determine the effect of plant age and spacing on stem yield and quality. 'Coronation Gold' yarrow was planted on 30-, 60-, 90-, or 120-cm centers and the other species were planted at 30-cm centers. For 'Coronation Gold' yarrow, flower yield, average stem diameter, and stem length were smallest the first year, and no differences were found in subsequent years. The closest spacing had the poorest yield per plant, highest yield per square meter and greatest number of long stems for 'Coronation Gold' yarrow. Yield for the other species increased over time.

Durkin and Janick (1966) found that yield per plant decreased as plant density increased on greenhouse grown carnations (*Dianthus caryophyllus* L.) in benches. An "edge effect" was noted where plants on the edges of the bench were more productive than plants in the center of the bench. Since yield increased over a short time with little change in quality at the higher density plantings, short duration crops could benefit more than long duration crops from closer spacing. However, as time progressed, the yield advantage disappeared and quality decreased. Greater productivity of outside rows compared to center rows was also noted by Weinard and Decker (1930) on roses (*Rosa hybrida* L.) and carnations.

Multiple Planting Dates

For annual cut flowers such as globe amaranth (*Gomphrena globosa* L.), perennial bachelor's buttons (*Centaurea macrocephala* Pushk. ex Willd.), strawflower (*Helichrysum bracteatum* (Venten.) Andr.), or statice (*Limonium sinuatum* (L.) Mill.), one planting date produces flowers all season, but the stems from later harvests are shorter and thinner than those from the first or second harvest (Armitage, 1992a). The use of multiple plantings was suggested to provide a constant supply of quality flowers for bulb crops, calendula (*Calendula officinalis* L.), zinnia (*Zinnia elegans* Jacq.), and common sunflower (*Helianthus annuus* L.) (Armitage, 1992a; MacPhail, 1986). Other cut flowers such as celosia (*Celosia cristata* L.) do not produce season long production. Stevens and Gast (1992) suggested staggering plantings every two weeks, commencing in July, to provide a continuous supply of flowers.

Objectives

Most research over seed germination has shown that wildflowers benefit from a moist, cold storage. Therefore, the objective of the dormancy and seed germination study was to determine the optimum weeks of stratification required for maximum germination, minimum days to germination, and minimum days from first to last germinating seed for wild blue indigo (*Baptisia australis* (L.) R. Br.), purple coneflower (*E. purpurea*), Maximilian sunflower (*H. maximiliani*), spike goldenrod (*Solidago petiolaris* Ait.) and Missouri ironweed (*Vernonia missurica* Raf.).

The objectives of the spacing study were to determine the optimum spacing for increased yield per plant and yield per square meter for several specialty cut flowers, to determine a cost analysis for the different spacings, and to determine if there was an "edge effect".

The objective of the annual study was to determine the effect of staggered planting dates on season long production and stem length of three annual cut flowers species—*Celosia cristata* 'Golden Triumph' celosia, *Cosmos bipinnatus* Cav. Ann. 'Sensation' cosmos, and *Pennisetum setaceum* (Forssk.) Chiov., fountain grass.

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CHAPTER II

STRATIFICATION IMPROVES GERMINATION OF FIVE NATIVE CUT FLOWERS

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Additional index words. *Baptisia australis*, *Echinacea purpurea*, *Helianthus maximiliani*, *Solidago petiolaris*, *Vernonia missurica*

Abbreviations: RNG, germination range, days from first to last germinating seed.

Abstract. The effect of length of stratification on germination rate, percentage and range was investigated on *Baptisia australis* (L.) R. Br., wild blue indigo; *Echinacea purpurea* (L.) Moench., purple coneflower; *Helianthus maximiliani* Schrad., Maximilian sunflower; *Solidago petiolaris* Ait., spike goldenrod; and *Vernonia missurica* Raf., Missouri ironweed. Seed viability was determined using triphenyl tetrazolium chloride staining and germination based on percent viable seed. Seeds were stratified 0, 2, 4, 6, 8, or 10 weeks at 5C. The number of days to germination decreased in all five species as weeks of stratification increased. Germination percent for all five species increased as weeks of cold increased, but was most significant for Maximilian sunflower and Missouri ironweed. Days from first to last germinating seed significantly decreased in all five species as weeks of cold increased. Optimum storage time for maximum germination was four weeks for purple coneflower and Missouri ironweed, six weeks for Maximilian sunflower, and ten weeks for wild blue indigo and spike goldenrod.

Introduction

Interest in the use of native wildflowers as low-maintenance ornamentals, landscape plantings, and for prairie preservation has increased (Cox and Klett, 1984; Salac, et al. 1982). Wildflowers may be suited for cut flower production in Oklahoma because of their adaptation to the local environment, relatively low maintenance requirement, and low water requirements. Preliminary work (Dole, unpublished) identified five species with potential use as cut flowers—wild blue indigo, purple coneflower, Maximilian sunflower, spike goldenrod, and Missouri ironweed. Some criteria for selecting possible wildflowers included rapid, uniform germination and rooting; resistance or tolerance to insect and disease damage; attractive flower color; strong stems with sufficient length for cut flowers; and a long postharvest flower life.

Germination requirements have been determined for certain wildflowers (Allen and Meyer, 1990; Kitchen and Meyer, 1991; Salac and Hesse, 1975). The physiological dormancy associated with many wildflowers discourages growers since plugs for transplanting and flowers for cutting cannot be produced uniformly and in a timely manner. Developing procedures for breaking seed dormancy could benefit the industry since larger, more uniform crops could be produced. Field establishment for purple coneflower was unaffected by either spring or fall sowing (Smith-Jochum and Albrecht, 1987). Germination rate was highest when placed in moist sand or peat at 0C for one month.

Germination of Maximilian sunflower for revegetation of disturbed rangelands was evaluated at several moisture stress levels and temperature regimes. Cumulative germination was highest at water potentials of 0 and -0.25 Mpa in the 25/15C (day/night) temperature regime (Owens and Call, 1985). Direct seeding and field establishment of Maximilian sunflower yielded the highest emergence in either November or April in Nebraska (Salac, et al. 1982).

Successful germination procedures are needed for growers to produce transplants in greenhouses. Therefore, this study was conducted to determine the optimum weeks of stratification each species required for maximum germination, minimum days to germination, and minimum days from first to last germinating seed.

Materials and Methods

Seeds of spike goldenrod and Missouri ironweed were collected in Fall 1990, and seeds of purple coneflower, wild blue indigo, and Maximilian sunflower were obtained from producers (Park Seed Co., Greenwood, S.C.; Germania Seed Co., Chicago, IL). The seeds were stored at 20 $\pm$4C until initiation of experiment on 15 June 1991.

The viability of the five wildflower species was determined using triphenyl tetrazolium chloride staining. Four 50-seed replications were soaked in distilled water in the dark for 12 h and then pierced with a needle. The seeds were placed in 9-cm plastic petri dishes lined with P8-creped filter paper (Fisher Scientific, Pittsburgh, PA) containing a 0.1% (w/v) solution of triphenyl tetrazolium chloride (TTC). After 48 hours the seeds were bisected under a dissecting microscope. Embryos stained red were considered viable, while all others were considered not viable (Allen and Meyer, 1990).

Seeds of all five species were subjected to six treatments: 20 $\pm$3C (0-week stratification), 5 $\pm$2C for 2 weeks (2-week stratification), 5 $\pm$2C for 4 weeks (4-week stratification), 5 $\pm$2C for 6 weeks (6-week stratification), 5 $\pm$2C for 8 weeks (8-week stratification), and 5 $\pm$2C for 10 weeks (10-week stratification). For each treatment four 50-seed replications of all species, except wild blue indigo (10/seeds per replication), were randomly placed in covered petri dishes and moistened with distilled water as needed. Petri dishes were placed in the dark at 5C for the duration of each stratification treatment, and following removal the seeds were placed at 20$\pm$3C in the light. The experiment was repeated in 1992 for wild blue indigo with the same materials and methods as in the first year with seeds per replication increased to eighteen.

Number of germinated seeds was recorded daily; seed was considered germinated when the radicle was 1 mm. The number of days from first to last germinating seed within a species was the germination range (RNG). Germination percent was based on percent of viable seeds for each species. For example, if viability was determined to be 50% and 25 seeds germinated out of 50 seeds planted, then percent germination was 100%. Optimum weeks of stratification for each species was determined and equations were calculated to predict days to desired percent germination using regression techniques (SAS Institute, Cary, N.C.).

Results and Discussion

Wild blue indigo. Germination percentage for seeds at two and four weeks of stratification was significantly lower than seeds which received zero weeks of stratification. However, after four weeks of stratification the germination percentage steadily increased (Figure 2.1). Possibly the seeds developed secondary dormancy upon initial exposure to the low temperature and then eventually overcame this dormancy (Bewley and Black, 1982). The highest germination percentage was obtained after ten weeks stratification. Both percent germination and number of days to germination were quadratically effected by length of the cold storage (Table 2.1). Number of days from first to last germinating seed, RNG, decreased linearly. Days to desired percent germination (y) after ten weeks of stratification could be predicted using the equation $y=1.7 + 9.26(x*v)^3$ ($R^2=0.43$, $P\geq 0.0001$), where x=percent germination desired and v=viability of the species. Viability was 67.5%.

Purple coneflower. Four weeks of cold produced the highest germination percentage and germination percentage was not increased with further weeks of stratification (Figure 2.2). The germination percent exhibited a quadratic response, while RNG decreased linearly (Table 2.1). Number of days to germination responded cubically. The equation to predict the number of days to desired percent germination after four weeks of stratification was $y=1.54 + 4.62(x*v)^2$ ($R^2=0.93$, $P\geq 0.0001$). Viability was 93.5%.

Maximilian sunflower. The highest overall germination percentage was at six weeks of stratification and further weeks of stratification did not significantly increase the germination percentage (Fig. 2.3). Germination percent responded cubically in relation to the weeks of cold (Table 2.1). The RNG decreased linearly, and days to germination was a cubic response. To estimate the number of days to desired percent germination after six weeks of stratification, the equation $y=0.55 + 5.59(x*v)^2$ ($R^2=0.90$, $P\geq0.0001$) could be used. Viability was 94%.

Spike goldenrod. The optimum weeks of stratification was ten weeks (Fig. 2.4). As the seeds remained in the cold, days to germination responded quadratically (Table 2.1). Days to desired percent germination after ten weeks of stratification could be predicted with the equation $y=2 + 26.7(x*v)$ ($R^2=0.67$, $P\geq0.0001$). Viability was 20.5%.

Missouri ironweed. The optimum treatment was four weeks of stratification (Fig. 2.5). Germination percent and RNG both showed a positive linear response (Table 2.1). Number of days to germination exhibited a quadratic response. Number of days to desired percent germination after four weeks of stratification could be predicted with the equation $y=1.11 + 8.39(x*v)$ ($R^2=0.93$, $P\geq0.0001$). Viability was 63.5%.

The four weeks of cold for optimum germination of purple coneflower (Table 2.1, Fig. 2.2) was similar to previous findings that at 0C for one month, germination is increased (Smith-Jochum and Albrecht, 1987). Maximilian sunflower reached 98% of total germination with a range of six days after six weeks of stratification (Table 2.1, Fig. 2.3). Even though further weeks of cold raised it to 100%, the RNG remained the same. Also, after six weeks at 5C, seeds had already germinated in the cooler.

While all of the wildflower seeds responded positively to stratification, neither wild blue indigo nor Missouri ironweed germinated to their full potential. These species might benefit from longer periods of stratification since both species possibly went into secondary dormancy and further weeks of cold may be necessary to break the secondary dormancy. All viable seeds of purple coneflower, Maximilian sunflower, and spike goldenrod germinated.

Growers often face difficulties with producing plugs of species with low germination percentage, uneven germination and a large RNG. Plugs are important for the production of transplants; already 88 percent of total bedding plant production is from plugs (Martens, 1989). Depending on the species, RNG was decreased significantly, and the germination percentage of the five species was increased with four to ten weeks cold, which is important for rapid germination resulting in less disease and shorter production times. Therefore, with this information growers could increase their plug production performance.

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Table 2.1. Trend analysis on the effect of temperature on percent germination, days from first to last germinated seed (RNG) and average days to germination of five native wildflowers after 0, 2, 4, 6, 8, or 10 weeks of 5C stratification.

	Percent germination	RNG	Days to germination
		Wild blue indigo	
Linear	NS	0.0001	0.0001
Quadratic	0.01	NS	0.0001
Cubic	NS	NS	NS
		Purple coneflower	
Linear	NS	0.04	0.0001
Quadratic	0.01	NS	0.0001
Cubic	NS	NS	0.0147
		Maximilian sunflower	
Linear	0.0001	0.0043	0.0001
Quadratic	0.0001	NS	0.0001
Cubic	0.0001	NS	0.016
		Spike goldenrod	
Linear	NS	NS	0.0001
Quadratic	NS	NS	0.0170
Cubic	NS	NS	NS
		Missouri ironweed	
Linear	0.0001	NS	0.0001
Quadratic	NS	NS	0.0011
Cubic	NS	NS	NS

[NS]Nonsignificant

Fig. 2.1. Percent germination (based on percent of viable seeds) (··●··), days from first to last germinated seed (RNG –⊟–), and average days to germination (–◇–) of wild blue indigo after 0, 2, 4, 6, 8, or 10 weeks of 5C stratification. Values are means ± SE.

Fig. 2.2. Percent germination (based on percent of viable seeds) (··●··), days from first to last germinated seed (RNG –⊟–), and average days to germination (–◇–) of purple coneflower after 0, 2, 4, 6, 8, or 10 weeks of 5C stratification. Values are means ± SE.

Fig. 2.3. Percent germination (based on percent of viable seeds) (··●··), days from first to last germinated seed (RNG –⊟–), and average days to germination (–◇–) of Maximilian sunflower after 0, 2, 4, 6, 8, or 10 weeks of 5C stratification. Values are means ± SE.

Fig. 2.4. Percent germination (based on percent of viable seeds) (··●··), days from first to last germinated seed (RNG –⊟–), and average days to germination (–◇–) of spike goldenrod after 0, 2, 4, 6, 8, or 10 weeks of 5C stratification. Values are means ± SE.

Fig. 2.5. Percent germination (based on percent of viable seeds) (··●··), days from first to last germinated seed (RNG –⊟–), and average days to germination (–◇–) of

Missouri ironweed after 0, 2, 4, 6, 8, or 10 weeks of 5C stratification. Values are means ± SE.

Fig. 2.1.

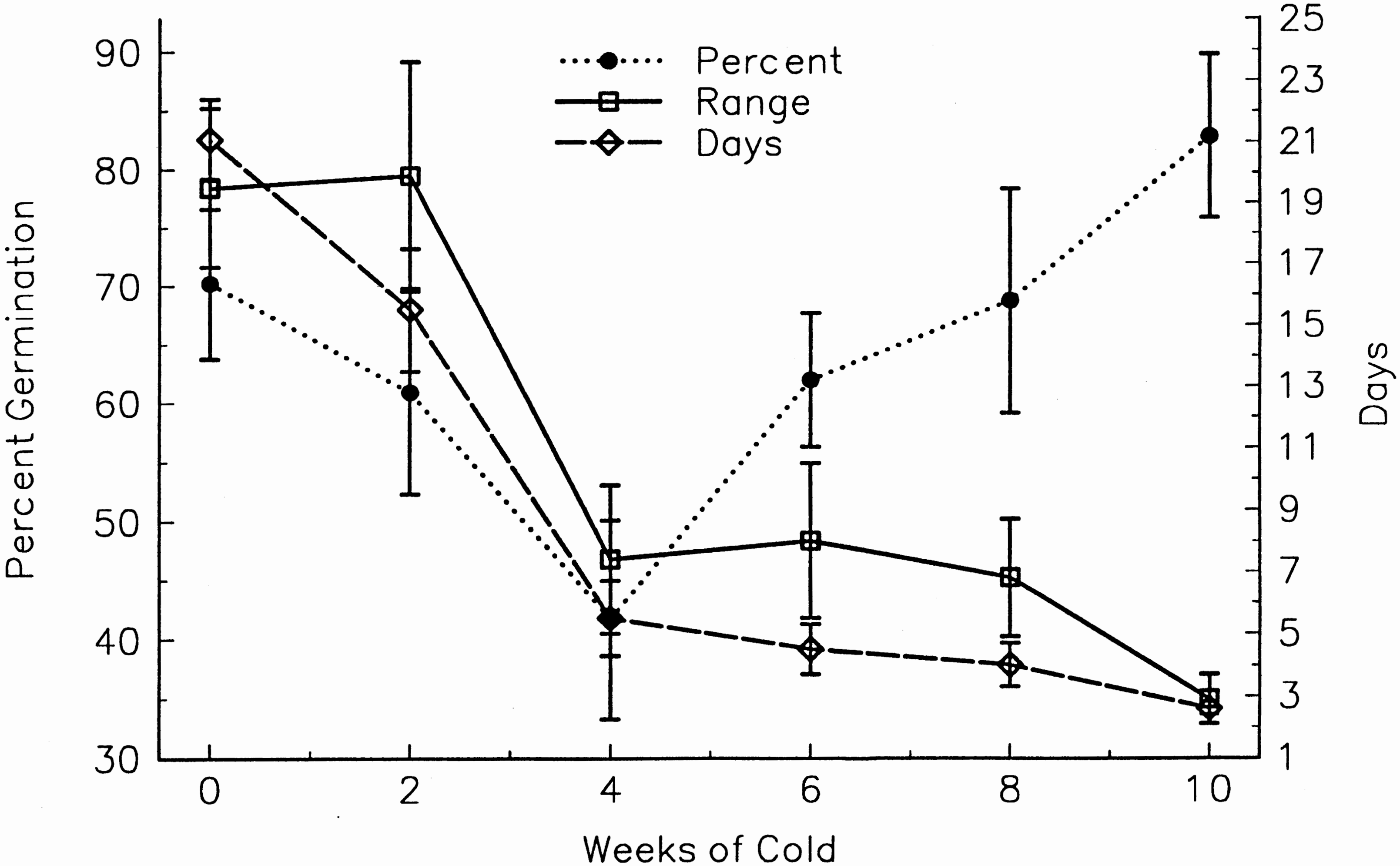
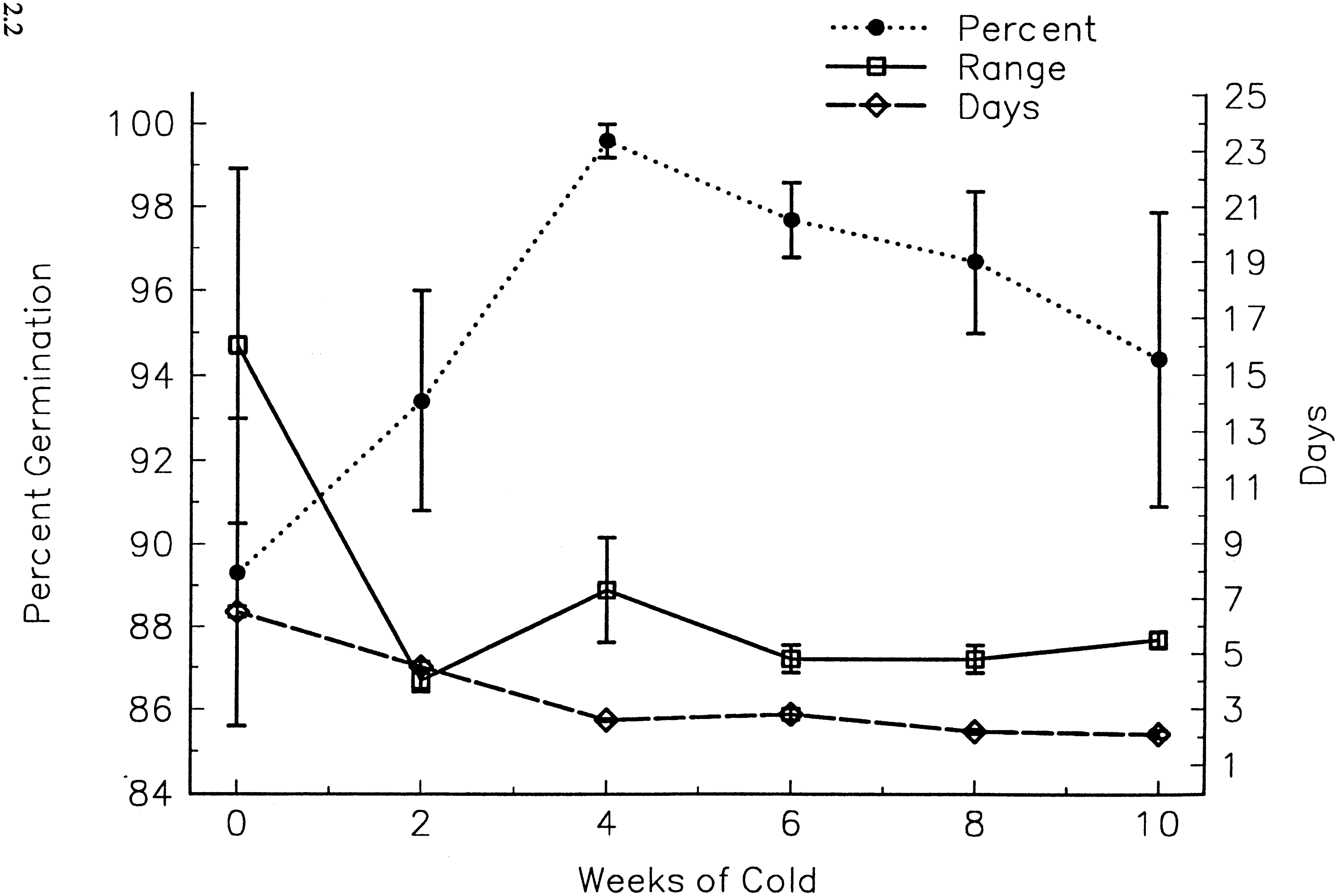
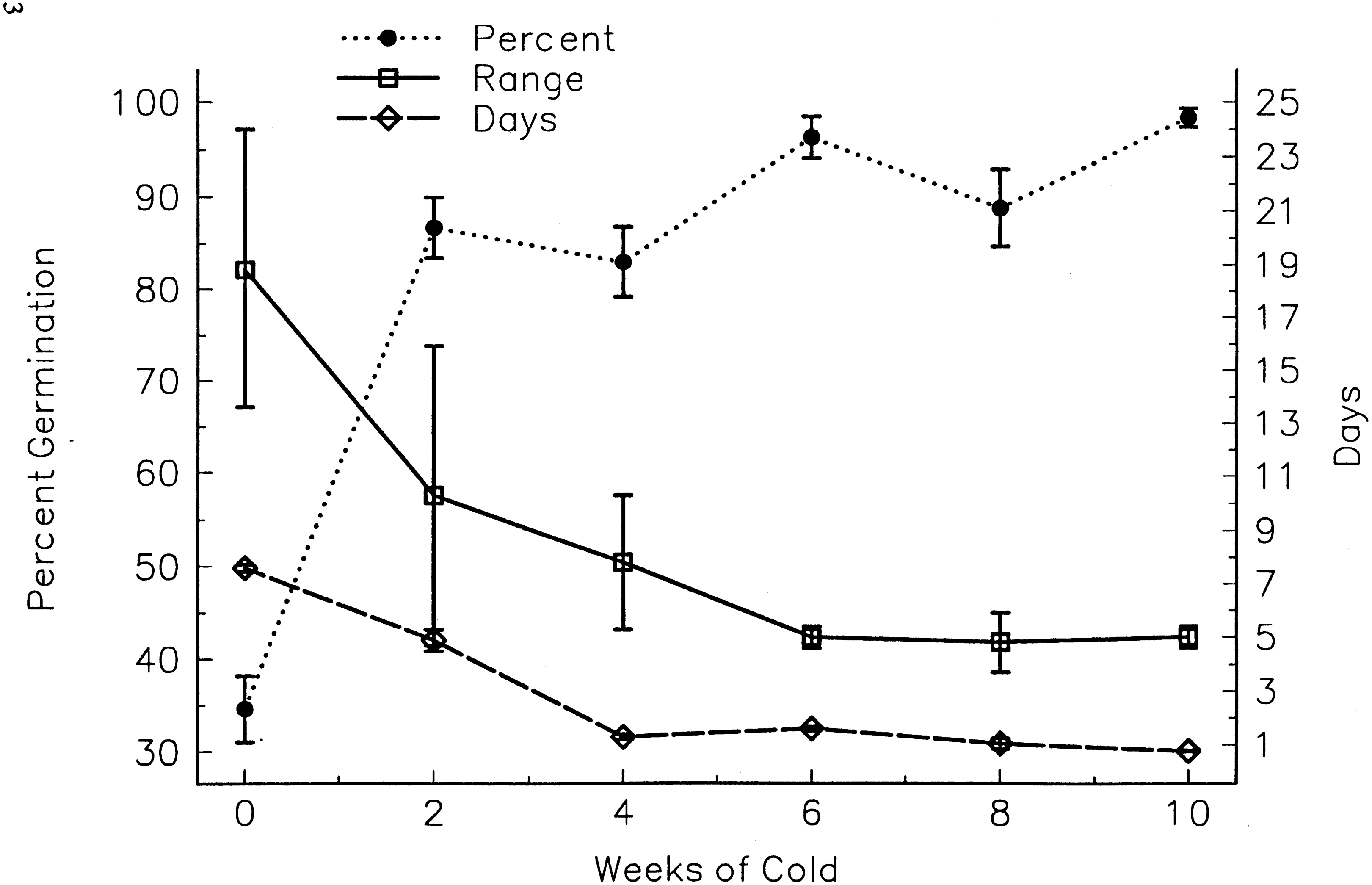

Percent
Range
Days
Percent Germination
Days
Weeks of Cold
90
80
70
60
50
40
30
25
23
21
19
17
15
13
11
9
7
5
3
1
0
2
4
6
8
10

Fig. 2.2



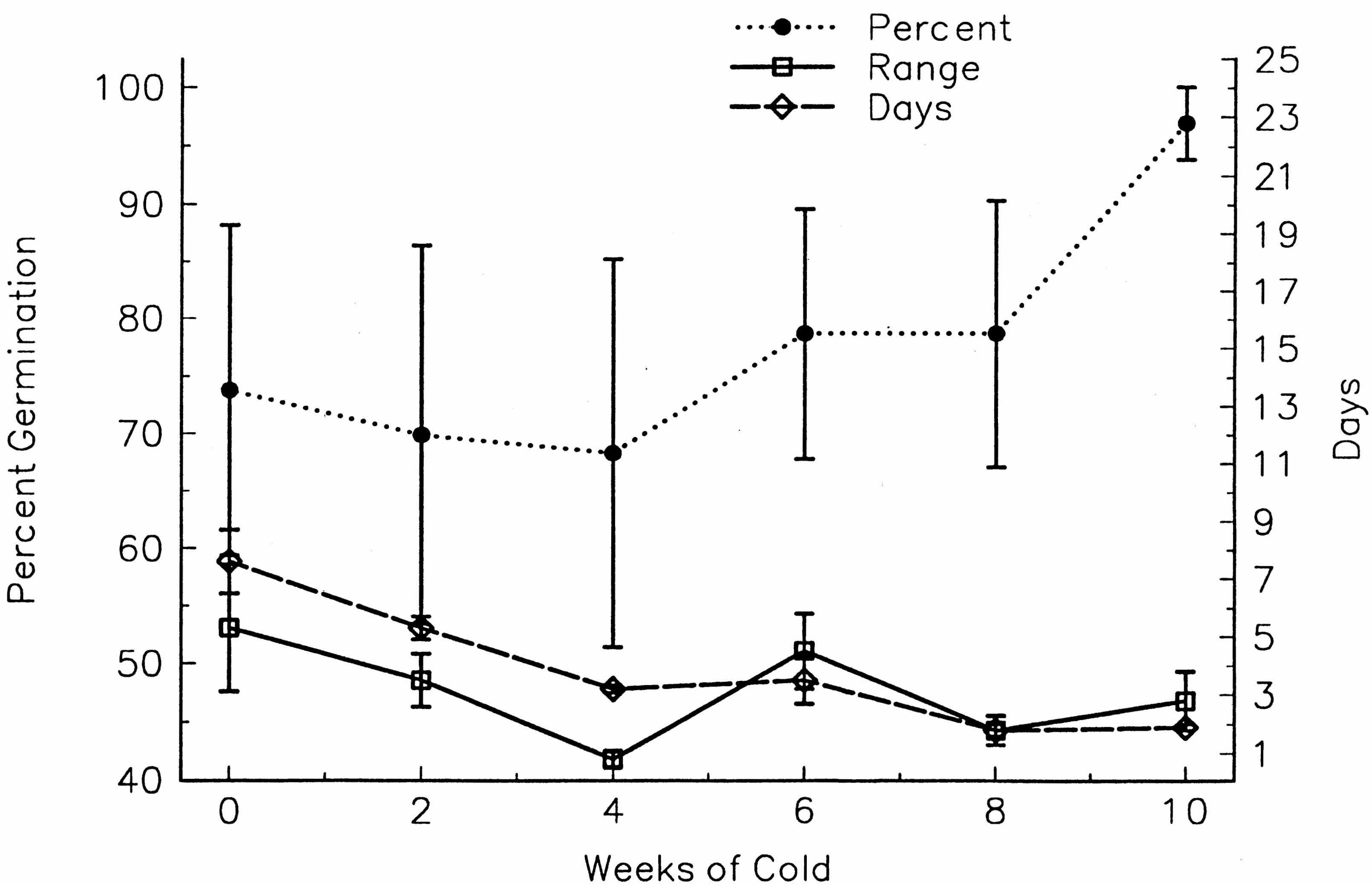
Percent
Range
Days
Percent Germination
Days
Weeks of Cold
100
98
96
94
92
90
88
86
84
25
23
21
19
17
15
13
11
9
7
5
3
1
0
2
4
6
8
10

Fig. 2.3



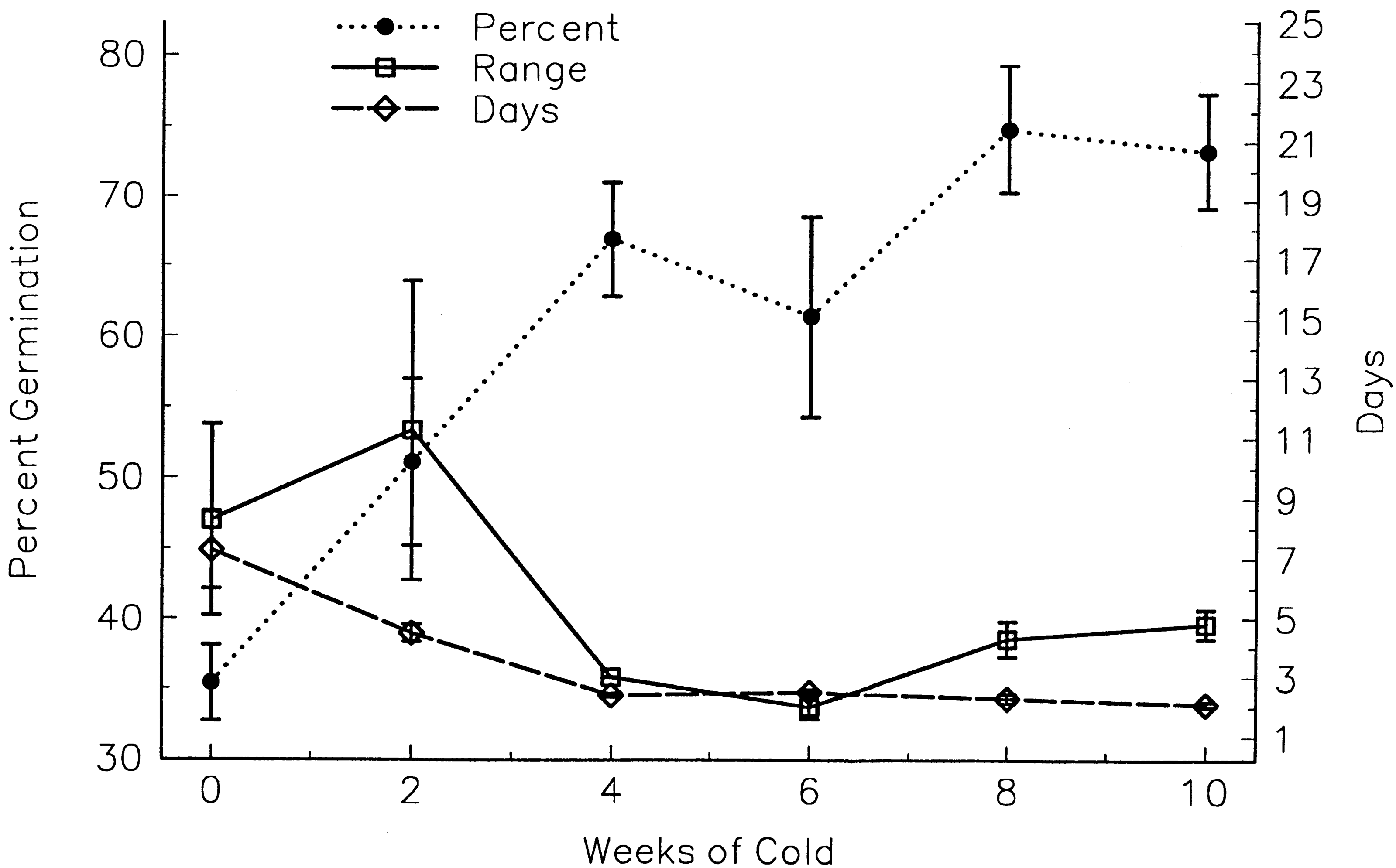
Percent
Range
Days
Percent Germination
100
90
80
70
60
50
40
30
25
23
21
19
17
15
13
11
9
7
5
3
1
Days
0
2
4
6
8
10
Weeks of Cold

Fig. 2.4



Percent
Range
Days
Percent Germination
Days
Weeks of Cold
100
90
80
70
60
50
40
25
23
21
19
17
15
13
11
9
7
5
3
1
0
2
4
6
8
10

Fig. 2.5



Percent
Range
Days
Percent Germination
80
70
60
50
40
30
25
23
21
19
17
15
13
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9
7
5
3
1
Days
0
2
4
6
8
10
Weeks of Cold

CHAPTER III

SPACING AND COST ANALYSIS OF FIELD-GROWN SPECIALTY CUT FLOWERS IN OKLAHOMA

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Additional index words. *Achillea filipendulina* 'Cloth of Gold', *Achillea millefolium* 'Summer Pastels', *Achillea taygetea* 'Debutante', *Eustoma grandiflora* 'Blue', *Kniphofia uvaria* 'Pfitzer Hybrid', *Baptisia australis*, *Centaurea macrocephala*, *Pennisetum setaceum*, *Celosia cristata*, *Gomphrena globosa*, and *Limonium sinuatum*.

Abstract. *Achillea millefolium* L. 'Summer Pastels' yarrow, *Achillea taygetea* Boiss. and Heldr. 'Debutante' yarrow, *Eustoma grandiflora* (Raf.) Shinn. 'Blue' prairie gentian, and *Kniphofia uvaria* L. 'Pfitzer Hybrid' red hot poker were planted at three different spacings: 30 x 15-cm, 30 x 30-cm, and 30 x 45-cm. *Achillea filipendulina* Lam. 'Cloth of Gold' yarrow was planted at seven spacings: 15 x 15-cm, 15 x 30-cm, 30 x 15-cm, 30 x 30-cm, 45 x 15-cm, 45 x 30-cm, and 45 x 45-cm. For all the species an increase in spacing distance increased yield per plant, but decreased yield per square meter. With the greater number of plants per square meter, cost per square meter increased. Cost per stem was lowest for the wider spacings in 'Cloth of Gold' yarrow, 'Debutante' yarrow, and 'Pfitzer Hybrid' red hot poker. 'Blue' prairie gentian had the lowest cost per square meter at the closest spacing. Cut flower stems harvested from plants growing in the center of the bed were longer than those harvested from edge plants for *Baptisia australis* (L.) R. Br., wild blue indigo; *Pennisetum setaceum* (Forssk.) Chiov., dwarf top feather grass; and *Gomphrena globosa* L. 'Lavender Lady' globe amaranth. Stem length was not influenced by position within the bed for *Centaurea macrocephala* Pushk. ex Willd., perennial bachelor's button. Yield per plant was not effected for any species by bed position.

Introduction

General recommendations for the spacing of field-grown specialty cut flowers by Armitage (1992a) indicated that plants are typically spaced at 22.5 x 22.5 cm, 22.5 x 30-cm, 30 x 30-cm, or 30 x 32.5 cm. Some species may be spaced at 15 x 15-cm to increase yield per square foot, but the stems are usually weaker because of lack of air movement and reduced light. Since many field grown cut flowers are herbaceous perennials that increase by spreading with age, Armitage (1987) studied the following species planted on 30-, 60-, 90-, or 120-cm centers—*Achillea filipendulina* 'Coronation Gold', *Achillea millefolium* L. 'Rose Beauty', *Physostegia virginiana* L., *Liatris pycnostachya* Michx., and *Salvia leucantha* Cav. for 2-3 years. He found that with increased spacing the number of flowering stems per plant increased, but the number of stems per square meter decreased with time. He also suggested that for 'Coronation Gold' yarrow the 90-cm spacing was optimum for long stems. Even though the wider spacings had significantly increased yield per plant, the yield per square meter may have declined with increased spacing because of greater non-productive space per unit area.

In order to determine the effect of plant age and plant spacing on stem yield and quality for different species of *Achillea*, Armitage (1992b) grew *Achillea filipendulina* 'Coronation Gold'; six cultivars of *Achillea millefolium*, 'Heidi', 'Kelwayi', 'Lilac Beauty', 'Paprika', 'Sawa Sawa', and 'White Beauty'; *Achillea ptarmica* L.; and four cultivars of the Galaxy series, 'Appleblossom', 'The Beacon', 'Great Expectations', and 'Salmon Beauty', (*Achillea taygetea* Boiss. & Heldr. x *Achillea millefolium*).

'Coronation Gold' yarrow was planted on 30-, 60-, 90-, or 120-cm centers, while all other plants in the study were planted on 30-cm centers following recommendations from Armitage (1987). Flower yield, average stem diameter, and stem length were least the first year, and no differences occurred between the 2-5 years for 'Coronation Gold' yarrow. The 30-cm spacing resulted in the poorest yield per plant, the highest yield per square meter, and the greatest number of long stems for 'Coronation Gold' yarrow. The Galaxy hybrids reached their full potential for stem length and flower size during the second season, but yield continued to increase with time. *Achillea ptarmica* yield increased significantly from the first to the second year, which was attributed to the more vigorous root systems in the older plant.

Studies over plant density have also been performed in the greenhouse. Durkin and Janick (1966) found that yield per plant decreased as plant density increased on greenhouse grown carnations (*Dianthus caryophyllus* L.) in benches. An "edge effect" was noted where plants on the edges of the bench were more productive than plants in the center of the bench. Weinard and Decker (1930) also noted greater productivity on outside rows compared to center rows with roses (*Rosa hybrida* L.) and carnations. Previous work by Dole (unpublished) indicated that depending upon the species, plants in the center of the bed typically produced longer-stemmed flowers than those on either edge.

Since documented studies over spacing were only found for the production of yarrow, and many other plants are being grown as specialty cut flowers, a study of other species would be beneficial to growers. The objectives of this study were to determine the optimum spacing for several specialty cut flowers, to determine the effect of position within the bed and to estimate the profitability of growing these cut flowers.

Materials and Methods

Expt. 1. Seed of 'Cloth of Gold' yarrow, 'Summer Pastels' yarrow, 'Debutante' yarrow, 'Blue' prairie gentian, and 'Pfitzer Hybrid' red hot poker were obtained from producers (Park Seed Co., Greenwood, S.C.) and sown in a commercial soilless mix (Fafard Growing Peat Mix No. 2, Hummert Seed Co., St. Louis, MO). The transplants were planted in beds of a norge loam (fine-silty, mixed, thermic Udic Paleustolls) soil at Oklahoma State University located in climate zone 7a (U.S. Department of Agriculture, 1990) in Spring 1990. Following a soil analysis, 7.9 g ammonium nitrate and 15.8 g limestone were incorporated per square meter into the beds. A controlled-release fertilizer (19-6-12, Osmocote, Hummert Seed Co., St. Louis, MO) was applied at 0.8 $g \cdot m^{-2}$ as a side-dressing in the spring. The plants were arranged in a split-plot design with plant spacing as the whole plot and edge (inside plants in a cross row versus outside plants in a cross row) as the sub-plot. 'Cloth of Gold' yarrow was planted at 45 x 15-cm, 45 x 30-cm, or 45 x 45-cm spacings with 12 plants per replications; 30 x 15-cm, or 30 x 30-cm with 16 plants per replication; 15 x 15-cm, or 15 x 30-cm spacings with 28 plants per replication, with all seven spacings at three replications. All other species were planted at three replications with 16 plants per replication at the following spacings: 30 x 15-cm, 30 x 30-cm, or 30 x 45-cm, and for statistical analysis, data from border rows were not used, resulting in 12 plants per replication. Border rows were used in the calculations for 'Cloth of Gold' yarrow because the plants became a dense mat in a short time, and therefore individual rows could not be distinguished. The stem length of 'Blue' prairie gentian was recorded as less than 30 cm or greater than 30 cm instead of an actual length.

Stems were harvested as needed and yield per plant and stem length (from base of stem to top of flower) were recorded. Stems within cultivars were analyzed by analysis of variance (ANOVA) with mean differences analyzed by trend analysis and Duncan's multiple range test (SAS Institute, Cary, N.C.).

A spreadsheet template was created to calculate the costs associated with installation, maintenance, and upkeep of the cut flower beds (Microsoft Excel, Microsoft Corporation, Redmond, WA) which determined the cost per square meter of bed space for species grown in Expt. 1 and 2 (Fig. 3.1). Costs included in the analysis were all supplies used for the irrigation system, such as polyvinylchloride pipe, flexible polyethylene pipe, bi-wall drip irrigation tubing, feeder tubes, and a filter (Hummert Seed Co., St. Louis, MO); herbicides and fertilizers (Senesac, 1988; Stimart, 1988); t-posts and netting used for support of the stems; initial field labor such as plowing, planting, and installation of the irrigation system; and weekly field labor associated with general maintenance and cultivation. Labor costs for the harvesting of the cut flowers was determined for each species as a predetermined estimation of harvest time per stem. Costs not included in the analysis were land, equipment, depreciation and water use. The cost per square meter of bed was determined and was used to determine the cost of each stem produced in the bed. A second spreadsheet was created to determine the cost for individual species.

Expt. 2. In addition to the edge effects studied in Expt. 1, the following plants were spaced on 30-cm centers in a completely randomized design with three replications of 16 plants each—wild blue indigo, perennial bachelor's buttons, 'Lavender Lady' globe amaranth, 'Forest Fire' celosia, florist's statice, and dwarf feather top grass. Plants in the border rows were not used in the statistical analysis. Field preparation and data taken were the same as in Expt. 1. Stem length of 'Forest Fire' celosia and florist's statice was recorded as less than 30 cm or greater than 30 cm instead of an actual length. Stem length was measured at harvest and analyzed within each cultivar using analysis of variance (ANOVA).

Results and Discussion

'Cloth of Gold' yarrow. Yield significantly decreased from the first to the second year between spacings (Table 3.1). An increase in spacing distance increased yield per plant with a decreased yield per square meter. Stem length was effected by spacing with the longest stem length at the smallest spacings in 1991 (Table 3.1). As discussed by Armitage (1992b), the longer stem lengths at decreased spacings indicated that plants branched poorly at such dense spacing. Bed position did not effect stem length or yield per plant (data not presented) and there was no interaction between spacing and edge. Even though the initial results indicated the 15 x 15-cm spacing was optimum for increased stem length and yield per square meter, decreased

spacing required a larger number of plants per square meter, resulting in a higher cost per square meter than increased spacing for 1991 (Table 3.2). Also, there were fewer stems per plant at decreasing spacing (Table 3.1). Therefore, stems from plants grown on the 15 x 15-cm spacing cost $0.113 while stems from plants grown on the 45 x 45-cm spacing cost $0.068 for 1991 (Table 3.2).

'Summer Pastels' yarrow. Yield increased significantly the second year, while stem length decreased (Table 3.3). Different spacings had no effect on stem length or yield; the plants may have grown rapidly and filled in the first year, and thus spacing had little or no effect. The effect of edge on stem length was not significant for 1990 or 1991 (Table 3.4). No interaction was found between edge and spacing. Results indicated that closer spacing would result in the highest yield. For 1990 and 1991 the cost per stems varied largely with the first year producing a small crop and the second year producing a larger crop. The most profitable and productive spacing would be difficult to predict because of the large variability. For 1991, the lowest cost per stem was $0.076 for the 30 x 15-cm spacing, while the highest cost per stem was $0.108 at the 30 x 30-cm spacing (Table 3.2).

'Debutante' yarrow. No treatment difference was found in each year for length or yield, but yield increased the second year compared to the first year (Table 3.3). Although stems per square meter decreased with the increased spacing, the results were not significant (Table 3.3). Edge did not have an effect on stem length or yield (Table 3.4). For 1990, stems from plants spaced at 30 x 15-cm cost $0.897, while stems from plants spaced at 30 x 45-cm cost $0.599 to produce (Table 3.2). The cost

was higher per stem in 1990 because of low production in the first year. The cost per stem for 1991 did not decrease with the increased spacing. Therefore, the most profitable spacing would be difficult to accurately predict.

'Blue' prairie gentian. Stems greater than 30 cm per plant curvilinearly increased as spacing increased (Table 3.3). Data were taken only for 1990 because many of the plants died during the following winter. Edge did not have an effect on yield per plant (data not presented). Stems from plants grown on the closest spacing cost the least to produce, $0.165, using only stems greater than 30 cm in the calculation. Therefore, for this species decreased spacing resulted in the highest yield per square meter with the lowest cost per stem.

'Pfitzer Hybrid' red hot poker. As the spacing increased, the number of stems per plant increased linearly in 1992. The yield significantly from 1991 to 1992. Plants were planted in 1990, but did not yield flowers until 1991. The cost per stem decreased as spacing increased in 1992 (Table 3.2). For 1992, stem from plants spaced at 30 x 15-cm cost $0.518, while stems from plants spaced at 30 x 45-cm cost $0.344 (Table 3.2). Therefore, this species would be more profitably grown at increased spacings.

Wild blue indigo. Transplants were placed in the field in 1990, but flowers were not produced until 1991. All plants were spaced on 30-cm centers and the cost per stem was $0.385 (Table 3.2). Flowers cut from plants on either end of the cross-row, *i.e.*, the edge, were significantly shorter than the flowers from plants in the center of the row (Table 3.4).

'Lavender Lady' globe amaranth. Differences in yield between 1990 and 1991 may have been caused by weather conditions, so the cost per stem varied for each year. All plants were spaced on 30-cm centers and the cost per stem was $0.015 for 1990 and $0.067 for 1991 (Table 3.2). Stems from plants on the edge were significantly shorter than stems from plants in the center of the bed in both years (Table 3.4).

Dwarf feather top grass. Stems cut from the center of the row were significantly longer than those from the edge (Table 3.4).

Perennial bachelor's button. The location of a plant within a row did not have an effect on the stem length (Table 3.4).

Florist's statice. There was no significant difference between inside plants versus outside plants on yield per plant (data not presented).

'Forest Fire' celosia. The number of stems from edge plants was not significantly different than the number of stems from center plants (data not presented).

All species had the highest yield per square meter at decreased spacings. While 'Blue' prairie gentian had the lowest cost per stem at the closest spacing, the other species generally had the lowest cost per stem at increased spacing. For species where location within the bed was significant on stem length, a production system with more plants in the center of the bed may be desired to produce longer stems. This study has shown that to produce specialty cut flowers many factors contribute to quality cut flower production. Even though yield was increased per square meter in most cases at decreased spacings, the cost of producing the stems at decreased spacing may be higher because of an increase in plant material cost. The choice of spacing should be based on the amount of available space and the desired profit per stem.

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Table 3.1. Two-year cut flower production of 'Cloth of Gold' yarrow at various spacings.

Year	Spacing (cm)	Stems/plant	Stems·m^{-2}	Length (cm)
1991	15 x 15	3.1	132.9	79.9 a[z]
	15 x 30	4.4	93.6	80.8 a
	30 x 15	2.7	57.5	66.4 b
	30 x 30	5.0	53.4	66.4 b
	45 x 15	4.9	69.7	69.8 b
	45 x 30	7.4	53.1	67.9 b
	45 x 45	11.9	56.3	68.4 b
1992	15 x 15	1.7	71.9	59.4 ab
	15 x 30	2.3	48.9	62.7 ab
	30 x 15	1.3	27.7	52.8 b
	30 x 30	1.6	16.8	56.6 ab
	45 x 15	1.5	22.0	66.9 a
	45 x 30	2.9	20.8	59.9 ab
	45 x 45	4.0	19.1	59.8 ab
Significance		*	**	

*, ** Significant at P=0.01 and 0.001, respectively.

[z]Means with the same letter are not significantly different using Duncan's multiple range test, P=0.05.

Table 3.2. Effect of spacing on cost per square meter and cost per stem for various cut flower species.

Year	Spacing (cm)	Cost·m^{-2} ($)	Cost/stem ($)
		'Cloth of Gold' yarrow	
1991	15 x 15	14.993	0.113
	15 x 30	8.731	0.093
	30 x 15	8.713	0.151
	30 x 30	5.589	0.105
	45 x 15	6.628	0.095
	45 x 30	4.560	0.086
	45 x 45	3.843	0.068
1992	15 x 15	14.963	0.208
	15 x 30	8.709	0.178
	30 x 15	8.879	0.320
	30 x 30	5.572	0.331
	45 x 15	6.604	0.300
	45 x 30	4.540	0.218
	45 x 45	3.825	0.201
		'Summer Pastels' yarrow	
1990	30 x 15	8.689	1.136
	30 x 30	5.568	0.608
	30 x 45	4.536	0.893
1991	30 x 15	8.741	0.076
	30 x 30	5.589	0.108
	30 x 45	4.556	0.099
		'Debutante' yarrow	
1990	30 x 15	8.689	0.897
	30 x 30	5.567	0.728
	30 x 45	4.537	0.599

1991	30 x 15	8.716	0.137
	30 x 30	5.579	0.172
	30 x 45	4.552	0.122
		'Pfitzer Hybrid' red hot poker	
1991	30 x 15	8.688	1.223
	30 x 30	5.557	2.347
	30 x 45	4.536	0.912
1992	30 x 15	8.693	0.518
	30 x 30	5.569	0.475
	30 x 45	4.539	0.344
		Wild blue indigo	
1991	30 x 30	5.803	0.385
		'Lavender Lady' globe amaranth	
1990	30 x 30	5.993	0.015
1991	30 x 30	5.838	0.067

Table 3.3. Effect of spacing on length and yield of various cut flower species.

Year	Spacing (cm)	Stems/plant (cm)	Stems·m^{-2}	Length
		'Summer Pastels' yarrow		
1990	30 x 15	0.3	5.9	37.3
	30 x 30	0.9	9.3	36.5
	30 x 45	0.7	5.5	36.1
	Linear	NS	NS	NS
	Quadratic	NS	NS	NS
1991	30 x 15	5.3	114.1	33.7
	30 x 30	4.8	51.7	33.7
	30 x 45	6.3	67.8	34.9
	Linear	NS	NS	NS
	Quadratic	NS	NS	NS
		'Debutante' yarrow		
1990	30 x 15	0.4	9.5	34.1
	30 x 30	0.7	7.8	35.0
	30 x 45	1.1	7.5	33.9
	Linear	NS	NS	NS
	Quadratic	NS	NS	NS
1991	30 x 15	2.9	63.5	38.8
	30 x 30	3.0	32.5	37.2
	30 x 45	5.2	37.5	38.3
	Linear	NS	NS	NS
	Quadratic	NS	NS	NS

		'Pfitzer Hybrid' red hot poker		
1991	30 x 15	0.3	7.1	59.6
	30 x 30	0.2	2.4	62.6
	30 x 45	0.7	4.9	64.7
	Linear	NS	NS	NS
	Quadratic	NS	*	NS
1992	30 x 15	0.8	16.8	56.9
	30 x 30	1.1	11.7	58.1
	30 x 45	1.8	13.2	59.6
	Linear	*	NS	NS
	Quadratic	NS	NS	NS
		'Blue' prairie gentian		
1990	30 x 15	2.5	54.0	
	30 x 30	2.6	28.5	
	30 x 45	3.3	23.4	
	Linear	*	NS	
	Quadratic	*	*	

^{NS},* Nonsignificant or significant at P=0.01, respectively.

Table 3.4. Effect of position within the row on stem length of various cut flower species.

Species	Year	Edge (cm)	Within row (cm)	Significance
'Summer Pastels' yarrow	1990	34.1	34.13	NS
	1991	37.2	35.9	NS
'Debutante' yarrow	1990	33.9	34.7	NS
	1991	38.3	37.7	NS
Wild blue indigo	1991	36.7	40.8	*
'Lavender Lady' globe amaranth	1990	37.6	38.7	*
	1991	51.0	54.0	*
Dwarf feather top grass	1990	53.4	57.1	*
'Pfitzer Hybrid' red hot poker	1991	58.4	63.4	NS
	1992	59.1	57.5	NS
Perennial bachelor's button	1991	32.1	34.1	NS

^{NS},*Nonsignificant or significant at P=0.01, respectively.

Fig. 3.1. Spreadsheet template of expenses associated with cut flower production.

		Length (feet)	Width (feet)	Bed Size (sq.ft.)
What is the length and width (in feet) of the proposed bed?		120	4.00	480.00
What is the width of the walkway (in feet) between beds?			4.00	
How many beds do you propose constructing?	7			
What is the distance from your irrigation well to the header line for the beds?			25.00	

Qty/field	Unit	Material Description	Longevity (years)	Unit Cost($)	Extended Cost($)	Cost($)/year	Cost($)/year/sq.ft.	Cost($)/year/sq.m.
98	ea	T-Post with clips, 5 1/2'	15	2.02	197.96	13.20	0.0039	0.0423
25	feet	PVC Pipe, 1", Sch. 40	10	0.42	10.50	1.05	0.0003	0.0034
52	feet	Flexible Polyethylene Pipe	10	0.20	10.14	1.01	0.0003	0.0032
2583	feet	Bi-wall Drip Irrigation Tubing, 10 mil	1	0.03	85.24	85.24	0.0254	0.2731
21	feet	Feeder Tubing	1	0.02	0.38	0.38	0.0001	0.0012
1	ea	Spin Clean Supply Line Filter	10	19.00	19.00	1.90	0.0006	0.0061
840	feet	Plant Support Netting	2	0.10	84.00	42.00	0.0125	0.1346
2.08	qt	Pre-emergent Herbicide, Surflan	1	25.75	53.63	53.63	0.0160	0.1718
0.05	gal	Post-emergent Herbicide, Poast	0.5	157.55	8.62	17.23	0.0051	0.0552
4.38	oz	Spreader Sticker	0.5	0.39	1.72	3.45	0.0010	0.0110
4.63	lbs	Ammonium Nitrate, 34-0-0	1	0.14	0.64	0.64	0.0002	0.0021
9.26	lbs	Limestone	1	0.04	0.32	0.32	0.0001	0.0010
56	lbs	Osmocote, 19-6-12 (3-4 month)	1	0.98	54.77	54.77	0.0163	0.1755
40	hrs	Field Preparation	1	5.00	200.00	200.00	0.0595	0.6407
72	hrs	Field Maintenance and Cultivation	1	5.00	360.00	360.00	0.1071	1.1533
						Start Up Cost/year/sq.m.		2.2106
						Initial Investment/year/sq.m.		0.4638

CHAPTER IV

MULTIPLE PLANTING DATES ALLOW SEASON LONG PRODUCTION OF ANNUAL CUT FLOWERS

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Abstract. *Celosia cristata* L. 'Golden Triumph' celosia, and *Cosmos bipinnatus* Cav. Ann. 'Sensation' cosmos transplants were planted on four dates, May 16, June 2, June 18, and July 13, 1991, and *Pennisetum setaceum* (Forssk.) Chiov., fountain grass, transplants on two dates, June 2 and 18, 1991 to determine if staggered planting dates could be used to extend the production season of annual cut flowers. While the number of days to harvest increased from the June 2 to July 13 planting for 'Golden Triumph' celosia, the May 16 planting took the longest to flower. Number of days to harvest was not affected by the planting date, and the stem length increased with the later planting dates for 'Sensation' cosmos. For fountain grass, the number of days to harvest significantly decreased with later planting dates, but stem length was not affected by the planting date.

Introduction

Field production of specialty fresh or dried cut flowers typically consists of annuals and perennials. While perennials are often not commercially productive until the second year (Armitage, 1992b), annuals offer flowers for harvest in one year. A problem associated with the use of annuals is the lack of season long production for some species. It would be profitable for a grower to extend the flowering season. Staggered plantings, every two weeks in July, were suggested by Stevens and Gast (1992) to provide a continuous supply of flowers in Kansas. The use of multiple plantings was suggested by Armitage (1992a) and MacPhail (1986) to provide a constant supply of quality flowers for bulb crops, zinnia (*Zinnia elegans* Jacq.), and common sunflower (*Helianthus annuus* L.). However, limited published studies over this practice were found for annual cut flower production.

Healy and Aker (1988) studied the production season of asters (*Aster chinensis* (L.) Nees.), crested celosia (*Celosia cristata*), and zinnia. The harvest period for these species was extended four to six weeks through sequential plantings, spaced two weeks apart. Zinnia and celosia responded to the number of degree days, and days to harvest significantly decreased with later planting dates.

The practice of multiple planting dates has been studied in other crops. Chercuitte et al. (1991) investigated four planting dates on strawberries (*Fragaria* X *ananassa* L.) and found earlier season establishment produced larger plants and increased leaf area. Though optimum yield potential was not reached with the late planting date, the production season was extended beyond June. Multiple planting dates (early, mid, and late season) were also used on tomatoes (*Lycopersicon esculentum* Mill.) and did not have an effect on plant height, but the later planting date increased fruit weight compared to the earlier planting dates (Drost and Price, 1991). Yield per plant decreased with later planting dates. Another study with tomato found that later plantings also reduced yield compared to earlier plantings (Gray et al. 1979).

The objective of this study was to determine the effect of staggered planting dates, or multiple plantings, on season long production and stem length of *Celosia cristata* L. 'Golden Triumph' celosia, *Cosmos bipinnatus* Cav. Ann. 'Sensation' cosmos, and *Pennisetum setaceum* Chiov., fountain grass.

Materials and Methods

Seeds of 'Golden Triumph' celosia, 'Sensation' cosmos, and fountain grass were obtained from producers (Park Seed Co., Greenwood, S.C.; Germania Seed Co., Chicago, IL) and sown in a commercial soilless mix (Fafard Growing Peat Mix No. 2, Hummert Seed Co., St. Louis, MO). Following germination under mist (Ball, 1985), two-week old seedlings were transplanted into six-cell packs (Com-Pack Bedding Plant Containers, Hummert Seed Co., St. Louis, MO) and grown at 25C . The transplants were hand-planted in beds with a norge loam (fine-silty, mixed, thermic Udic Paleustolls) soil in Stillwater, OK in climatic zone 7a (USDA, 1990). 'Golden Triumph' celosia and 'Sensation' cosmos were planted 16 May, 2 June, 18 June, and 3 July 1991, and fountain grass was planted on 3 June and 18 June 1991. Seeds of 'Sensation' cosmos were sown four weeks before each planting date, and seeds of 'Golden Triumph' celosia and fountain grass were sown seven weeks before each planting date. 'Sensation' cosmos and fountain grass were planted on 30 x 30-cm centers with sixteen plants in each replication. 'Golden Triumph' celosia was planted on 15 x 15-cm centers with 28 plants per replication. Three replications of each species were placed in a completely randomized design. The plants were watered with bi-wall drip tube irrigation as needed. Following a soil analysis, 7.9 g ammonium nitrate, 15.8 g limestone, and 0.8 g controlled-release fertilizer (19-6-12, Osmocote, Hummert Seed Co., St. Louis, MO) were incorporated per square meter into the beds. Inflorescences were harvested at first flower anthesis, and date of flower and stem length were recorded. 'Sensation' cosmos was harvested several times and data were divided into two sets. At the initial harvest, stems were cut at the fourth node from the base and this stem was considered the first cut. Later cuts from the remaining nodes were considered the second cuts. Analysis of variance (ANOVA) was used to analyze stems within each species with mean differences analyzed by trend analysis (SAS Institute, Cary, N.C.).

Results and Discussion

'Golden Triumph' Celosia. Planting date curvilinearly affected the number of days to harvest, and length of stems increased linearly with later planting dates (Table 4.1). While the June 2 planting flowered the quickest and the May 16 planting flowered the slowest, the number of days to harvest decreased with the later planting dates. The decreasing number of days to harvest later in the season was similar to previous findings that celosia responds to the number of degree days (Healy and Aker, 1988). Originally, celosia was considered to have a day-neutral flowering response, but Piringer and Borthwick (1961) showed that it was a quantitative SD plant. Short days accelerated flowering, but the plants flowered regardless of photoperiod because an increase in total sunlight and temperature substituted for short days. The growing

season might be extended through the use of staggered planting dates sequenced farther apart than two weeks, perhaps every month for two months. Even though the season would not be extended to all summer, the plants from the later planting dates would be more profitable to a grower because of the significant increase in stem length.

'Sensation' Cosmos. Planting date did not significantly affect the number of days to harvest (Table 4.1). For the first cut, stem length increased with later planting dates. The stems from the second cut showed no significant differences in stem length, and days to harvest did not differ. The use of staggered planting dates in cosmos was successful in extending the season of production. The number of days to harvest did not decrease; therefore, planting cosmos every 2-3 weeks could be recommended. An added advantage for cosmos was the increase in stem length with later planting dates and the production of second cuts. While cosmos has been described as a late season bloomer, a photoperiod requirement was not found in the literature (Still, 1988). Therefore, cosmos may be a day neutral plant because no difference in days to harvest was found with each planting date.

Fountain Grass. The June 18 planting date flowered almost 23 days quicker than the first planting date and stem length was not affected by the two different planting dates (Table 4.1). The plants from the second planting date matured at a faster rate; therefore, the use of staggered planting for this species was not beneficial for increasing season long production. This suggested that fountain grass was a qualitative long day plant, because with the later planting date days to harvest was decreased. Once flowering began, this species flowered all season thus multiple plantings would not be necessary.

In summary, the use of multiple planting dates was successful in producing extended season flowering for 'Golden Triumph' celosia and 'Sensation' cosmos. In addition, stem length of 'Golden Triumph' celosia was significantly increased, but further work is necessary to determine if the season long production is possible.

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Table 4.1. Effect of planting date on number of days to harvest and stem length of 'Golden Triumph' celosia, 'Sensation' cosmos, and fountain grass.

Planting Date		Days to Harvest	Length (cm)
		'Golden Triumph' celosia	
May 16		66.3	57.7
June 2		59.0	64.3
June 18		63.0	74.5
July 3		65.0	83.6
	Linear	NS	*
	Quadratic	*	NS
	Cubic	*	NS
		'Sensation' cosmos	
May 16		65.5	69.4
June 2		65.0	65.1
June 18		61.1	79.9
July 3		60.7	65.1
	Linear	NS	*
	Quadratic	NS	NS
	Cubic	NS	NS
		Fountain grass	
June 2		90.6	59.2
June 18		67.1	65.2
	LSD	*	NS

[NS],*Nonsignificant or significant at P=0.01, respectively.

CHAPTER V

SUMMARY

Specialty cut flower production has steadily increased for the last few years with a large selection of species that can be economically produced. While many of the specialty cut flowers were first introduced to the United States by overseas growers, domestic growers have now found their product in demand. Despite the lower wages paid to overseas workers and lower production costs, domestic growers could compete by providing high quality flowers and service, and by utilizing more lucrative marketing techniques, such as mass marketers.

As agricultural producers look for ways to diversify their operations and increase profit margins, field production of cut flowers offers a profitable solution. The Oklahoma climate is suited to the production of field grown cut flowers with the long growing season. Many species that are grown as cut flowers are native to Oklahoma and thus suited for outdoor production. In order for new growers to produce cut flowers, production techniques need to be determined. The overall purpose of this study was to develop methods of producing cut flowers. Three aspects were studied—seed germination, spacing requirements, and annual production.

The development of new species could create greater demand for Oklahoma-grown cut flowers. However, the dormancy associated with wildflower seeds must be overcome in order for growers to produce transplants. Seeds of wild blue indigo, purple coneflower, Maximilian sunflower, spike goldenrod, and Missouri ironweed were given six treatments, from zero weeks stratification to ten weeks stratification in two week increments. For wild blue indigo, the highest germination occurred after the seeds were stratified for ten weeks. However, wild blue indigo did not germinate to its full potential and further research is needed. Purple coneflower had the highest germination percentage after four weeks of stratification, and germinated to its full potential based on calculated viability. The highest overall germination percentage was six weeks of stratification for Maximilian sunflower, which also germinated to its full potential based on calculated viability. Spike goldenrod reached optimum germination to its full potential after ten weeks of stratification. While the optimum germination occurred after four weeks of stratification for Missouri ironweed, the seeds did not germinate to their full potential and further research is needed.

In order to determine optimum spacing in the field and estimate profit, several species of cut flowers were planted at various spacings. As 'Cloth of Gold' yarrow spacing distance increased, yield per plant increased and yield per square meter decreased. Also, decreased spacings required more plants per square meter, which increased cost per square meter.

Neither stem length nor yield per plant of 'Summer Pastels' yarrow and 'Debutante' yarrow were affected by the different spacings. However, stems per square meter decreased with increased spacing for both species. The most profitable and productive spacing would be difficult to predict because of the large variability.

For 'Debutante' yarrow, the first year stems at the largest spacing cost the least to produce. However, in the second year the cost per stem did not decrease as spacing increased. 'Blue' prairie gentian yield per plant was increased and stems per square meter decreased at the largest spacing. 'Pfitzer Hybrid' red hot poker stems per plant increased as the spacing increased. Plants spaced at the greatest distance were the least costly per stem to produce. Therefore, it was more profitable for a grower to space 'Pfitzer Hybrid' red hot poker at the largest spacing. In order for a grower to determine which spacing to use for each species, he must consider the amount of space available versus his desired profit per stem.

Transplants of 'Golden Triumph' celosia, 'Sensation' cosmos, and fountain grass were planted at multiple dates. Stem length of 'Golden Triumph' celosia increased, and the number of days to harvest decreased with later planting dates. Planting date did not affect the number of days to harvest, and stem length decreased with later planting dates for 'Sensation' cosmos. The second planting of fountain grass flowered more quickly than the first planting, which suggested that fountain grass was a qualitative long day plant. After the plants began flowering, stems were produced all season; therefore, multiple planting dates would not be necessary. Plantings made every two weeks and every month would be successful for cosmos and celosia, respectively. These results should be verified with further research.

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VITA 2

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