Ornamental Seed Production in Field Cages with Insect Pollinators[1]

Mark P. Widrlechner, Craig A. Abel, and Richard L. Wilson
U.S. Department of Agriculture — Agricultural Research Service, North Central Regional Plant Introduction Station, Iowa State University, Ames, Iowa 50011-1010

RATIONALE

The North Central Regional Plant Introduction Station (NCRPIS), located at Iowa State University in Ames, is one of the primary sites of the U.S. National Plant Germplasm System (Roath et al., 1990; White et al., 1989). The NCRPIS specializes in the management of germplasm of agronomic and horticultural crops and their wild relatives that are primarily allogamous (outbreeding). Each year, crop-specific curators at the NCRPIS regenerate seeds of hundreds of germplasm accessions in the field and under glass, controlling pollination to preserve the genetic integrity of the collections. Pollinations for some crops, such as pumpkins, domesticated sunflowers, and corn, are made by hand. A few others, such as amaranths and chenopods, can be regenerated in plastic tents without special pollinators (Williams and Brenner, 1995), provided there is some air movement in the tents. But most crops maintained at the NCRPIS are insect pollinated in nature and their flowers are tedious to pollinate by hand.

In the late 1970s, researchers at the NCRPIS developed a field-cage system wherein managed populations of insects pollinate germplasm accessions (Ellis et al., 1981). The system had to be sufficiently sturdy to withstand midwestern wind and storms, quickly assembled and disassembled, and readily storable when not in use. Ideally, the system would also consist of widely available, inexpensive materials. Prototypes of our field cages, when used with nucleus boxes of honeybees, generally produced so much more seed per investment when compared to hand pollinations that, by the early 1980s, the NCRPIS adopted this system for many crops and began to refine it. Beyond the increased seed production, there were secondary benefits resulting from this system. The cages protect the plants from herbivorous insects that either cause direct damage or serve as pathogen vectors and from birds and mammals that consume the fruits and seeds.

Although many International Plant Propagators' Society members propagate plants by seed, many purchase their seeds from outside suppliers. Those that do produce seeds in house generally rely on spatial and temporal isolation to preserve the seeds' genetic purity. Such methods greatly restrict the number of populations of any one species that can be regenerated per year. For insect-pollinated species, effective pollinators may not be present in sufficient numbers at the proper time for pollination. And for those species with fleshy or nutritious fruits and seeds, birds or other animals may reduce seed harvest when unprotected. Taken together, these advantages suggest that our field-cage and insect-management methods should be valuable to commercial propagators, who seek to produce "genetically pure" seeds.

[1] Journal Paper J-17104 of the Iowa Agriculture and Home Economics Experiment Station, Ames, Project No. 1018, and supported by Hatch Act and State of Iowa funds.

FIELD CAGES

The cages now in use at the NCRPIS are constructed of 1.3-cm (0.5-in.) diameter galvanized pipe frames, connected by key clamps, and covered with one-piece UV-resistant lumite mesh fabric. The edges of the mesh screens are buried in trenches that are dug around the frames. Entry to the cages is through Velcro-sealed openings in the screens.

There are two standard cage sizes. We have about 1000 cages measuring 1.6 m × 1.6 m × 6.5 m (5.25 ft × 5.25 ft × 21.33 ft) (height × width × length) for plants that grow less than about 1.5 m (5 ft) tall. For taller plants, such as wild sunflowers, hollyhocks, and many shrubs, we have about 120 3.2 m × 3.2 m × 6.5 m (10.5 ft × 10.5 ft × 21.33 ft) cages. These larger cages require interior cable bracing to enable them to withstand high winds.

POLLINATING INSECTS

Both bees and flies have been used to pollinate the plants in the field cages. In most cases, we employ queened honeybee (*Apis mellifera*) colonies housed in specially designed, 16.8 cm × 26.9 cm × 48.5 cm (6.6 in. × 10.6 in. × 19.1 in.) (height × width × length), nucleus boxes holding six frames and ca. 5000 worker bees. Cox et al. (1996) provides further information about this system in a detailed description of honeybee management at the NCRPIS.

In recent years, we have field tested other bees, such as bumblebees (*Bombus* spp.) and various solitary bees, as germplasm pollinators. We are now regularly using hornfaced bees (*Osmia cornifrons*) on a large scale for oilseed *Brassica* and on a trial basis for many other plants. These bees are active at cooler temperatures than are honeybees, and they hold pollen on their abdomens, which readily touch the stigmas of *Brassica* flowers as the bees forage. Portable *Osmia* domiciles can be made from 5.1-cm (2-in.) diameter pvc pipe filled with nesting straws. On a smaller scale, we have also been using bumblebees (*Bombus bimaculatus*) for plants, such as snapdragons, with flowers better suited to a larger pollinator with a relatively long tongue or that require buzz pollination. In addition, house flies (*Musca domestica*) are reared at the NCRPIS for use in conjunction with bees in cages of Apiaceae. About 250 fly pupae are placed in the cages weekly to supplement bee activity. It is also possible to purchase house flies commercially, although to date we have not done so.

TESTS OF OUR SYSTEM AND VARIOUS POLLINATORS

A series of experiments has been conducted to test the integrity of our cage system for preventing pollen flow from outside the cages and, more broadly, to preserve the genetic integrity of our collections. Wilson (1989) conducted a 3-year study of various honeybee management strategies with caged pollen-sterile sunflowers. He showed that the NCRPIS regeneration system reduced cross-contamination to an extremely low level (0.1 to 0.2%). Widrlechner et al. (1992) evaluated allozyme profiles for 157 different pairs of cucumber seedlots produced both by uncaged hand pollination and caged insect pollination. They found no statistically significant differences in the overall enzyme composition, or in the frequencies of rare allozyme alleles; but there was a significant increase in homozygosity with caged pollination, suggesting that the genetic integrity of individual accessions is better maintained with caged pollination.

Table 1. List of ornamental genera regenerated at the NCRPIS with insect pollinators in field cages. All genera were pollinated by honeybees unless otherwise indicated.

Genus
Agastache
Alcea
Althaea
Antirrhinum (both honeybees and bumblebees)
Aronia (hornfaced bees)
Calendula
Campanula
Celosia
Chrysanthemum
Consolida
Cuphea
Dianthus
Duchesnea
Echinacea
Flueggea
Gypsophila
Hesperis
Lavatera
Leucanthemum
Ligustrum
Linum
Malva
Melampodium
Monarda
Petrorhagia
Potentilla
Pycnanthemum
Salvia
Sanvitalia
Silene
Simsia
Sorbaria (both honeybees and hornfaced bees)
Spiraea (hornfaced bees)
Tagetes
Tanacetum
Tithonia
Vaccaria
Verbena
Viola
Zinnia

The efficacy of various pollinators and combinations of different pollination protocols has also been tested for carrot (Wilson et al., 1991), sunflower (Wilson and Collison, 1988), *Cuphea* (Wilson and Roath, 1992), and *Brassica* (Wilson et al., in review). Those studies indicated that: (1) a combination of house flies and honeybees produced significantly higher quantities of carrot seed than did either insect alone; (2) the use of different races of honeybees did not result in significant differences in sunflower seed production; (3) small numbers of bumblebees were at least as efficient as a colony of honeybees in effecting *Cuphea* pollination; and (4) hornfaced bees were equally effective pollinators for *Brassica* as were honeybees and leafcutter bees.

ORNAMENTALS SUCCESSFULLY REGENERATED WITH OUR SYSTEM

The first caged increases of ornamental plants at the NCRPIS were conducted in 1981 on annual zinnias. In 1986, we established our first 2-year field, which enabled us to regenerate biennials and perennials that would not flower without overwintering. More recently, we began testing various shrubs in larger cages 2- to 3-year trials of our regeneration system. Table 1 lists the ornamental genera successfully regenerated in field cages, along with the pollinators used.

LIMITATIONS

The NCRPIS cage regeneration system is not without limitations. Some of our most severe challenges are related to our local climate. For biennial and perennial ornamentals that overwinter in the field, death may occur from low-temperature injury or poor drainage. On warm, sunny days with light winds, very high air temperatures [up to 46C (115F)] can occur inside the cages, which may damage flowers, destroy pollen, and, ultimately, lower seed quality. Conversely, stormy days with very high winds can wreak havoc on cages, by deforming frames, breaking joints, and unearthing or tearing screens.

Another challenge stems from the poor match between the number of honeybees that can be nourished by the pollen and nectar produced by the flowers inside a cage versus the number of bees required to maintain a colony. At even the densest planting rates, there are generally fewer than 200 plants in a cage. Ayers and Widrlechner (1994) recommended a field planting of at least 307 m^2 (3300 ft^2) of anise hyssop (*Agastache foeniculum*), a very productive nectar source, to support one honeybee hive. Clearly, 200 plants inside a cage cannot support honeybees without special intervention. We have used two approaches to maintain our honeybees: allowing them to work periodically outside the cages or feeding them syrup and pollen substitute. One can design a schedule allowing the bees to forage outside the cages, if the nucleus boxes are equipped with a sliding drawer, so that bees can only work inside or outside the cage, but not both. This system works best when there is sufficient local forage to support the number of colonies on site. Otherwise, labor-intensive artificial feeding is required. We expect that solitary bees and social bees, such as bumblebees, which have much smaller colonies than do honeybees, may ultimately prove better suited for caged pollination.

At the NCRPIS, research to refine caged seed production is ongoing. We are now testing our system on previously untried plants, refining methods to establish honeybee colonies quickly in the spring, developing protocols to produce and manage bumblebees and solitary bees, and measuring the relative effectiveness of various pollinators for particular crops.

PLANS FOR YOUR OWN CAGES

If you wish to experiment with field cages for seed production, we can provide plans for field cages, screens, and the various structures used to house the pollinators. Please contact us at the address shown at the beginning of this paper, or contact Craig Abel by e-mail at: cabel@iastate.edu.

Acknowledgements. We wish to thank Charles Brummer, Raymond Clark, and Lowell Ewart for valuable critiques of this report and Roger Fuentes-Granados for assistance preparing graphics for the presentation.

LITERATURE CITED

Ayers, G.S. and **M.P. Widrlechner.** 1994. The genus *Agastache* as bee forage: An analysis of reader returns. Amer. Bee J. 134:477-483.

Cox, R.L., C. Abel, and **E. Gustafson.** 1996. A novel use of bees: Controlled pollination of germplasm collections. Amer. Bee J. 136:709-712.

Ellis, M.D., G.S. Jackson, W.H. Skrdla, and **H.C. Spencer.** 1981. Use of honey bees for controlled interpollination of plant germplasm collections. HortScience 16:488-491.

Roath, W.W., R.L. Clark, M.P. Widrlechner, and **R.L. Wilson.** 1990. Germplasm resources at the North Central Regional Plant Introduction Station. pp. 84-90. In. Advances in new crops. J. Janick and J.E. Simon (eds.). Timber Press, Portland, OR.

White, G.A., H.L. Shands, and **G.R. Lovell.** 1989. History and operation of the National Plant Germplasm System. Pl. Breeding Rev. 7:5-56.

Widrlechner, M.P., L.D. Knerr, J.E. Staub, and **K.R. Reitsma.** 1992. Biochemical evaluation of germplasm regeneration methods for cucumber, *Cucumis sativus* L. FAO/IBPGR Plant Genetic Res. Newsl. 88/89:1-4.

Williams, J.T. and **D. Brenner.** 1995. Grain amaranth (*Amaranthus* sp.) pp. 129-186. In: Cereals and pseudocereals. J.T. Williams (ed.). Chapman & Hall, London.

Wilson, R.L. 1989. Minimizing extraneous transfer of sunflower pollen by honey bees (Hymenoptera: Apidae) in field cages. J. Kans. Ent. Soc. 62:387-391.

Wilson, R.L., C.A. Abel, and **R.L. Luhman.** 1997. Using the hornfaced bee, *Osmia cornifrons*, for controlled pollination of selected Brassicaceae species. (submitted, J. Agricultural Research)

Wilson, R.L. and **V.L. Collison.** 1988. Field cage study of the effects of four wild honey bee strains and hand pollination on the seed of a wild sunflower. Seed Sci. & Technol. 16:471-475.

Wilson, R.L. and **W.W. Roath.** 1992. Potential of three lepidopteran species as pests and three hymenopteran species as pollinators of *Cuphea*. J. Kans. Ent. Soc. 65:316-320.

Wilson, R.L., M.P. Widrlechner, and **K.R. Reitsma.** 1991. Pollination methods for maintaining carrot germplasm collections. FAO/IBPGR Plant Genetic Res. Newsl. 85:1-3.