

# Breeding Systems of Plants Used for Prairie Restorations: A Review

Brenda Molano-Flores  
Illinois Natural History Survey  
Center for Wildlife and Plant Ecology  
607 East Peabody Drive, Champaign, IL 61820.  
molano@inhs.uiuc.edu  
217-265-8167 (Work)  
217-265-5110 (Fax)

## ABSTRACT

Compatibility systems (i.e., self-compatible vs. self-incompatible) and types of individuals (e.g., heteromorphic, dioecious, etc.) in prairie plant species are usually ignored in prairie flower publications. Lack of knowledge regarding this information can hinder the success of prairie restoration. In this paper, I provide an explanation for why those involved in restoration should be concerned about the compatibility system and types of individuals of prairie plants. In addition, a list of the compatibility systems and types of individuals for some of the most common species used in prairie restorations is provided.

---

Prairie restoration is becoming a big business for landscapers and a major effort undertaken by many state (e.g., Departments of Natural Resources) and federal agencies (e.g., United States Department of Agriculture Forest Service, United States Fish and Wildlife Service). However, in most cases it is local environmental groups, local park districts, and some individuals doing prairie restorations. Most people doing prairie restorations are very knowledgeable about the biology of prairie plant species, such as their habitat and seed germination requirements and the best propagation techniques. However, many are unaware of additional factors affecting the reintroduction, establishment, and persistence of a species in a restoration, such as patch dynamics, pollinator guilds, and reproductive biology including plant compatibility systems (i.e., self-compatible vs. self-incompatible), and that some prairie species have different individual types (e.g., heteromorphic, dioecious, etc.). This oversight is understandable because many guides and other books on prairie plants fail to provide this basic information and explain how these factors influence the success and persistence of a species in a restoration. Making this information accessible will ensure a higher level of public awareness.

One aspect of plant biology that is rarely reported is the species' compatibility system. The compatibility system of a plant species is concerned with which pollen is accepted or rejected. In general, plants fall into two categories: self-compatible and self-incompatible. Self-compatible means that both self and outcross pollen will be accepted by a flower (stigma). In the case of self-incompatibility, only cross pollen will be accepted by the flower (stigma). For example, most members of the Carrot Family (Apiaceae) and plants

with both chasmogamous and cleistogamous flowers (see Appendix for definition) are self-compatible. Published data indicates that 49 percent of prairie species are known to be self-compatible (Table 1). Members of the Sunflower (Asteraceae) and Milkweed (Asclepiadaceae) families generally are considered to be self-incompatible (Wyatt and Broyles 1994; Richards 1997; Schlessman and Graceffa 2002). Published data indicates that 39 percent of prairie species are known to be self-incompatible (Table 1). For the remaining 12 percent of prairie species, either data was not available or the species has a mixed compatibility system (i.e., self-compatible/self-incompatible; Table 1).

For species that are propagated by cuttings or are clonal (i.e., vegetative reproduction), self-incompatibility may limit reproduction if only one or a few genotypes are used in the restoration. One example of such a situation is the self-incompatible *Filipendula rubra* (Queen-of-the-prairie). If all the plants in a restoration are cloned from a single plant, fruit set will be hindered (i.e., no fruit set) because only self pollen will be transferred (Aspinwall and Christian 1992). To avoid such reproductive problems, particular emphasis should be placed on seed or cutting origin. Collection of seeds or cuttings from multiple nearby populations (sites) may decrease this reproductive problem, because more genotypes will be available.

Regardless of compatibility system, collecting seeds from a single population or from widely separated populations might result in either inbreeding or outbreeding depression, which can reduce reproductive success and fitness. Inbreeding depression is when genetically similar (i.e., closely related) individuals cross with each other resulting in the reduction in fitness of the offspring. Outbreeding depression is when very genetically different (i.e., distantly related) individuals cross with each other resulting in the reduction of the fitness of the offspring. Both inbreeding and outbreeding depression can hinder species persistence in a restoration.

Another usually overlooked aspect of reproductive biology is that some prairie species have different types of individuals (e.g., heteromorphic (pin/thrum), monoecious, dioecious, gynodioecious; see Appendix for definitions). Published data indicates that 24 percent of prairie species have different types of individuals (Table 1). Most prairie plants produce only one type of plant, hermaphroditic. However, some prairie species produce plants of different sexes. An example of a prairie species with different types of individuals is *Lobelia siphilitica* (Blue lobelia). This species has two breeding types in natural populations: hermaphroditic and female (i.e., gynodioecious). If a restoration project with this species includes hermaphroditic individuals, reproduction may succeed, however, if a high proportion of females are re-planted, reproduction will be negatively affected.

A more subtle situation is heterostyly, in which different plants bear their stigmas and anthers at different levels in different plants. An excellent example is *Lithospermum canescens* (Hoary puccoon). This species has two types of individuals, pin and thrum. Individuals that are thrum have flowers with the style half way down the corolla tube and the anthers visible at the top of the corolla tube. Pin individuals are the opposite. Both types of individuals have to be present for successful reproduction. Populations that depart from equal numbers of pin and thrum individuals suffer reduced reproduction. In addition, plant species with pin and thrum flowers are usually self-incompatible (Richards 1997, Proctor et al. 1996).

Table 1 lists the compatibility system and types of individuals, when applicable, for some of the more common species used in restorations. A total of 67 species were chosen either because they are commercially available or easy to establish. Also, the species were chosen because information about compatibility systems and types of individuals was found in peer-reviewed publications. An appendix has been included defining terminology presented in this paper or that the readers may encounter in the literature cited. Hopefully this data will provide an additional tool to improve prairie restorations.

### ACKNOWLEDGMENTS

I thank Geoffrey Levin, Christopher Ivey, Mary Ann Feist, and anonymous reviewers for their valuable comments to improve the manuscript.

### REFERENCES

- Ashman, T.L. 2000. Pollinator selectivity and its implications for the evolution of dioecy and sexual dimorphism. *Ecology* 81: 2577-2591.
- Aspinwall, N. and T. Christian. 1992. Pollination biology, seed production, and population structure in queen-of-the-prairie, *Filipendula rubra* (Rosaceae) at Botkin Fen, Missouri. *American Journal of Botanical* 79: 488-494.
- Becker, W. A. and L. C. Ewart. 1990. Pollination, seed set, and pollen tube growth investigations in *Viola pedata* L. *Acta Horticulturae* 272: 33-36.
- Bertin, R.I. and G.M. Gwisc. 2002. Floral sex ratios and gynomonoeicy in *Solidago* (Asteraceae). *Biological Journal of the Linnean Society* 77: 413-422.
- Boe, A. and K. Fluharty, 1993. Reproductive biology of a Canada milk-vetch population from eastern South Dakota. *Prairie Naturalist* 25: 65-72.
- Byers, D.L. 1995. Pollen quantity and quality as explanations for low seed set in small populations exemplified by *Eupatorium* (Asteraceae). *American Journal of Botany* 82: 1000-1006.
- Chambers, H.L. 1961. Chromosome survey and analysis of artificial hybrids in *Pycnanthemum* (Labiatae). *Brittonia* 13: 116-128.
- Clinebell R. R. and P. Bernhardt. 1998. The pollination ecology of five species of *Penstemon* (Scrophulariaceae) in the tallgrass prairie. *Annals of the Missouri Botanical Garden* 85: 126-136.
- Cole, C.T. and D.D. Biesboer. 1992. Monomorphism, reduced gene flow, and cleistogamy in rare and common species of *Lespedeza* (Fabaceae). *American Journal of Botany* 79: 567-575.
- Costelloe, B.H. 1988. Pollination ecology of *Gentiana andrewsii*. *Ohio Journal of Science* 88: 132-138.
- Cruden, R.W. 1973. Reproductive biology of weedy and cultivated *Mirabilis* (Nyctaginaceae). *American Journal of Botany* 60: 802-809.
- Cruden, W.R. 1977. Pollen-ovule ratios: A conservative indicator of breeding systems in flowering plants. *Evolution* 31:32-46.
- Cruden, R.W., L. Hermanutz, and J. Shuttleworth. 1984. The pollination biology and breeding system of *Monarda fistulosa* (Labiatae). *Oecologia* 64: 104-110.
- Cruden, R.W. and D.L. Lyon. 1989. Facultative xenogamous: Examination of a mixed mating system. In J. Bock and Y.B. Linhart [eds.], 171-207, *Evolutionary ecology of plants*. Westview Press, Boulder, CO.
- Cruden, R.W., K.K. Baker, T.E. Cullinan, K.A. Disbrow, K.L. Douglas, J.D. Erb, K.J. Kirsten, M.L. Malik, E.A. Turner. 1990. The mating systems and pollination biology of three species of *Verbena* (Verbenaceae). *Journal of the Iowa Academy of Science* 97: 178-183.

- Delbart, C., B. Bris, A. Nouvelot, and D. Coustaut. 1983. Sulfatides and pollination in *Oenothera missouriensis*. *Phytochemistry* 22: 869-874.
- Dellaporta, S.L. and A. Calderon-Urrea. 1993. Sex determination in flowering plants. *The Plant Cell* 5: 1241-1251.
- Douglas, K. L., and R. W. Cruden. 1994. The reproductive biology of *Anemone canadensis* (Ranunculaceae): breeding system and facilitation of sexual selection. *American Journal of Botany* 81:314-321.
- Edwards, J. and J.R. Jordan. 1992. Reversible anther opening in *Lilium philadelphicum* (Liliaceae): A possible means of enhancing male fitness. *American Journal of Botany* 79: 144-148.
- Fester, C.B. 1995. Mirror image flowers and their effect on outcrossing rate in *Chamaecrista fasciculata* (Leguminosae). *American Journal of Botany* 82: 46-50.
- Fore, S.A. and S.I. Guttman. 1999. Genetic structure of *Helianthus occidentalis* (Asteraceae) in a preserve with fragmented habitat. *American Journal of Botany* 86: 988-995.
- Gleason, H. G. and A. Cronquist. 1991. *Manual of Vascular Plants of Northeastern United States and Adjacent Canada*. 2<sup>nd</sup> edition. New York Botanical Garden, USA.
- Hashemi, A., A. Estilai and H.H. Naqvi. 1989. Intersectional hybrids between induced tetraploid guayule (*Parthenium argentatum*) and natural tetraploid *Parthenium integrifolium* (Asteraceae). *Botanical Gazette* 150: 78-83.
- Heywood, J.S. 1993. Biparental inbreeding depression in the self-incompatible annual plant *Gaillardia pulchella* (Asteraceae). *American Journal of Botany* 80: 545-550.
- Huff, D. R., and L. Wu. 1992. Distribution and inheritance of inconstant sex forms in natural populations of dioecious buffalograss (*Buchloe dactyloides*). *American Journal of Botany* 79: 207-215.
- Imbert, F.M. and J.H. Richards. 1993. Protandry, incompatibility, and secondary pollen presentation in *Cephalanthus occidentalis* (Rubiaceae). *American Journal of Botany* 80: 395-404.
- Johnston, I.M. 1952. Studies in the Boraginaceae, XXIII a survey of the genus *Lithospermum*. *Journal of the Arnold Arboretum* 33: 299-363.
- Johnston, M. 1991. Natural selection on floral traits in two species of *Lobelia* with different pollinators. *Evolution* 45: 1468-1479.
- Kephart, S.R. 1981. Breeding system in *Asclepias incarnata* L., *A. syriaca* L., and *A. verticillata* L. *American Journal of Botany* 68:226-232.
- Kirt, R. R. 1995. *Prairie plants of the Midwest: Identification and ecology*. Stipes Publishing L.L.L., Champaign, IL.
- Leuszler, H.K., V.J. Tepedino, and D.G. Alston. 1996. Reproductive biology of purple coneflower in southwestern North Dakota. *Prairie Naturalist* 28: 91-102.
- Levin, D.A. 1968a. The breeding system of *Lithospermum caroliniense*: adaptation and counter-adaptation. *The American Naturalist* 102: 427-441.
- Levin, D.A. 1968b. The structure of a polyspecies hybrid swarm in *Liatris*. *Evolution* 22: 353-372.
- Levin, D.A. and H.W. Kerstern. 1970. Phenotypic dimorphism and populational fitness in *Phlox*. *Evolution* 24: 128-134.
- Lindsay, A.H. 1982. Floral phenology patterns and breeding systems in *Thaspium* and *Zizia* (Apiaceae). *Systematic Botany* 7: 1-12.
- Lipow, S.R. and R. Wyatt. 1999. Floral morphology and late-acting self-incompatibility in *Apocynum cannabinum* (Apocynaceae). *Plant Systematics and Evolution* 219: 99-109.
- Lipow, S.R. and R. Wyatt. 2000. Towards an understanding of the mixed breeding system of swamp milkweed (*Asclepias incarnata*). *Journal of the Torrey Botanical Society* 127: 193-199.
- Long, R.W. 1966. Artificial interspecific hybridization in *Ruellia* (Acanthaceae). *American Journal of Botany* 53: 917-927.
- Menges, E.S. 1995. Factors limiting fecundity and germination in small populations of *Silene regia* (Caryophyllaceae), a rare hummingbird-pollinated prairie forb. *American Midland Naturalist* 133: 242-255.
- McKone, M.J. 1985. Reproductive biology of several brome grasses (*Bromus*): Breeding system, pattern of fruit maturation, and seed set. *American Journal of Botany* 72: 1334-1339.
- McKone, M.J., C.P. Lund, and J.M. O'Brien. 1998. Reproductive biology of two dominant prairie grasses (*Andropogon gerardii* and *Sorghastrum nutans*, Poaceae): male-biased sex allocation in wind-pollinated plants? *American Journal of Botany* 85: 776-783.

- Molano-Flores, B. 2002. Pollination biology and flower visitors of the gynodioecious species *Lobelia spicata* Lam. (Campanulaceae). The Journal of the Torrey Botanical Society 128: 187-193.
- Molano-Flores, B. 2001. The reproductive biology of *Eryngium yuccifolium* Michx. (Apiaceae), a prairie species. The Journal of the Torrey Botanical Society 128: 1-6.
- Molano-Flores, B. and S.D. Hendrix. 1999. The effects of population density and population size on the reproductive output of *Anemone canadensis* L. (Ranunculaceae). The International Journal of Plant Sciences 160: 759-766.
- Molano-Flores, B., S.D. Hendrix and S.B. Heard. 1999. The effect of population size on stigma pollen load, fruit set, and seed set in *Allium stellatum* Ker. (Liliaceae). The International Journal of Plant Sciences 160: 753-757.
- Molano-Flores, B. and S.D. Hendrix. 1998. Reproductive biology of Candle Anemone. The Prairie Naturalist 30:169-179.
- Owens, S.J. and S. McGrath. 1984. Self-incompatibility and the pollen-stigma interaction in *Tradescantia ohiensis*. Protoplasma 121: 209-213.
- Parrish, J.A.D. and F.A. Bazzaz. 1979. Difference in pollination niche relationships in early and late successional plant communities. Ecology 60: 597-610.
- Proctor, M., P. Yeo and A. Lack. 1996. The Natural History of Pollination. Timber Press Oregon, USA.
- Richards, A. J. 1997. Plant breeding systems. Chapman and Hall, London, UK.
- Sanders, T.B. and J.L. Hamrick. 1980. Variation in the breeding system of *Elymus canadensis*. Evolution 34: 117-122.
- Schaal, B.A. and D.A. Levin. 1978. Morphological differentiation and neighborhood size in *Liatris cylindracea*. American Journal of Botany 65: 923-928.
- Schlessman, M. A. and L.M. Graceffa. 2002. Protogyny, Pollination, and Sex Expression of Andromonoecious *Pseudocymopterus montanus* (Apiaceae, Apioideae). The International Journal of Plant Sciences 163:409-417.
- Steiner, E. and D.A. Levin, 1977. Allozyme SI gene cytological and morphological polymorphisms in a population of *Oenothera biennis*. Evolution 31: 127-133.
- Straley, G.B. 1977. Systematics of *Oenothera* section *Kneiffia* (Onagraceae). Annals of the Missouri Botanical Garden 64: 381-424.
- Wyatt, R. and S.B. Broyles. 1994. Ecology and evolution of reproduction in milkweeds. Annual Review of Ecology and Systematics 25: 423-441.
- Wyatt, R. and R. L. Hellwing. 1979. Factors determining fruit set in heterostylous Bluets, *Houstonia caerulea* (Rubiaceae). Systematic Botany 4: 103-114.
- Wyatt, R. 1976. Pollination and fruit-set in *Asclepias tuberosa*: A reappraisal. American Journal of Botany 63: 845-851.

Table 1. List of the compatibility systems and individual types for some of the most common species used in prairie restorations (SC = self-compatible; SI = self-incompatible; SI/SC = both compatibility systems found; SI/sc = mostly self-incompatible but self-compatibility found occasionally; SC/si = mostly self-compatible but self-incompatibility found occasionally; CH = chasmogamous; CL = cleistogamous; H = Heterostylous; GD = Gynodioecious; GM = Gynomonocious; ? = suspected but unconfirmed; \* = in Canada).

Genus/species	Common Name	Family	Compatibility system
<i>Allium stellatum</i>	Cliff onion	Liliaceae	SC (Molano-Flores et al., 1999)
<i>Amorpha canescens</i>	Leadplant	Fabaceae	SC (Parrish and Bazzaz, 1979)
<i>Andropogon gerardii</i>	Big bluestem	Poaceae	SI (McKone et al., 1998)
<i>Anemone canadensis</i>	Canada anemone	Ranunculaceae	SI (Douglas and Cruden, 1994)
<i>Anemone cylindrical</i>	Thimbleweed	Ranunculaceae	SC (Molano-Flores and Hendrix, 1998)
<i>Anemone patens</i>	Pasque flower	Ranunculaceae	SC (Cruden, 1977)
<i>Apocynum cannabinum</i>	Hemp dogbane	Apocynaceae	SI (Lipow and Wyatt, 1999)
<i>Asclepias incarnata</i>	Swamp milkweed	Asclepiadaceae	SC/si (Lipow and Wyatt, 2000)
<i>Asclepias sryriaca</i>	Common milkweed	Asclepiadaceae	SI/sc (Kephart, 1981)
<i>Asclepias tuberosa</i>	Butterfly milkweed	Asclepiadaceae	SI/sc (Wyatt, 1976)
<i>Asclepias verticillata</i>	Whorled milkweed	Asclepiadaceae	SI (Kephart, 1981)
<i>Astragalus canadensis</i>	Canada milk-vetch	Fabaceae	SC (Boe and Fluharty, 1993)
<i>Baptisia leucantha</i>	White false indigo	Fabaceae	SC (Haddock and Chaplin 1982)
<i>Baptisia leucophaea</i>	Cream false indigo	Fabaceae	SC (Haddock and Chaplin 1982)
<i>Bromus kalmii</i>	Prairie brome	Poaceae	SC (McKone, 1985)
<i>Buchloe dactyloides</i>	Buffalo grass	Poaceae	Dioecious [SC-monoecious, hermaphrodite] (Huff and Wu, 1992)
<i>Chamaecrista fasciculata</i>	Partridge-pea	Fabaceae	SC (Fenster, 1995)
<i>Cephalanthus occidentalis</i>	Buttonbush	Rubiaceae	SI (Imbert and Richards, 1993)
<i>Coreopsis lanceolata</i>	Sand coreopsis	Asteraceae	SI (Banovetz and Scheiner, 1994)
<i>Dalea purpureum</i>	Purple prairie clover	Fabaceae	SC (Parrish and Bazzaz, 1979)
<i>Echinacea angustifolia</i>	Pale-purple coneflower	Asteraceae	SI/sc (Leuszler, 1996)
<i>Elymus canadensis</i>	Canadian wild rye	Poaceae	SC (Sanders and Hamrick, 1980)
<i>Eryngium yuccifolium</i>	Rattlesnake master	Apiaceae	SC (Molano-Flores, 2001)
<i>Eupatorium perfoliatum</i>	Common boneset	Asteraceae	SI (Byers, 1995)
<i>Fragaria virginiana</i>	Wild strawberry	Rosaceae	SC [GD] (Ashman, 2000)
<i>Filipendula rubra</i>	Queen-of-the-prairie	Rosaceae	SI (Aspinwall and Christian, 1992)
<i>Gaillardia pulchella</i>	Blanket-flower	Asteraceae	SI (Heywood, 1993)
<i>Gentiana andrewsii</i>	Closed gentian	Gentianaceae	SC (Costelloe, 1988)
<i>Gentiana puberula</i>	Downy gentian	Gentianaceae	SC (Parrish and Bazzaz, 1979)
<i>Helianthus occidentalis</i>	Western sunflower	Asteraceae	SI (Fore and Guttman, 1999)
<i>Houstonia caerulea</i>	Bluets	Rubiaceae	SI [H (distyly)] (Wyatt and Hellwing, 1979)
<i>Lespedeza capitata</i>	Round-headed bush clover	Fabaceae	SC [CH/CL] (Cole and Biesboer, 1992)
<i>Liatris aspera</i>	Rough blazing star	Asteraceae	SI (Levin, 1968b)
<i>Liatris cylindrical</i>	Prairie blazing star	Asteraceae	SI (Schaal and Levin, 1978)
<i>Liatris spicata</i>	Dense blazing star	Asteraceae	SI (Levin, 1968b)
<i>Lilium philadelphicum</i>	Wood lily	Liliaceae	SI (Edwards and Jordan, 1992)
<i>Lithospermum canescens</i>	Hoary puccoon	Boraginaceae	SI? H (distyly) (Johnston, 1952)
<i>Lithospermum carolinense</i>	Hairy puccoon	Boraginaceae	SI/sc [CH/CL, H (distyly), homostylous] (Levin 1968a)
<i>Lithospermum incisum</i>	Yellow puccoon	Boraginaceae	SC [CH/CL] (Johnston, 1952)
<i>Lobelia cardinalis</i>	Cardinal flower	Campanulaceae	SC (Johnston, 1991)
<i>Lobelia siphilitica</i>	Blue lobelia	Campanulaceae	SC [GD] (Johnston, 1991)

Table 1. continued.

Genus/species	Common Name	Family	Compatibility system
<i>Lobelia spicata</i>	Spiked lobelia	Campanulaceae	SC [GD] (Molano-Flores, 2002)
<i>Lythrum alatum</i>	Winged loosestrife	Lythraceae	SI? [H (distyly)] (Brown and Mitchell, 2001)
<i>Mirabilis nyctaginea</i>	Four-o'-clock	Nyctaginaceae	SC [CH (early summer) and CL (late summer)] (Cruden, 1973)
<i>Monarda fistulosa</i>	Wild bergamont	Lamiaceae	SC (Cruden et al., 1984)
<i>Oenothera biennis</i>	Common evening primrose	Onagraceae	SC/si (Steiner and Levin, 1977)
<i>Oenothera missouriensis</i>	Missouri evening primrose	Onagraceae	SI (Delbart et al., 1983)
<i>Oenothera pilosella</i>	Prairie sundrops	Onagraceae	SI (Straley, 1977)
<i>Parthenium integrifolium</i>	Wild quinine	Asteraceae	SI (Hashemi et al., 1989)
<i>Penstemon digitalis</i>	Foxglove beard tongue	Scrophulariaceae	SC (Clinebell and Bernhardt, 1998)
<i>Penstemon pallidus</i>	Pale beard tongue	Scrophulariaceae	SC (Clinebell and Bernhardt, 1998)
<i>Phlox pilosa</i>	Prairie phlox	Polemoniaceae	SI (Levin and Kerster, 1970)
<i>Pycnanthemum virginianum</i>	Mountain mint	Lamiaceae	Apomixis* (Chambers, 1961)
<i>Ruellia humilis</i>	Hairy wild petunia	Acanthaceae	SC [CH/CL] (Long, 1966)
<i>Silene regia</i>	Royal catchfly	Caryophyllaceae	SC (Menges, 1995)
<i>Solidago nemoralis</i>	Field goldenrod	Asteraceae	SI? [GM] (Bertin and Gwisc, 2002)
<i>Solidago speciosa</i>	Showy goldenrod	Asteraceae	SI? [GM] (Bertin and Gwisc, 2002)
<i>Sorghastrum nutans</i>	Indian grass	Poaceae	SI (McKone et al., 1998)
<i>Stipa spartea</i>	Porcupine grass	Poaceae	SC [CH/CL] (Cruden and Lyon, 1989)
<i>Thalictrum dasycarpum</i>	Meadowrue	Ranunculaceae	Dioecious (Gleason and Cronquist, 1991)
<i>Tradescantia ohioensis</i>	Spiderwort	Commeliaceae	SI (Owens and McGrath, 1984)
<i>Verbena hastata</i>	Blue vervain	Verbenaceae	SC (Cruden et al., 1990)
<i>Verbena stricta</i>	Hoary vervain	Verbenaceae	SC (Cruden et al., 1990)
<i>Viola pedatifida</i>	Prairie violet	Violacea	SC [CH/CL] (Kirt, 1995)
<i>Viola pedata</i>	Birdfoot violet	Violacea	SI (Becker and Ewart, 1990)
<i>Zizia aptera</i>	Heart-leaf meadow parsnip	Apiaceae	SC (Lindsay 1982)
<i>Zizia aurea</i>	Golden alexanders	Apiaceae	SC (Parrish and Bazzaz, 1979)

## APPENDIX

Dellaporta and Calderon-Urrea (1993) have listed (with some modifications) and defined a variety of terms used to describe types of individuals at different levels in plants (female = pistil(s); male = stamen(s):

### Individual Flowers

- Hermaphrodite - bisexual flower with both female and male
  - ◆ Cleistogamy - Closed flowers that self pollinate
  - ◆ Chasmogamy - Open flowers capable of open pollination
  - ◆ Heterostyly - Modification of flower parts
- Unisexual - flower is either female or male

### Individual Plants

- Hermaphrodite - the plant has only hermaphrodite flowers
- Monoecious - unisexual male and female flowers are on the same plant
- Dioecious - unisexual male and female flowers are on different plants
- Gynoecious - only female flowers
- Androecious - only male flowers
- Gynomonoecious - both hermaphrodite and female flowers
- Andromonoecious - both hermaphrodite and male flowers
- Trimonoecious (polygamous) - hermaphrodite, male, and female flowers are all on the same plant

### Plant Populations

- Hermaphrodite - only hermaphrodite plants
- Monoecious - only monoecious plants
- Dioecious - only dioecious plants
- Gynodioecious - both female and hermaphrodite plants
- Androdioecious - both male and hermaphrodite plants
- Trioecious (or subdioecious) - hermaphrodite, male, and female plants are all in the same population