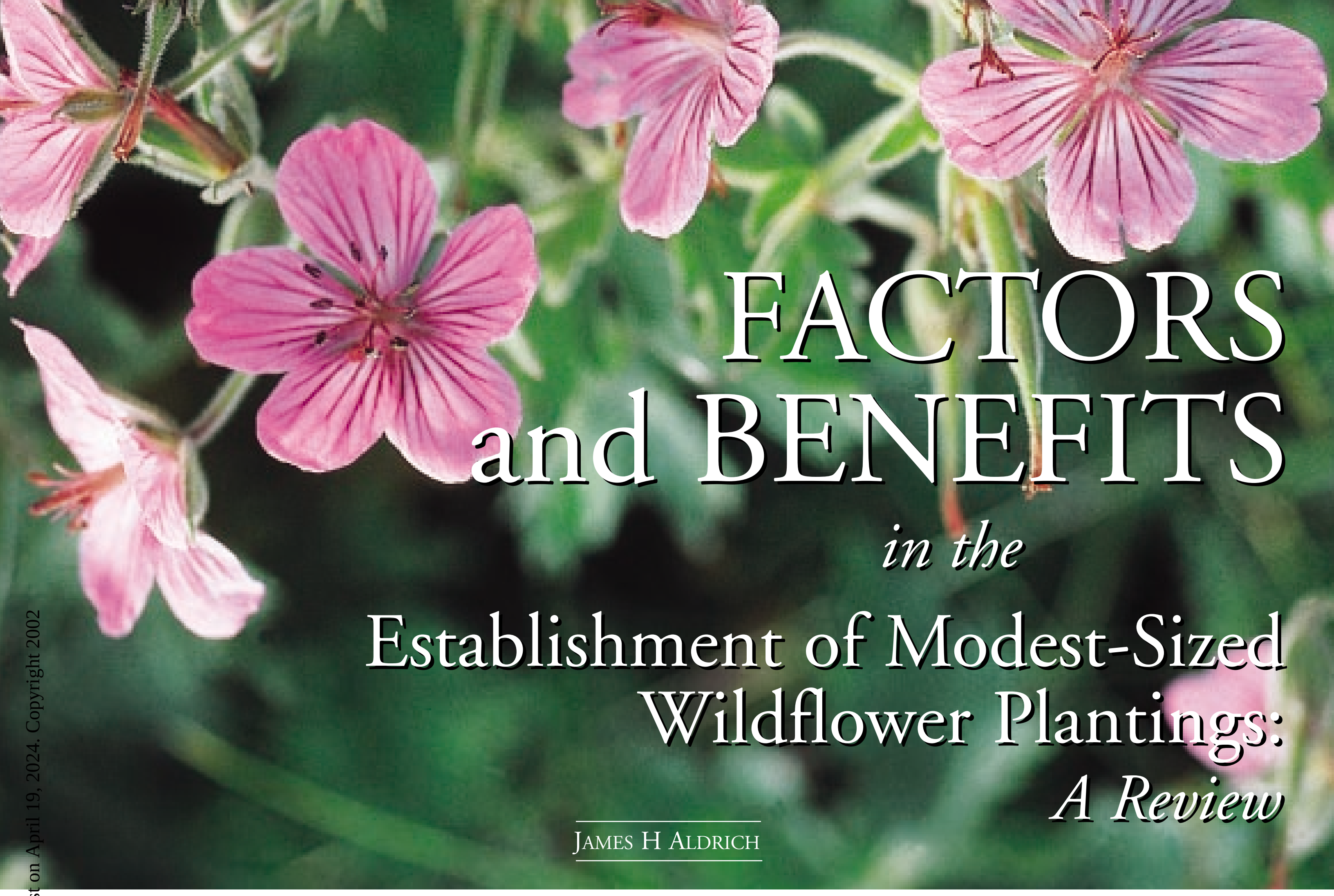

FACTORS and BENEFITS *in the* Establishment of Modest-Sized Wildflower Plantings: *A Review*

James H Aldrich

*Sticky geranium (*Geranium viscosissimum *Fisch. & C.A. Mey. ex C.A. Mey [Geraniaceae]).*

Photo by Kas Dumroese

ABSTRACT

Wildflower plantings have become increasingly more apparent and important on a federal, state, and local level. Numerous research papers and theses have detailed results of various parts of this extensive subject. This review article highlights some of this previous research in an effort to consolidate and elucidate an integrated pattern of recommendations to establish modest-sized (for example, roadsides, meadows, parks, golf courses, gardens) wildflower plantings. Components include: 1) preplanting concerns; 2) planting and maintenance (for example, seed germination and density, seeding method, planting date, fertilization, cover crops, weed control, irrigation, reseeding, and suspending natural succession); 3) wildflower dividends; and 4) wildflower establishment recommendations.

KEY WORDS: seeds, herbicide, site preparation, maintenance, ecotype, weed control

NOMENCLATURE: (fungi) AAFC (2001); (insects) BIOSIS (1997); (arbuscular mycorrhizae) ECORC (2000); (plants; fungi) ITIS (2000)

Use of native plant species throughout the US is not new; 3 states had roadside planting programs in 1921 and such programs have been gaining momentum since President LB Johnson signed the Beautification Act of 1965. The earlier native plantings included wildflower gardens, meadows, and roadside rights-of-way (Aiken 1933; Bailey 1982; ODOT 1988), but native plantings are now becoming common in diverse settings like construction and reclamation sites, parks, golf course roughs, wildlife habitats, and seed production farms (Ahern and others 1992; Agnew and Hatterman-Valenti 1993; Kutka and Tinderholt 1996; Branhagen 1997; NIPC 1998). By definition, a native plant "occurs naturally in a particular region, state, ecosystem, and habitat without direct or indirect human actions" (Morse and others 1999). Therefore, native plants were in North America prior to European exploration and had adapted to survive in particular environments. "During the thousands of years when wildflowers were slowly increasing to cover large areas of the plains, these plants existed in the complete and utter absence of all European weeds" (Baldwin 1998). A principal factor to consider is soil disturbance asso-


Photo by Thomas G Barnes

*Short's aster (*Symphyotrichum shortii *(Lindl.) Nesom formerly* Aster shortii *Lindl. [Asteraceae]).*

ciated with planting that allows invasive weed seeds an opportunity to germinate. Over time, weeds have deposited seeds in the topsoil which germinate and grow at various times. It is suggested that between 98 and 3068 viable weed seeds occur in the upper 15 cm (6 in) of soil in a 0.1 m^2 (1 ft^2) section (Gallitano and others 1993). Another estimate of the extent of the weed seedbank is that there are 202 kg/ha (180 lb/ac) in the top 5 cm (2 in) of soil (Albright Seed 1998a). In other words, weed control is key to successful establishment of a native wildflower planting. Success starts with evaluation of the proposed wildflower site.

PRE-PLANT CONSIDERATIONS

Site Evaluation

Initially, a site evaluation needs to be performed (Daar 1994; Johnson 1995; Lickorish and others 1997; Morrison 1999). An inventory of soil conditions (pH, drainage, fertilizer and moisture levels, solar aspect, elevation, compaction, sun intensity, and soil type) and current vegetation of a site provide some insight into the level of non-native vegetation, the aggressiveness of non-native species, and the possible success of a native planting. For instance, a rather barren area with topsoil removed, receiving full sun most of the day, and having low fertility and adequate drainage is likely to favor native over non-native wildflowers. Unfortunately, most sites will not reflect these conditions in one or more characteristics. Therefore, the site needs modification in some manner.

Site Preparation

Site preparation is one of the most important considerations for weed control in a native planting. The 2 principal methods of site preparation are non-disturbed and disturbed, describing whether existing topsoil is cultivated. Non-disturbed includes one or more herbicide applications, fire, mowing, or some combination of these actions. Disturbance of topsoil includes tillage or some combination of both principal methods (for example, mowing followed by tilling then herbicide application or tillage followed by fumigation or soil solarization). The main purpose of site preparation is to at least significantly reduce the potential for infestation from the quiescent weed seed bank. One method would be to have a contractor physically remove the topsoil with its weed seed bank for use on another project, thereby generating money and greatly reducing weeds at the donor site (Scott 1996; Lickorish and others 1997). Whitney (1983) sowed prairie species into 3 sites with all or some of the sod removed, then harrowed and compacted the areas. The more subsoil exposed, the more it resulted in minor weed infestations and virtually no annual weeds. Increased wildflower diversity was noted on the poorer soils.

Fumigation

Soil fumigants destroy living plant tissue and dormant weed seeds (Corley 1991; Gallitano 1991; Dickens 1992; Johnson 1995; Skroch and others 1995) and are generally considered one of the most dangerous classes of pesticides. Although application requirements are fumigant-type specific, generally soil is tilled and the material is applied either under a tarp or immediately covered with plastic or cultipacked or rolled to seal in the fumigant. Both liquid metam sodium (Vapam or Sectagon) and granular dazomet (Basamid) fumigants have been studied as alternatives to the costly and ozone-depleting gaseous fumigant methyl bromide. Dependent on rate applied, site incorporation depth, aeration tillage depth and timing, and weed species, a Basamid application followed by compression sealing was recommended overall as the most effective alternative (Skroch and others 1995). In another study, Basamid under plastic resulted in subjective ratings of "good" weed control and "excellent" wildflower establishment (Corley 1991). Fumigation with methyl bromide is a labor-intensive and hazardous procedure although almost 100% effective on all seeds in the weed seedbank, except hardseeded legumes like clovers (*Trifolium* spp. L. [Fabaceae]) (Gallitano and others 1993; Skroch and others 1995), Carolina geranium (*Geranium carolinianum* L. [Geraniaceae]), and nutsedge (*Cyperus* spp. L. [Cyperaceae]) (Gallitano and others 1993). Fumigation is usually performed in late summer or early fall as moist, warm soil is recommended. Dazomet can be applied at cooler temperatures than metam sodium or methyl bromide. A soil bioassay, after the label recommended waiting period for replanting has expired, is suggested for all 3 types of fumigants to determine if the fumigant has dissipated from the soil. Bioassays are especially critical for metam sodium and dazomet since both fumigants persist longer in soil.

Soil Solarization

Solar energy is another method to control weeds and weed seeds (Bainbridge 1990; Corley 1991; Elmore and others 1993, 1998; Chellemi and others 1997a,b). To ensure best results, the site is tilled and preferably the soil moisture level is close to field capacity. Then plastic is laid either mechanically (procedure used in forming tomato (*Lycopersicon* spp. P. Mill. [Solanaceae]) and pepper (*Capsicum* spp. L. [Solanaceae]) beds) or manually (particularly suited for small sites). Depending on weather conditions over the next 6 to 9 wk, the topsoil temperature could reach 60 °C (140 °F) with results that mimic fumigation (Stevens and others 1990). A double layer of plastic can raise the temperature another 3.3 °C (6 °F) (GardenGuides 2000a). Weed seeds and weed seedlings are controlled, along with some nematodes, soil-borne diseases, and insects. Like fumigation, soil solarization will not result in 100% control of soil pests. Chellemi and others (1997b) reported Texas panicum (*Urochloa texana* [Buckl.] R. Webster [Poaceae]) and purslane (*Portulaca* sp. L. [Portulacaceae]) escaped control by solarization. Bainbridge (1990) presents a partial list of weeds and their control by solarization. Yields of vegetables (Stevens and others 1990; Chellemi and others 1997a,b) and field cut flowers (Elmore and others 1998) are generally increased by solarization compared to untreated and, at times, fumigated soils. Increased levels of bacteria and thermotolerant fungi (Stevens and others 1990) or nitrate nitrogen (Bainbridge 1990) are possible explanations. Bainbridge (1990) states that mycorrhizae and actinomycetes are unaffected by solarization.

Singular and Combination Methodologies

The most common procedure for preparation of a relatively level site is some cyclic combination of grazing, mowing, herbicide application, or burning the existing vegetation followed by tilling(s) and/or herbicide application(s) (Doubrava 1979; Martin 1986; ODOT 1988; Elmhirst and Cain 1990; Corley 1991, 1995; Dickens 1992; Stokes and Stokes 1993; Skroch and others 1995; Lickorish and others 1997; Wilson 1999; Hampshire 2000; Prairie Frontier LLC 2001). The primary herbicide used is glyphosate (Roundup), which has a broad spectrum, non-selective, systemic mode of action. Repeated glyphosate applications for several years have been recommended (Albright Seed 1998b). Johnson (1995) suggests 1 or 2 glyphosate applications, then preparing a pulverized seed bed by tilling and fumigation or incorporated preplant herbicides. In an attempt to exhaust the weed seed bank, multiple deep tillings (Corley 1991; Prairie Frontier LLC 2001) or rotovation at different depths on a periodic basis (Stokes and Stokes 1993) have been suggested. Multiple tillings, herbicide application, or a combination of both typically control perennial weeds better. Covering or mulching with various materials (for example, black plastic, boards, tarps, leaves), possibly following tillage, is another method (Martin 1986; Stokes and Stokes 1993; NIPC 1998; Prairie Frontier LLC 2001). Another alternative is to hand weed, especially smaller areas. Time permitting, a cover crop may be planted between tillings to stabilize soil, compete with weeds, and provide organic matter (Elmhirst and Cain 1990; NIPC 1998). To minimize erosion on an embankment, Corley (1995) applied glyphosate and tilled 5 cm (2 in) deep in late summer with seeding then mulching in November or December. Prescribed fire is also used to eliminate

> *Certainly, native plants are hardy, rugged, and well-suited to our climate. However, there is one critical factor that we repeatedly overlook. As well suited to our environment as native plants may be, the environment they once dominated is not the same environment they exist within today. Introduction of hundreds of different weed species over the past century from Europe and Asia has created an environment vastly different from the one these plants were once established under; and no matter what we would like to believe, wildflowers are not invulnerable to weed competition.*
>
> *Baldwin (1998)*

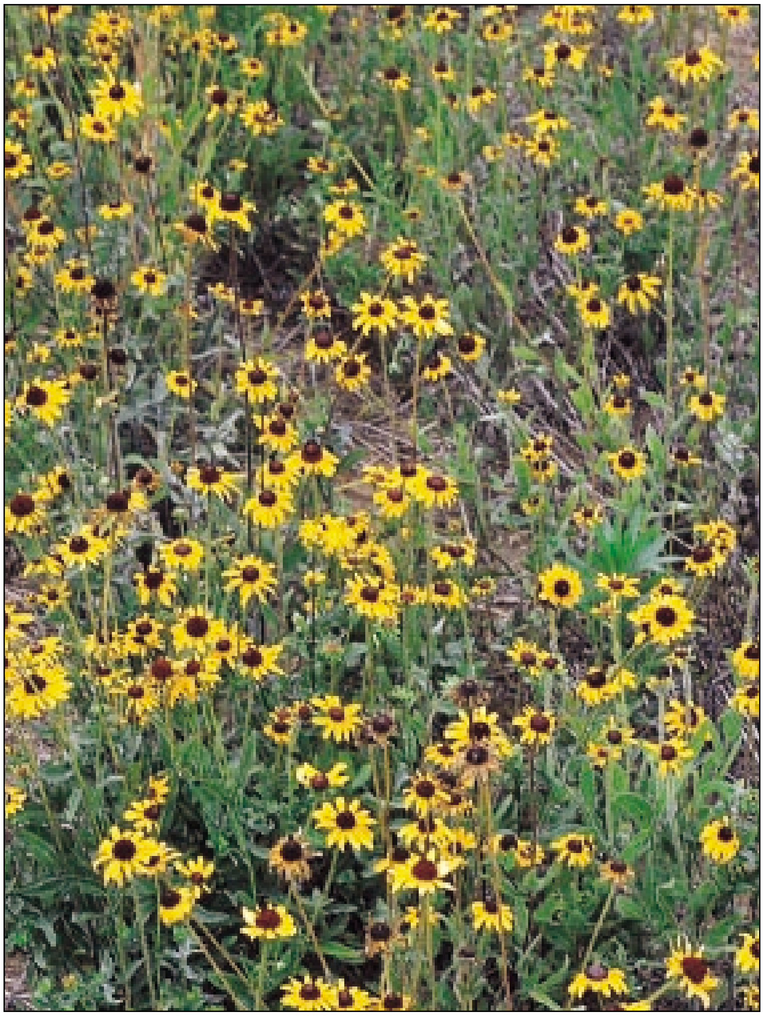

Photo by Jeff Norcini

Figure 1 • A local ecotype of Rudbeckia hirta *in seed production in Florida.*

vegetation (NIPC 1998), but when burning near roads, direction of fire and smoke movement has to be carefully calculated in order not to impair drivers. Although most site preparations include some method of tillage and herbicide application, the cost of labor, machinery, and chemical(s), not to mention environmental factors such as soil erosion from multiple tillings and impacts from herbicide applications, are factors to be considered.

Additional Establishment Factors

Although site preparation is a significant factor in the establishment of a wildflower site, other influential factors are soilless seed beds (for example, composted materials), seed source, and pH.

Soilless Seedbeds

Use of composted municipal waste and industrial co-product (either alone or combined 1:1, v:v) and biosolids and woodchips as artificial seedbeds has been studied (Pill and others 1994; Barker and O'Brien 1995). Equal volumes of composted municipal waste and industrial co-product in a 10 cm (4 in) deep bed resulted in a more balanced wildflower distribution and greater wildflower density, but also increased weed density and reduced dry mass of wildflowers and weeds compared to soil 400 d after planting (Pill and others 1994). Due to interplant competition, wildflowers and weeds were less vigorous than that of the soil bed. Barker and O'Brien (1995) concluded that either a layer of newspaper (4 sheets thick) covered with 2.5 cm (1 in) compost (biosolids and woodchips) or just 4 cm (1.5 in) compost only applied on field soil resulted in equivalent wildflower biomass, but 4 cm (1.5 in) of compost on newspaper prevented weeds.

Wildflower Seed Source

Origin of wildflower seeds to be planted is important. Over the years, state roadside plantings have become more and more oriented toward use of locally adapted seed sources, although some states (North Carolina) and environmental groups (The Nature Conservancy) (Randall and Reichard 1999) subscribe to the use of non-invasive non-natives. Indeed, most named cultivars are simply ecotypic selections by horticulturists. However, a growing number of states such as Georgia (Corley 1995), Ohio (Tatman 1993), Utah, South Dakota, and Maryland (Public Works 1996) are selecting local or regional ecotypes (Figure 1). McCully (1999) lists an ecotype as being adapted to an area within a 161 to 322 km (100 to 200 miles) radius with similar soil and climatic conditions. One principal of a 1994 Presidential Executive Memorandum on landscaping guidance, recommended use of "regionally native plants" for federal highway landscape projects (FHWA 1995). In the United Kingdom, use of native seeds from local provenances is recommended (Lickorish and others 1997).

One positive ramification of planting native wildflower species is that they may be more competitive with weed species in local growing conditions (Gallitano and others 1993). In a Florida study, one advantage of local ecotype compared to non-local ecotype seeds was the increase in length of blooming time of blackeyed Susan (*Rudbeckia hirta* L. [Asteraceae]), lanceleaf tickseed (*Coreopsis lanceolata* L. [Asteraceae]), Indian blanket (*Gaillardia pulchella* Foug. [Asteraceae]), standing-cypress (*Ipomopsis rubra* [L.] Wherry [Polemoniaceae]), and partridge pea (*Cassia fasciculata* Michx. [Fabaceae]) (Norcini and others 1998). Native plants tolerate the higher altitudes of Colorado better than non-native plants (Sherman 1995). Florida Department of Transportation unsuccessfully tried out-of-state commercial seeds (Elmhirst and Cain 1990) but now uses natives and non-reseeding non-natives (Public Works 1996). Indiana DOT uses native prairie forbs and "garden" wildflowers (Dana and others 1996).

Site pH

The pH level is another important factor. In fact, Lickorish and others (1997) state it was essential to select the wildflower species to sow on the basis of site pH. Aitken (1994) suggests that the pH range for wildflowers is 5.5 to 7. Add lime if the soil pH is about 5, but if the pH is around 4, then plant acid-loving plants (Miles 1976).

PLANTING AND FOLLOW-UP MAINTENANCE

Seed Germination Factors

Successful seed germination in a field setting depends on a number of factors including, but not limited to: 1) use of viable seeds; 2) the ability to overcome seed dormancy; 3) seed storage; 4) temperature; 5) light; 6) moisture; 7) oxygen; 8) site; 9) planting date; and 10) seed to soil contact. In order for seeds to germinate, seeds must be viable or capable of germinating. Seed dormancy is the internal condition that inhibits germination until conditions for survival are optimal. Seed stratification (moist cold storage), can overcome dormancy and result in an increase in, and uniformity of, germination. Bratcher and others (1993) determined that stratification at 5 °C (41 °F) for 4 to 10 wk increased percent germination and decreased time to initial germination and range of germination time with increasing amount of stratification time for 5 perennials. Temperature can regulate seed germination and seedling growth. Pyle (1999) lists germination temperatures grouped in 2.7 °C (5 °F) increments from 16 to 29 °C (60 to 85 °F), except the 18 to 21 °C (65 to 70 °F) range for over 75 perennials. Another method to overcome seed dormancy is scarification, mechanically or chemically damaging or removing the seed coat to allow imbibition. When storage is necessary, ideally seeds are in a sealed container at 4 to 7 °C (40 to 45 °F) at 40% to 50% relative humidity (Pyle 1999). Light, darkness, or day length can either enhance or delay germination, while a lack of moisture can reduce or inhibit germination. Warden (1990) and Tuttle (1995) provide good overviews of how seed viability, dormancy, temperature, light, and moisture influence germination and how to address them culturally to better ensure germination. Oxygen level of the planting medium, whether soil or soilless, can also affect seed germination (Tuttle 1995; Pyle 1999). Dana and others (1996) showed differences in total number of germinated seedlings of prairie wildflowers species from company to company and year to year and Pyle (1999) even suggests from different lots from the same company for perennials.

Although the other factors listed above influence or even control germination in some type of interactive method, seed to soil contact is typically the only factor listed of concern to in-field production. Without good seed to soil contact, seeds will not germinate because of lack of moisture. Tamping, raking, cultipacking, rolling, "fence" plowing, and irrigation of broadcast seeds all serve to assure seed to soil contact (Dusablon 1988; Gallitano and others 1993). Good seed to soil contact is another reason seedbed preparation includes removal of debris and clumps of vegetation.

Planting Date

One highly variable factor affecting wildflower establishment is planting date. Different planting dates and sites resulted in variable prairie wildflower performance (Dana and others 1996). Regional differences in temperatures, rainfall, and sunlight, not to mention the requirements of the wildflower species itself to be planted, preclude designating a single, ultimate planting date. Planting date should coincide with seasonal rainfall (ODOT 1988). Generally, if perennial seeds have a high dormancy requirement, fall planting is recommended. Annuals and low-dormancy-requirement perennials can be spring planted (generally by April). However, annuals can be fall planted if soil temperature is low enough (below 21 °C [70 °F]) to postpone germination until spring (Prairie Frontier LLC 2001). Some perennial species seem to favor a fall or spring planting; others do equally well with either planting season (Zajicek and others 1986; Corley and Smith 1990). Fall planting of perennials allows them to germinate and enter a resting state once true leaves are produced. When the spring growing season arrives, these perennials will develop sooner than if spring planted. Spring planting (when the soil can be prepared) allows removal of winter and early spring weeds by herbicide application, giving wildflower seedlings an opportunity to emerge in a relatively weed-free environment. However, a late spring frost can destroy tender wildflower seedlings (ODOT 1988). If site preparation is performed with planting time considered, weed control should already be addressed.

Fertilization

Most research concludes that fertilizing at planting provides little benefit for wildflowers, could increase weed pressure, and may result in increased wildflower foliage while reducing bloom (Corley and others 1989; Ahern and others 1992; Lickorish and others 1997). Two exceptions are: 1) if the site is nutritionally poor (for example, a fill area), or 2) if some annuals (requiring a higher, more immediate need of fertilizer) are seeded. Slow-release fertilizers have been recommended at planting to aid establishment (ODOT 1988; Corley 1990; Corley and Dean 1991).

Photo courtesy of Florida Department of Transportation, Environmental Management Office

Figure 2 • *The Florida Department of Transportation drilling wildflower seeds along a highway.*

Corley (1990) concluded that bloom quality and plant height of a southeastern US wildflower mix, averaged for all species within the mix, increased on 2 sites (loamy sand and clay) with biannual applications of 560 or 1120 kg/ha (500 or 1000 lb/ac) of $16N{:}4P_2O_5{:}8K_2O$ or $18N{:}6P_2O_5{:}12K_2O$. Application of 560 kg/ha (500 lb/ac) of $10N{:}20P_2O_5{:}20K_2O$ and organic material(s) that will improve the soil nutrient level and structure are recommended when no soil analysis is performed (Johnson 1995).

Seeding Density

Although wildflower seeding density has not been studied extensively, 1 rule of thumb is to apply wildflower seeds at twice the recommended rate (GardenGuides 2000b). Doubling the supplier's seeding rate to 13.4 kg/ha (12 lb/ac) for 14 species of a southeastern US mix resulted in better plant establishment of some species (Warden 1990). Increasing seeding rates above 11 to 17 kg/ha (10 to 15 lb/ac) is not a prudent effort for interim weed control (Corley and Smith 1990; Corley and others 1993). However, any seeding density is quite useless if weed control has not been incorporated in the planting plan (Albright Seed 1998a). Doubrava (1979) found that increasing the seeding density 4X the supplier's recommended rate increased number of plants per plot after 60 d. However, in only a third of the species was there any benefit to effective floral display and floral display duration.

Direct Seeding Methods

Broadcasting, seed drilling, hydroseeding, and hay strewing are the most widely used methods of direct seeding. Mode of application is influenced by several factors including site size, accessibility, soil type, and preparation (Elmhirst and Cain 1990). Broadcast seeding by hand or with a manually-operated rotary spreader is performed after mixing 1 part seeds with 4 parts damp or dry sand, sawdust, or vermiculite (Rittiner 1979; Elmhirst and Cain 1990; Corley 1995; Lickorish and others 1997). Seeds should be spread in more than 1 direction, because if an area is small, or there are ample volunteers to spread seeds, multidirectional sowing results in a rather "natural" seed distribution (ODOT 1988).

Drill seeding can be done in a larger area of existing vegetation (dead or closely mowed) or prepared soil (ODOT 1988; Elmhirst and Cain 1990; Lickorish and others 1997). Seed to soil contact is virtually assured when planting at a depth of < 0.5 cm (0.2 in) (Lickorish and others 1997). With good seed to soil contact, germination is increased and so the seeding rate can be reduced (Elmhirst and Cain 1990). Dana and others (1996) found no difference in establishment of some prairie wildflowers when planted at depths of 0.6 and 1.3 cm (0.25 and 0.5 in). However, a planting depth generally >1.3 cm (0.5 in) can result in a poor stand. Use of "no-till" or direct drilling into existing turf or bare soil (Figure 2) reduces cost by eliminating multiple tillings and herbicide applications (ODOT 1988). ODOT recommends drill seeding after mowing tall existing turf to 3.8 cm (1.5 in) with a flail mower. No-till reduces soil erosion compared to tillage methods. A drawback to drill seeding is the "unnatural" linear or row effect (Elmhirst and Cain 1990; Lickorish and others 1997) but this can be lessened by drilling half the seeds at right angles to the other half (Lickorish and others 1997).

Hydroseeding or hydromulching is the application of seeds and a fiber in a slurry to bare ground not suitable for broadcast or drill seeding (ODOT

1988; Elmhirst and Cain 1990). Since seeds are suspended in the fiber, the result is poorer seed to soil contact which causes as much as a 15% to 20% reduction in germination (ODOT 1988) or seedling desiccation (Rittiner 1979; Elmhirst and Cain 1990). Therefore, a hydroseeding mulch is best applied to areas with supplemental irrigation (ODOT 1988). If hydroseeding is required and irrigation is unavailable, a 2-step method can be used. The first step uses a mixture of water and seeds, followed by an application of mulch material and water, resulting in good seed to soil contact under a layer of mulch.

Hay strewing is another method to sow wildflower seeds (Rittiner 1979; Elmhirst and Cain 1990; Lickorish and others 1997). Basically, an area with adequate natural stands of wildflowers is "partially harvested" (a portion of the natural stand is not harvested to ensure natural reseeding to the donor area) and either immediately transported a short distance to another site (Rittiner 1979; Lickorish and others 1997) or stored in a dry place (Elmhirst and Cain 1990). The hay, with numerous undropped seeds, is spread in a thin layer on the recipient area, which should be half the size of the donor area (Lickorish and others 1997). To dislodge seeds, a chain harrow can be periodically dragged over the hay (Lickorish and others 1997) or the hay can be irrigated to assure seed to soil contact (Rittiner 1979). Wildflower hay mixed with up to 2.5 cm (1 in) topsoil increases germination over hay without topsoil (Rittiner 1979).

Indirect Seeding Methods

Three methods of wildflower site establishment that do not involve directly applying seeds to the site are plugs, transplants, and a sod or blanket of wildflowers. These methods are used to quickly establish a planting or change a site's diversity. Plugs can be used to augment a wildflower site by transplanting species that are slow to germinate or establish (Dana and others 1996; Lickorish and others 1997) or have limited or expensive seeds (Lickorish and others 1997). Establishment can be as high as 60% (Lickorish and others 1997). Transplanted plugs spaced on 30 X 30 cm (12 X 12 in) centers resulted in an instant wildflower site but the advantages compared to transplanting on 30 X 60 cm (12 X 24 in) centers faded by 8 wk (Harkess and Lyons 1997). Transplants are used exclusively in the Virginia Tech transplanted meadow (VTTM) technique (Harkess and Lyons 1997). With the VTTM technique, annual plants, grown as plugs, are transplanted to prepared sites for an instant meadow effect. Dana and others (1996) sowed 3 species of wildflowers in either 13- or 18-cm-deep (5- or 7-in) containers in the greenhouse and then transplanted to the field. Of the measured responses (for example, number of shoots or flower shoots and dry weights), 45% were increased by using deeper containers.

Three prairie wildflower perennials for greenhouse plug production were studied with or without 1 of 4 vesicular-arbuscular mycorrhizal fungi (VAM) species, 3 levels of phosphorus (P) fertilization, and 2 plug substrates in regards to P content, root colonization, and dry weight (Zajicek and others 1987). The 1:1 soil:sand (v:v) medium resulted in equal or greater total dry weight, root quantity, and root intensity than 1:1:1 soil:sphagnum peat:perlite (v:v:v) medium regardless of amended P level. For the 3 species, the soil:sand medium inoculated with *Glomus macrocarpum* Tulasne and Tulasne (Glomaceae) and amended with either 0.29 or 0.58 kg P/m^3 (0.02 or 0.04 lb P/ft^3) had equivalent or greater total dry weight than any other VAM X P level treatment. The soil:peat:perlite medium and the 0.29 kg P/m^3 (0.02 lb P/ft^3) inoculated with *G. macrocarpum* resulted in

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Photo by Kas Dumroese

*Silky lupinje (*Lupinus sericus *Pursh [Fabaceae]).*

continued from p 73

equal or increased total dry weight of all 3 species compared to other VAM X P level treatments. Once transplanted to the field, nursery-inoculated VAM plugs had increased plant height and number of flowering stalks the second growing season. In another study (Dana and others 1996), positive growth responses were found in only 25% of VAM-inoculated wildflower species 1 and 2 y after field transplanting. Indeed, some non-inoculated seedlings had increased levels of VAM after 2 y in the field compared to pre-inoculated seedlings.

Wildflower sod or blankets have also developed a niche in wildflower plantings. Sods or blankets can consist of: 1) shredded and formed recycled clothing (Lickorish and others 1997); 2) peat-like mixes with cheese cloth for root binding; 3) seeds raked into a composted material laid on plastic (Barker and O'Brien 1995); or 4) weed barrier or plastic covered with a coir fiber mat and a soilless medium (van der Grinten and Gregory 2000). Some of the uses for sods or blankets are on steep slopes, areas where tilling is impossible, a poor soil profile, or where an immediate wildflower site is needed. Sod or blankets with an organic base provide weed suppression and a source of nitrogen as the material degrades. Since the base material may take years to completely degrade, broadcasting additional seeds can enhance and prolong the site (Birdsall 1999).

Cover Crops

Cover or nurse crops are definitely recommended: 1) to stabilize erodible sites (ODOT 1988; Elmhirst and Cain 1990; Corley and Dean 1991; NIPC 1998); 2) for color from annuals while perennials establish (ODOT 1988; Branhagen 1997); and 3) to reduce aggressive weed encroachment (Elmhirst and Cain 1990). Corley and Dean (1991) recommend a 75% seeding rate for 3 of 4 nurse grass species studied plus 11.2 kg/ha (10 lb/ac) of wildflower seeds on erodible sites. However, Johnson (1995) recommends not to use grasses as cover crops (due to competition) with forbs. Branhagen (1997) suggests use of non-invasive annuals as a cover crop and even wildflowers as a minor component of a combination of cool- and warm-season grass planting. Elmhirst and Cain (1990) advocate planting clump-type grasses at a low seeding rate in a mixed wildflower and grass planting to stabilize the soil and limit weed intrusion.

Chemical Weed Control

Using herbicides to establish a stable wildflower site is one of the most active areas of recent research. Herbicides may be applied before planting to either kill existing vegetation or prevent weed emergence, before the emergence of wildflower seedlings, or after wildflower seedling growth or transplantation


Photo by Thomas G Barnes

*Colorado blue columbine (*Aquilegia caerula *James [Ranunculaceae]).*

(Elmhirst and Cain 1990; Gallitano and Skroch 1990; Skroch and others 1990, 1995; Derr 1993; Erusha and others 1991; Gallitano 1991; Agnew and Hatterman-Valenti 1993; Corley and Murphy 1994; Masters and others 1996; Harkess and Lyons 1997; Pywell and others 1998; Beran and others 1999a,b; Washburn and others 1999; Washburn and Barnes 2000). So far, the magic bullet that will completely control all broadleaf and grassy weeds without injury to all wildflower species is missing. Therefore, efforts continue to find the herbicide, or combination of herbicides, at rates and stage of the wildflower development that could prove the most useful on different wildflower species. These variables, in addition to differences in seed source, soils, climate, and uncertain herbicide availability attest to the amount of research that has, and could be undertaken, to address these factors.

The 4 major categories of herbicide application timing are related to wildflower seed sowing and weed development stage. Herbicide application timing to seed sowing and stage of weed development categories include: 1) preplant and postemergence; 2) preplant and preemergence; 3) postplant and preemergence; and 4) postplant and postemergence. The 2 herbicide application timings reflect whether the wildflower seeds have not yet been sown (preplant) or have been sown or seedlings transplanted (postplant). Two herbicide application timings in relation to herbicidal activity at the weed's stage of development are pre- and post-emergence or before and after the weed seedling emerges, respectively. Information pertaining to researchers' conclusions on herbicide evaluations of efficacy and/or phytotoxicity is mediated by many components. Factors such as the herbicide(s) evaluated, wildflower species and seed source, climatic conditions, herbicide formulation, soil type, management practice(s), and weed species interference interact to form a matrix. Therefore, only a general review of this area regarding potential or seeded sites will be presented. Thanks to the efforts of the National Agricultural IR-4 Ornamental Research Program and the contributions of numerous researchers, registration efforts for minor use crops like wildflowers is addressed. A partial list of pesticides and biopesticides for use on a wide range of ornamental crops including wildflowers is available in the IR-4 Project 2000 (NJ 2000). However, the information below does not constitute a recommendation for use since some herbicides listed are not currently cleared for use on wildflowers. Always read and follow label directions for any pesticide.

Preplant and postemergence herbicides are typically used for site preparation (described above). Glyphosate is one of the most widely used herbicides for eradication of existing vegetation but other materials used include MSMA, diquat, and paraquat (Dickens 1992).

Preplant and preemergence herbicides are applied before weed seedling emergence, but the former is applied before wildflower seeds are sown and the latter after sowing but before wildflower emergence. In a preplant herbicide study in Nebraska and Oregon, Erusha and others (1991) incorporated a combination of EPTC + trifluralin, then sowed seeds of annual and perennial wildflower species. In Nebraska, 8 of 23 annual and 6 of 23 perennial species, while in Oregon 7 of 22 annual and 7 of 19 perennial species sown had reduced stand ratings during establishment. In North Carolina, napropamide, EPTC, alachlor, pendimethalin, metolachlor, and trifluralin controlled annual grasses, broadleaf weeds, and nutsedges [Cyperaceae] with tolerance of wildflower species, such as *Rudbeckia hirta*, *Coreopsis lanceolata*, and *Chrysanthemum leucantheum* L. [Asteraceae], chemical and rate dependent (Johnson 1995). Dickens (1992) found germination and seedling emergence of yarrow (*Achillea* sp. L. [Asteraceae]), *Coreopsis lanceolata*, and *Chrysanthemum leucantheum* tolerated metolachlor, EPTC, trifluralin, benefin, and pronamide, but 3 other wildflowers did not. Application of 70 g ai/ha (1 oz ai/ac) imazapic or imazethapyr to a tilled, cultipacked, and irrigated seed bed of 3, 5, and 2 wildflower species in 1994, 1995, and 1996, respectively improved wildflower establishment, especially if weed competition was intense (Beran and others 1999).

TABLE 1

Response of 7 wildflower species to several herbicides applied to transplants or an established planting [a]

Herbicide	References [b]	*Chrysanthemum leucantheum*	*Coreopsis lanceolata*	*Echinacea purpurea* [c]	*Gaillardia* spp.	*Monarda* [d] spp.	*Phlox* [e] spp.	*Rudbeckia hirta*
Alachlor	2						+/-	
Benefin	6						+	
Bensulide	6						+	
DCPA	2, 5, 6			+	+	+	-, +	
Isoxaben	3	-	+/-	+/-	-			
Metolachlor	1, 3, 5, 6	+	+	+	+/-, +		-, +	
Metholachlor + Isoxaben	3	-	+/-	-	+/-			
Metolachlor + Oxadiazon	3	+	+	-	+/-			
Metolachlor + Simazine	3	-	-	-	-			
Napropamide	2, 4, 6	+				+	+, +	
Napropamide + Oxadiazon	2					+	+/-	
Pendimethalin	1, 5							+
Oryzalin	1, 2, 4	+					-, -	
Oxadiazon	2					+	+/-	
Oxyfluorfen	2					+/-	+/-	
Simazine	2					+	-	
Terbacil + Oryzalin	4	+						
Terbacil	4	+						
Trifluralin	7				+			+

[a] This is not a recommendation because some listed herbicides are not registered for use on wildflowers. Wildflower responses: (+) = none or minimal phytotoxicity; (+/-) = inconclusive results; (-) = high level of phytotoxicity.

[b] Numbers correspond to references: 1 = Agnew and Hatterman-Valenti (1993); 2 = Ahrens (1981); 3 = Derr (1993); 4 = Gallitano and Skroch (1990); 5 = Johnson (1995); 6 = Skroch and others (1990).

[c] Asteraceae

[d] Lamiaceae

[e] Polemoniaceae

Application of preemergence herbicides have been researched extensively after planting seeds or transplanting liners of wildflowers but before weed emergence. Herbicides that cause little or no damage and may have provided reasonable to excellent weed control are listed in Table 1.

Postplant and postemergence herbicides kill weeds in wildflowers with little to no damage to the latter. Gramicides only control grasses, which in the case of establishing wildflower plantings, can be extremely useful. Four principal gramicides used are fluazifop (Dickens 1992; Agnew and Hatterman-Valenti 1993; Johnson 1995), sethoxydim (Dickens 1992; Agnew and Hatterman-Valenti 1993; Johnson 1995), fenoxaprop-ethyl (Agnew and Hatterman-Valenti 1993; Johnson 1995), and quizalofop-ethyl (Johnson 1995).

Quinclorac, another postemergence herbicide, at 0.6 kg ai/ha (0.5 lb ai/ac), suppressed white clover (*Trifolium repens* L. [Fabaceae]) but resulted in a good display of *Rudbeckia hirta*, *Coreopsis lanceolata*, and *Gaillardia* spp. among others, while 1.1 kg ai/ha (1 lb ai/ac) controlled clover but resulted in transient phytotoxicity to *C. lanceolata* and *Gaillardia* spp. (Corley and Murphy 1994). Corley (1995) applied sulfometuron methyl, monosodium methylarsonate, clopyralid, and quinclorac 6 and 20 mo after establishing 9 single species plantings. Six species showed tolerance to sulfometuron methyl, 5 species were tolerant to monosodium methylarsonate, and 3 species were tolerant of either clopyralid or quinclorac.

Imidazolinone herbicides (imazapyr, imazethapyr, and imazapic) are absorbed by the plant through roots and foliage (Beran and others 1999a). This class of herbicide showed activity on numerous broadleaf weeds and grasses with little or no injury to numerous native forbs and grasses. They also stated that establishment of some forbs was enhanced if elevated weed levels were present at application of imazapic and imazethapyr. Beran and others (1999b) showed that 3 of 6 legumes, partridge pea (*Chamaecrista fasciculata* Michx. [Fabaceae]), purple prairieclover (*Dalea purpurea* Vent. [Fabaceae]), and crownvetch (*Coronilla varia* L. [Fabaceae]), tolerated imazethapyr and imazapic particularly in weedy sites. Imazapic showed postemergence activity on broadleaf weeds and "weedy" grasses in the establishment of native grasses and wildflowers (Washburn and Barnes 2000).

Hand Weeding

Manually removing weeds, if practical, is still an excellent means of weed control. The ability to identify wildflowers from weeds, especially at the seedling stage, is a must, and hand pulling or snipping at ground level is recommended (Prairie Frontier LLC 2001). Weeding when the soil is moist minimizes soil disturbance and should result in less subsequent weed seed germination (Wilson 1999). Weed control around the perimeter of a wildflower site is also important (Dusablon 1988) and mowing is a suggested method (Slater and Tregea 1995).

Biological Weed Control

Biocontrol, another form of weed control, uses plant pathogens, nematodes, insects, mites, and even fish or sheep. Biocontrol has been successful for specific incidences (Kok 1997, 1998; Weeden and others 1999). For example, the plant pathogenic bacterium *Colletotrichum gloeosporioide* (Penzig) Penzig & Saccardo (Melanconiaceae) controls northern jointvetch (*Aeschynomene virginica* [L.] B.S.P. [Fabaceae]) (Weeden and others 1999). Sometimes a combination of biocontrol agents are used. The thistle-head weevil (*Rhinocyllus conicus* [Curculionidae]) and rosette weevil (*Trichosirocalus horridus* [Curculionidae]) attack different developmental stages of musk thistle (*Carduus nutans* L. [Asteraceae]) (Kok 1997, 1998). Although no research directly related to use of biocontrol agents on weeds in wildflowers is cited, control of invasive weeds would, at least, indirectly benefit native wildflower plantings.

Allelopathy is the chemical effect of 1 plant on another, even of its own species (auto-allelopathy). Weeds as well as wildflowers may possess and influence each other by means of allelopathy. Species of goldenrod (*Solidago* L. [Asteraceae]) and aster (*Aster* L. [Asteraceae]) are allelopathic. Weeds such as bermudagrass (*Cynodon dactylon* (L.) Pers. [Poaceae]), Johnsongrass (*Sorghum halepense* (L.) Pers. [Poaceae]), yellow nutsedge (*Cyperus esculentus* L. [Cyperaceae]), and purple nutsedge (*Cyperus rotundus* L. [Cyperaceae]) are at least thought to have allelopathic properties (Gallitano and others 1993). Allelopathy, as in the relationship of wildflower effectively controlling weeds, is poorly studied, but must be acknowledged as influencing wildflower establishment.

Mulching

A thin mulch applied after seed sowing may aid wildflower establishment. Mulching with a weed seed-free organic material helps keep wildflower seeds from blowing away, protects them against wildlife foraging, conserves moisture, moderates soil temperatures, protects seedlings from weather extremes, and reduces weed competition (Miles 1976; Martin 1986; Corley and others 1989; Corley and Smith 1990; Stokes and Stokes 1993; Aitken 1994; Johnson 1995). Doubrava (1979) found more plants of 5 of 6 wildflower species were established with, rather than without, pine straw mulch and that the length of effective floral display was increased for plains tickseed (*Coreopsis tinctoria* Nutt. [Asteraceae]).

Several mulches can be used (for example, wheat straw, pine straw, fine textured wood chips, leaves, tobacco stems, chopped corncobs, or cocoa hulls) if free of weed seeds. A thick mulch layer may prevent wildflower seeds from receiving adequate sunlight to germinate or prevent seedlings from growing through it. In warm and humid regions, wood chips work well as mulch but may reduce soil nitrogen as the products decompose (Martin 1986). Therefore, if wood products are used, additional fertilizer might be needed.

Steep slopes present a special challenge to mulching. Tacking the seedbed with a fibernet or putting down coarse gravel and then sowing wildflower seeds (Martin 1986) are 2 suggestions for seeding steep slopes. The latter method allows wildflower seedlings to emerge through fissures in the gravel.

Site Irrigation

Proper irrigation can also aid wildflower establishment. Once seeds are sown, the site should not dry out to prevent negative effects on germination. Soil moisture was the most important success factor in the establishment of wildflowers in detention basins (EPA 1999). Some wildflower species have specific moisture requirements for germination, since 2 wildflower species germinated at 90% in experimental conditions but none germinated in a field with limited soil moisture (Tuttle 1995).

Recommendations for supplemental scheduled watering vary, probably reflecting regional differences. Aitken (1994) suggests wildflower seeds in South Carolina need good soil moisture for 4 to 6 wk after sowing. A weekly watering of 0.6 cm (0.25 in) is recommended by the wildflower and grass seed company, Prairie Frontier LLC (2001) of Wisconsin. Adequate soil moisture for 1 to 2 wk is put forth by Stokes and Stokes (1993) for the area west of the Rocky Mountains. In Victoria, British Columbia, a good supply of water throughout the summer yields good growth and high quality flowers (Slater and Tregea 1995). The most specific watering schedule is presented by Albright Seed Company of California (1998a); they suggest three 3-wk periods. For the first 3-wk period, only the soil surface needs to be moistened by, for example, frequent light irrigations. During the next 3-wk period, gradually reduce watering as seedlings emerge. For the final 3 wk, thoroughly water wildflowers once a week. Overwatering might cause weed pressure to increase (Albright Seed 1998a). Additionally, watering in late afternoon or evening is preferred during plant establishment, while morning watering is suggested after successful establishment (Prairie Frontier LLC 2001).

Consideration of the site's soil type should be included in determining supplemental watering schedules. Special caution is warranted when planting in clay soil as once saturated, it is difficult to dry-down. Finally, the quality of the irrigation water should be examined to determine applicability (Slater and Tregea 1995). Four factors influence water quality: salt content, sodium to other cation ratio, carbonate and bicarbonate to calcium and magnesium ion concentrations, and toxin levels (for example heavy metals) (Hergert and Knudsen 1997). Use of unsuitable irrigation water could result in difficulties in establishment and maintenance of a wildflower stand.

Pests

Excessive moisture, saturated heavy soils, and poor water quality can lead to the development of diseases and failure or poor wildflower establishment. The single most important and widely found disease affecting wildflower establishment is a root rot fungus (*Phytophthora* sp. Bary [Pythiaceae]) (Slater and Tregea 1995). Other diseases such as damping-off and scabs, as well as insects like gall-wasps, can influence establishment of certain wildflower species.

Postponing Natural Succession

Starting the first year and throughout the future of a wildflower planting, the natural succession process or the transition from herbaceous wildflowers to the site's climax vegetation (for example, a hardwood forest) is constantly present. The natural succession of the wildflower site could be available in the form of a historical record. Knowing the natural order of succession provides substantial information to use when considering future management techniques. In times past, fire was a tool that delayed natural succession. Fire not only destroys or injures non-herbaceous plants, it reduces biomass buildup, releases nutrients back to the soil, and opens areas to increased sunlight (Branhagen 1997). Some forbs respond favorably to fire with a better floral display and seed production.

Photo courtesy of Florida Department of Transportation, Environmental Management Office

Figure 3 • A roadside wildflower planting in Florida.

Now, anthropogenic land use, particularly mowing, has almost completely replaced grazing and significantly reduced burning. Mowing, as many of the factors in wildflower establishment are, is site specific or at least regionally specific. Mowing interrupts successional progression and allows expansion of the wildflower site through natural reseeding. Gallitano and others (1993) state mowing also improves aesthetics of the wildflower site. Different references recommend mowing at various wildflower developmental times, and for slightly different reasons. Most of these differences are concentrated within the first year of establishment. Mowing has been suggested: 1) after weeds grow 20 to 30 cm (8 to 12 in) tall (cut them back to 10 to 15 cm [4 to 6 in]; Matzke [1998]); 2) for midsummer (reduce weed height by half) (Wilson 1999); 3) twice annually (EPA 1999); 4) about 4 times annually (Lickorish and others 1997); 5) during August, if required (Branhagen 1997); and 6) after the first frost (Dusablon 1988). NIPC (1998) recommends occasional mowing during the first 2 to 3 y. Other suggestions for the second year include mowing to ground level and removing debris in early spring followed by a second mowing by early summer if weeds are persistent (Matzke 1998). Some recommendations are to mow annually, ideally after wildflowers have set seeds but before weed seeds ripen (Gallitano and others 1993; Sherman 1995) or late fall (EPA 1999). Cut to 5 cm (2 in) and remove cuttings if possible (Lickorish and others 1997). They suggested mowing spring flowering areas in September and summer flowering areas in April and September. Matzke (1998) suggested annual cutting for 2 y after planting then every 3 to 5 y. Of course, the site's wildflower and weed species, rainfall, climatic conditions, and even wildlife utilization can influence mowing schedules. One advantage of mowing was the extension of blooming for 3 species, by as much as 1.5 mo, if the most appropriate mowing dates studied were used (Salac and others; 1973). Corley (1995) stated although most spring blooming wildflowers did not favorably respond to summer mowing, summer and fall blooming wildflowers did. Mowing aided in reblooming when good soil moisture was available or was forthcoming.

Prescribed burning can be used in addition to mowing or as the primary agent against succession. Although fire is essential to some ecosystems, some do not tolerate it (Branhagen 1997). Suggestions of annual, biannual, or periodic burns are stated (Branhagen 1997; Matzke 1998; NIPC 1998). Burns in early spring retain winter cover for wildlife, but some areas should be left unburned for wildlife safety (Branhagen 1997). Special weather conditions and fire equipment are needed, proper buffers need to be maintained, and one should contact adjacent landowners and the proper authorities before burning. Helms and Jackson (1973) observed 3 changes in herbaceous species due to either a spring or a fall prescribed burn of forested areas in Illinois or Indiana. The post-burn response of wildflowers was related to what these species "normally" would encounter in their usual habitat. Generally, a species in a typically undisturbed area would decrease in density, a species typically found in a less stable area increased in density, and a species usually found only in disturbed forest sites would only occur in burned areas. However, herbaceous perennials from unchanged sites primarily reproduce vegetatively, therefore, fire could reduce the density unless these exposed parts are fire resistant. Reductions could be expected of species with shallow vegetative reproductive organs such as corms or rhizomes. Helms and Jackson (1973) state it was better to burn when the site's litter had a low moisture level, otherwise steam could be produced which is more damaging than dry heat.

Reseeding and Overseeding

Some wildflower species naturally reseed, but if human intervention is required it is considered overseeding. Reseeding has the potential to continue the viability of a site for years because in a site with mixed wildflower species, usually only a few species establish and others disappear (Gallitano and others 1993). Therefore, to help ensure species diversity or density, or to provide more timely floral displays, overseeding is performed (Elmhirst and Cain 1990; EPA 1999). If weeds are at a tolerable level, overseeding is considered a better option for reintroducing or enhancing certain species to a site compared to starting again with site preparation (Gallitano and others 1993). Overseed perennials in fall and annuals in late fall or early spring. Spread seeds with as little soil disturbance as possible to limit additional weed seed germination. Irrigation or rainfall, rather than mechanical or manual methods, should be relied upon to assure good seed to soil contact. Annuals should probably be overseeded annually, at least until the perennials are naturally reseeding. Overseeding perennials is suggested every fourth or fifth year for species diversity (Elmhirst and Cain 1990).

WILDFLOWER PLANTING BENEFITS

The benefits of wildflower plantings are many. Depending on the wildflower site, economical, educational, recreational, ecological, and aesthetical advantages may exist. Aesthetic value from wildflowers would include an overall pleasant, perhaps more relaxed, feeling when exposed to sharp colors, different hues, various shapes, textures, sounds, and odors (Ahern and others 1992; NIPC 1998). By differentiating rights-of-way, wildflower plantings can be aesthetically masterful (Figure 3). Several ecological benefits of a wildflower meadow on a right-of-way can be evident. The typical turf right-of-way contributes to lower water quality from the runoff of pesticides, petroleum products, lead, and sediments (Ahern and others 1992). Increased water quality and reduction in air pollution could be realized compared to turfed rights-of-way, because the plant's ability to trap and hold particulates and gaseous air pollutants is related to the amount of vegetative biomass (Ahern and others 1992; NIPC 1998). And, once trapped, pollutants are not apt to runoff as pollution to the groundwater, thereby improving water quality. Native forbs anchor soil with deep dense rooting to stabilize erodible slopes, river or stream banks, and beach dunes (NIPC 1998). Since wildflower plantings use little, if any, pesticides for maintenance, the potential for offsite movement of some pesticides is limited. Wildflower meadows act as greenways along roadsides, with wildlife using them for food, shelter, and transportation corridors. Wildflower plantings aid in habitat restoration and protection by attracting birds and insects, especially butterflies (NIPC 1998). Scott (1996) planted a 1.7 ha (4.3 ac) wildflower site and noted an increase in birds and invertebrates. Diversity is of key ecological importance and wildflower plantings can stimulate diversity (Ahern and others 1992; EPA 1999).

From an educational and recreational standpoint, natural landscapes that include wildflower plantings afford people the opportunity to observe, interact, appreciate, and understand more about natural settings (NIPC 1998). From use as parks, nature trails, and forest preserves, native plantings can be used to educate and offer an opportunity for activities such as walking, running, bird watching, and photography. Schools can use wildflower meadows as teaching aids in the areas of botany, entomology, ecology, gardening, photography, and painting.

The economic benefits of wildflower plantings can be substantial. By 1 estimate (NIPC 1998), installed turf sod can cost more than US$ 30,000/ha ($12,000/ac), turf grass seeding $9800 to $19,600/ha ($4000 to $8000/ac), while seeding a prairie mix would run $4900 to $9800/ha ($2000 to $4000/ac). As a detention basin in a New Jersey based study (EPA 1999), a wildflower meadow cost $0.11/m^2 ($0.01/ft^2) more than seeding a traditional turf but cost 90% less per year to maintain. Estimated in 1994, commercial cultivars of wildflowers are less costly than natives to establish but more expensive over the years when low maintenance costs of natives was considered (Dana and others 1996). Finally, as an estimate of income for an alternative crop, wildflower seeds selling between US$ 110 and $1100/kg ($50 and $500/lb) would provide a gross return per hectare between $1235 and $4446/ha ($500 and $1800/ac) the first year of production (Kutka and Tinderholt 1996).

WILDFLOWER ESTABLISHMENT RECOMMENDATIONS

From this literature review, the following general recommendation for a successful perennial wildflower planting (if one does not consider specific wildflower species in certain sites) on a modest scale is presented.

- Evaluate existing vegetation, soil fertility and pH levels, soil type, and drainage with sufficient lead time to make recommended adjustments before proceeding. Timing of initiation is on a case-by-case basis due to numerous factors.
- Burn or mow and remove debris.
- Choose a site preparation method:
  1. Apply non-selective postemergence herbicide(s) or till 2.5 to 5 cm (1 to 2 in) deep; if possible irrigate to force regrowth, then repeat as necessary to practically exhaust weed seedbank.
  2. Use soil solarization by tilling 10 to 15 cm deep (4 to 6 in), irrigating to field capacity, and covering with a double layer of plastic for 8 to 9 wk during summer.
  3. Create an artificial seedbed by spreading newspaper (4 sheets thick) covered with 3.8 cm (1.5 in) of composted municipal solid waste.
  4. Apply non-selective postemergence herbicide(s) to kill existing vegetation; once dead, remove the topsoil (if the subsoil exposed is not clay).
  5. Apply non-selective postemergence herbicide(s) to kill existing vegetation; once dead, bring in a non-clay based subsoil and put down to cover the site to a depth of 15 cm (6 in).
- Use local ecotype native wildflower seeds (a mix, if not for seed production by species) at 11 to 17 kg/ha (10 to 15 lb/ac).
- Choose a planting method:
  1. Broadcast seeds mixed with damp builder's sand (1:4 ratio) and lightly rake or irrigate to incorporate.
  2. Drill seeds using appropriate seeder.
  3. Install transplants.
  4. If an erodible site, use a wildflower sod or a two-step hydroseeding method.
- Irrigate about 0.6 cm (0.25 in) daily for 3 wk.
- Once wildflower seedlings emerge, reduce irrigation, if no rainfall equivalent, to 1.2 cm (0.5 in) twice per week for 1 mo.
- Complete these maintenance steps:
  1. Irrigate if drought conditions prevail.
  2. Look for signs of nutrient deficiency and correct as needed.
  3. Use a labeled postemergence gramicide to control grasses.
  4. Treat with labeled wildflower(s) species-tolerant postemergence herbicide(s), if site contains weedy forbs.
  5. If desired, harvest wildflower(s) seeds when ready, which may be 2 or 3 times per year, but leave what is the last (or only) harvest on the plant.
  6. If not harvesting seeds, mow with a flail mower or burn if appropriate after wildflower seeds mature but before weed seeds mature.
  7. Repeat maintenance as needed to suspend natural succession.

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