

ELEMENT STEWARDSHIP ABSTRACT
for

Convolvulus arvensis L.

Field Bindweed

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THE NATURE CONSERVANCY

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SPECIES CODE**SCIENTIFIC NAME**

Convolvulus arvensis L.

Convolvulus is derived from the Latin, *convolvere*, meaning to entwine, and *arvensis* means 'of fields' (Gray, 1970). The genus *Convolvulus* contains about 250 species (Zomlefer, 1994).

COMMON NAMES

Convolvulus species are referred to as bindweeds. Both 'bindweed' and 'wild morning-glory' are applied to all the weedy species in the genus (Cox, 1915), but 'field bindweed' is used almost exclusively to refer to *Convolvulus arvensis* L. and is accepted by the Weed Science Society of America as the "official" common name (Whitesides, 1979). Other common names are 'possession vine,' 'creeping jenny,' 'creeping charlie' (Wiese & Phillips, 1976), 'field morning-glory,' 'orchard morning-glory' (Whitesides, 1978), 'European bindweed' (Swan, 1980), 'corn-bind,' 'morning-glory' (Callihan *et al.*, 1990), and 'small-flowered morning-glory' (Weaver & Riley, 1982). In Canada the name '*liseron des champs*' (translation: field bindweed) may be used (Weaver & Riley, 1982).

DESCRIPTION AND DIAGNOSTIC CHARACTERS

Field bindweed is a persistent, perennial vine of the morning-glory family (Convolvulaceae) which spreads by rhizome and seed (Wiese & Phillips, 1976). It is a weak-stemmed, prostrate plant that can twine and may form dense tangled mats (Gleason & Cronquist, 1963). Stems can grow to 1.5m or longer, and its underground rhizomes may range from 5cm to 2.6m long. The extensive roots can measure 6.6m long and penetrate deeply into the soil (Wiese & Phillips, 1976).

Seedlings emerge from the soil erect and ascending. Seed leaves (cotyledons) are nearly as broad as long, somewhat round, and notched at the tip. They are dull green with readily visible veins. The petiole is flattened, and grooved on the upper side. The first true leaves are dull green and may be covered with fine granules on the upper surface. Leaves of this species are extremely variable, possibly reflecting variability in soil moisture and fertility (Fischer *et al.*, 1978). The most common leaf type is hastate or sagittate, which means they have distinctive arrowhead shapes with pointed lobes at the bases. Some leaves are round, ovate or oblong, and some may even be linear. These deviations from the typical leaf types may be found on plants growing in disturbed conditions (Fischer *et al.*, 1978). The veins on mature leaves are pale green and depressed on the upper surface. Veins on the lower surface are raised. Mature leaves are typically 2-6 cm long.

The flowers have five fused petals forming a 2-2.5cm long funnel-like corolla. Petals are generally white to very pale pink. The sepals are approximately 5mm long, oblong and separate. Five stamens of unequal lengths are attached to the base of the corolla. The pistil is compound with two thread-like stigmas (Weaver & Riley, 1982). Each flower is subtended by a pair of pointed, linear bracts located approximately 1.5-2.5cm below the flower and often appressed to the stem.

During fruiting, the sepals are retained. Each fruit is about 8mm wide, rounded, light brown. Seeds are dark brown to black, and have rough surfaces. They are 0.5-1.2cm long, and their shapes vary, depending on the number produced in the fruit; they are rounder when only one is produced and progressively thinner as more are produced (Brown & Porter, 1942). Field bindweed fruits usually contain 2 seeds, but 1-4 seeds are not uncommon; an anomalous Russian specimen was found with 10 seeds in a capsule (Brown & Porter, 1942).

The number of seed per plant varies between 25-300 (Brown & Porter, Weaver & Riley, 1982). Estimates of the number of seeds in a pure stand of field bindweed range from 50,000 to 20 million per hectare (Weaver & Riley, 1982).

Forms and varieties

C. arvensis var. *obtusifolium* Choisy is generally the only variety recognized in North America (Robinson & Fernald, 1908). Gray (1970) refers to two forms of field bindweed: *C. arvensis* f. *cardifolius* Lasch., which has wide cordate leaves and broad basal lobes, and *C. arvensis* f. *auriculatus* Descr., which has linear, oblong or lanceolate blades with acute ear-shaped lobes at the leaf bases. Sixty or more varieties have been identified in Europe but the characteristics used to distinguish these have been attributed to environmental factors (Kogan, 1986). Plants with characteristics intermediate to those of these varieties are common in North America, further discouraging the use of the varietal names in the USA (Brown, 1946). *Convolvulus ambigens* House is a hairy plant that has been grouped by Gleason (1952) with *C. arvensis*.

Confusion with other species

Field bindweed may be confused with *Polygonum convolvulus* L. and with *Calystegia sepium* (L.) R. Br. (Alcock & Dickinson, 1974; Callihan *et al.*, 1990). *Polygonum convolvulus* L. (black or corn bindweed) is a hairless annual species with fibrous roots and slender climbing stems. Unlike field bindweed, its arrow-shaped leaves (2-5 cm long) are not variable in shape. The showy, funnel-shaped flowers of *Convolvulus arvensis* are unlikely to be confused with *Polygonum convolvulus*'s clusters of inconspicuous, greenish-white flowers. Out of flower, *Polygonum convolvulus* can be identified because each leaf node is surrounded by a membranous or papery sheath, characteristic of the genus *Polygonum*. *Convolvulus* does not have such sheaths. The stems of *Polygonum convolvulus* are often red and twisted (Callihan *et al.*, 1990).

Calystegia sepium L. (synonym: *Convolvulus sepium* L.), commonly called hedge bindweed, glory vine, or great bindweed, is a robust sprawling plant with large trumpet-shaped pale-lilac to white flowers that are approximately 5cm across. This species may be distinguished from field bindweed by its two leafy, non-linear bracts that enclose and conceal the sepals (Callihan *et al.*, 1990). Leaves of this species are larger (3-13 cm) than those of field bindweed and are hairless. Each fruit contains a single seed with sharp angles and pointed ends. *Calystegia sepium* L. is native to the eastern United States, but is now found throughout the country (Britton & Brown, 1970; Hickman, 1993; Callihan *et al.*, 1990) and occurs in waste areas and fence rows (Callihan *et al.*, 1990).

STEWARDSHIP SUMMARY

Because of its wide distribution, abundance and economic impact, *Convolvulus arvensis* is considered one

of the ten ‘world’s worst weeds’ (Holm *et al.*, 1977). Jepson (1953) claims that it is “the most troublesome garden weed yet naturalized in California...and is especially obnoxious in the richest lands and moist alluvial loams.” Its impact on agricultural lands is well documented, especially in the central United States, but the threat it poses to natural areas is unclear. Almost all research on field bindweed pertains to agriculture. Preserve managers are most likely to find the weed on tracts once used for agriculture or in moist locations such as riparian corridors and irrigated areas. Nevertheless, preserve managers give field bindweed a relatively high threat rating. Some managers have had luck controlling the weed but in general have been unable to eradicate it.

Field bindweed has deep roots that store carbohydrates and proteins. They help field bindweed spread vegetatively and allow it to resprout repeatedly following removal of above-ground growth. Successful control is most likely if the above-ground biomass is removed (by tillage, hand-pulling or herbicide application) followed by competition from other species (*e.g.* from the surrounding vegetation or restoration efforts), and continuous monitoring for resprouts. In agriculture, control has been most successful where tillage is combined with herbicide application, although herbicide application alone can be effective. 2,4-D is the most widely used herbicide because it controls the weed effectively and is relatively inexpensive. Herbicide application should be applied when the herbicide will be translocated to the roots, but before seed set.

IMPACTS (THREATS POSED BY THIS SPECIES)

There is there is a great deal of information on field bindweed’s effects upon crops, but little is known about its impacts on rangelands or natural areas. It is considered a pest throughout the United States since it twines around crop plants and eventually topples them, although taller crops are considered to be at less risk (Cox, 1915). Like other weeds, field bindweed takes nutrients and water that would otherwise be available to desirable species (Swan, 1980; Frazier, 1943b). It can reduce the available soil moisture in the top 60cm of soil to below the wilting point for many species (Weaver & Riley, 1982). Overall, crop yields can be reduced to 50-60% where infestations are dense (Callihan, *et al.*, 1990). Wiese *et al.* (1996) found a significant increase in available soil water following increased control of field bindweed in an agricultural setting. Finally, exudates from field bindweed roots decrease germination of some crop seeds (Swan, 1980).

Field bindweed is found on several of The Nature Conservancy’s preserves and poses a threat to their restoration efforts. Stewards at the Phantom Canyon Preserve report that the species is most likely to invade areas that are degraded due to past land use, current human activity, and in areas that are not allowed to burn. Field bindweed is primarily a problem at this preserve’s riparian corridors and mountain-mahogany shrubland/grassland, where it can rapidly choke out native grasses and forbs. Stewards at Garden Creek Preserve in northern Idaho report that field bindweed threatens bunchgrass/forb-dominated habitats by decreasing biodiversity and is a direct threat to several species. At the Thousand Springs Preserve, field bindweed thrives under well-irrigated conditions and competes with other species for moisture, sunlight and nutrients. Managers there believe that field bindweed outcompetes native grasses. In northeastern Oregon on the Middle Fork Preserve, it occurs along roadsides and riparian areas (Youtie, 1994). As with most other troublesome weeds, its infestation is perpetuated by disturbance.

Field bindweed may be mildly toxic to some grazing animals. However, grazing has been used in the past as an attempt to control the weed (see below). The amount of field bindweed that can be safely eaten by sheep,

cattle, and goats is not known. It is reported to cause distress in hogs that eat it (Callihan *et al.*, 1990).

GLOBAL RANGE

Field bindweed is native to Eurasia (Sa'ad, 1967, per Weaver & Riley) but has spread to many parts of the world and is now a cosmopolitan species that grows between 60°N and 45°S latitudes. It is successful in many types of climates, including temperate, tropical, and Mediterranean, but is most troublesome for agriculture in the temperate zones where cereals, beans and potatoes are grown. It is a serious weed in Argentina, Australia, Borneo, Sri Lanka, France, Germany, Greece, India, Iran, Lebanon, New Zealand, Pakistan, South Africa, the former Yugoslavia, and is a “principle” or “common” weed in thirty-four other countries including Japan, the former Soviet Union, and Finland (Holm *et al.*, 1991).

Field bindweed is now a serious weed problem in all parts of the continental USA, except for the southeastern states. In Canada it is found in Alberta, British Columbia and Saskatchewan (Zamora, 1991). It is unclear when field bindweed was introduced to North America. Phillips (1978) suggests that introduction to the Atlantic coast occurred around 1790, but Callihan *et al.* (1990) suggest it was introduced to Virginia in 1739. It was first reported in Pennsylvania in 1812 and in Maine in 1824. It spread rapidly westward as railroads were built, and it appeared in Kansas in 1877, possibly from contaminated Ukrainian wheat seed (Phillips, 1978). Bellue suggests that the species was in San Francisco, California prior to 1870, and in southern California by 1890. It was firmly established in the west by the early 1900's (Weaver & Riley, 1982), by which time the USDA recognized it as a national menace (Callihan *et al.*, 1990). The species was present in every county in Idaho by 1955, occupying 570 km² (140,000 acres) of cropland. By 1989 it occupied over 2000 km² (500,000 acres) in that state (Callihan *et al.*, 1990). It is likely that field bindweed arrived in the Pacific Northwest by contaminated crop seed soon after the first settlers (Swan, 1980).

HABITAT

Field bindweed is found in a wide range of habitats: orchards, vineyards, roadsides, ditchbanks, cropland (Fischer, 1958), streambanks, and lakeshores (Alcock, 1974). Cox (1915) suggests that trees and shading help control the weed, and habitats that are most like agricultural lands (little competition, repeated disturbance and high light) are ideal for growth of field bindweed. In northern California and the Great Plains, field bindweed persists into autumn under severely dry conditions when most other plants are unable to sustain growth. Strong sunlight and moderate-to-low moisture appear to be optimal conditions for the growth of this species (Kogan, 1986; pers. obs.). Seed set is poor under very soggy conditions (Brown & Porter, 1942). While field bindweed might be troublesome in open, newly restored or old-field sites, it may be less persistent in an understory.

This species is also a pest in foggy areas along the Pacific coast (Cox, 1915; Gray, 1917) where water is more available. Alcock and Dickinson (1974) find the species restricted to areas with available moisture throughout the summer and autumn in Australia. O'Brien and O'Brien (1994) find that field bindweed thrives under irrigated conditions.

BIOLOGY-ECOLOGY

Growth Period

Field bindweed begins growing in the late spring or early summer and may persist until the first frost. In California, it grows from May through October (Jepson, 1953; Munz & Keck, 1959). Gray (1970) suggests a growth period of June to September for the northeastern United States. In Canada, growth begins when day temperatures are near 20°C and night temperatures are at least 14°C (Weaver & Riley, 1982).

Flowering, Pollination and Compatibility

Field bindweed flowers last for only one day (Weaver & Riley, 1982). In Canada flowers are produced late in June and plants continue to bloom as long as the growing conditions are favorable (Weaver & Riley, 1982). Observations in Lawrence, Kansas, determined that flowers were fully open by 8:00a.m. during late June and early July. Nectar is produced at the base of the tube of fused petals, and attracts various pollinators including Halictid bees, honeybees, bumblebees, butterflies and moths. Halictid foraging is highest from 8:30-11:30a.m (Waddington, 1976). Compared to other weed species found in Canada, field bindweed is intermediate in pollinator visitation (Mulligan & Kevan, 1973).

Shoots, Roots and Rhizomes

Field bindweed has an extensive underground root/stem system. Most roots perish at the end of the season, but some persist through the winter (Best, 1963b). The roots and rhizomes become winter hardy in autumn and can withstand temperatures as low as -60°C (Dexter, 1937). Rhizomes and attached lateral roots can persist independently if severed from the primary root (Weaver & Riley, 1982). Freezing temperatures kill shoots.

Field bindweed's root growth has been studied since the turn of the century. Young plants extend a taproot deep into the soil and then form lateral roots. Initially, these lateral roots function as feeding roots for above-ground growth (Frazier, 1943b) but later aid in vegetative reproduction. Buds may arise anywhere on the lateral roots. When 96-190cm long, some lateral roots begin growing downward. At this point, new shoots on the root may produce above-ground growth or additional lateral roots. Eventually a long series of shoots arise from the parent (Frazier, 1943a). The lateral roots are generally found within the top 30cm of soil (Swan, 1980) but approximately 1/3 of the total root system is in the vertical roots below the 60cm zone. Lateral and vertical roots become woody and store starch and sugars (Kogan, 1986; Wiese & Philips, 1976), presumably in the cortex and phloem (Kennedy & Crafts, 1931). It has not been determined if the connection between parent and offshoot is ever severed by the plants.

Best (1963a) investigated the spread of field bindweed by monitoring 25 shoots growing from transplants under non-competitive conditions. In the first year, new shoots reached 46-130cm from the parent plant and in the second year were as far as 180cm to 290cm from the parent plant. Best stressed that "the potential spread of this species from a single transplant serves to emphasize the danger of dragging root portions by machinery to field bindweed-free areas" (p.232). Brown (1946) found one plant was capable of producing 14 new shoots in one year.

Lateral root growth per year was found to be on average 4.6m although in Best's study (1963b) one plant's root grew to 7.0m. Plants with the largest leaves had the most aggressive root growth. Kennedy and Crafts

(1931) claim that the extent and form of the root system depends on soil permeability and water table depth.

Seed bank and seed viability

Field bindweed is extremely persistent as seed (Porter & Brown, 1952). Thirty days after field bindweed is pollinated, its seed matures. The moisture content drops to 10-13% and they grow hard, dark, and their coats become impermeable (Sripleng & Smith, 1960; Brown & Borter, 1942). Impermeable seeds must wait at least until the next season to germinate, and they may lie dormant in the soil for many years (Brown & Porter, 1942; Bellue *et al.*, 1959). Brown and Porter (1942) found that 65% of a carefully selected set of plump 55-year old dry-stored seeds were still germinable, and those buried deeply in the soil can persist nearly as long. Most herbicides are not absorbed by dormant seeds and are therefore ineffective at controlling them (Mulligan & Findlay, 1970; Swan, 1980). Field bindweed can produce seed within one season of germinating (Swan, 1980; Brown & Porter, 1942).

Germination

In order for a seed with a mature coat to germinate, its coat must become permeable to water. Seed coats can become permeable if exposed to adequate water, moist air, or fluctuating soil temperatures in the top 8cm of soil (Brown & Porter, 1942; Swan, 1980; Weaver & Riley, 1982). Under laboratory conditions optimal temperatures for germination of field bindweed ranged from 20-35°C, but seeds may also germinate at temperature as low as 10°C and as high as 40°C (Brown & Porter, 1942). Germination of fresh seed is not stimulated by light (Weaver & Riley, 1982). Permeability can be achieved artificially by treatments with concentrated sulphuric acid for 45-60 minutes (Brown & Porter, 1942; Rolston, 1978), ethyl alcohol for 20 hours (Rolston, 1978) or by mechanical scarification (Weaver & Riley, 1982). The germination rate of field bindweed is low, but still substantially higher than that of four other perennial weed species (Brown & Porter, 1942).

Fresh seeds from Iowa, Kansas, Nebraska, S. Dakota, and California collected over five years differed in percent germination rate (5-47%), impermeability (31-97%), and viability (47-94%), depending on the year and collection site (Brown & Porter, 1942). Seeds sown at two-week intervals had various germination rates—60-75% (spring), 44-57% (early summer), and 1-10% (midsummer). Seedlings that germinated in August and September reached a soil depth of 25-50cm by November, but they were unlikely to overwinter because their root systems were insufficiently established (Swan, 1980)

Seed Dispersal

Weaver and Riley (1982) believe that new introductions of field bindweed are primarily by seed. Seeds fall near the parent plant (Rolston, 1978) but can be transported by water (Weaver & Riley, 1982) or birds (Proctor, 1968). Field bindweed seeds remain viable in the stomachs of migrating Killdeer for up to 144 hours, and can pass through animals with little or no damage (Callihan *et al.*, 1990). Quail may retain the seed for 24 hours, ducks, 5, geese, 19, lesser yellowlegs, 6, green jays, 13, ravens, 8, mocking birds, 2 and starlings 10 (Callihan *et al.*, 1990).

MANAGEMENT PROGRAMS

Avoiding Infestations

Field bindweed can contaminate nursery stock, so Callihan *et al.* (1990) suggest that nursery stock be purchased only from nurseries that guarantee that their soils are free of weed roots and seed. Field bindweed propagules may be carried by animals, humans and machinery (Swan, 1980). If you are borrowing large equipment it should be examined and cleaned before it is used on your property.

CONTROL-GENERAL

Managers are generally pessimistic about field bindweed control and question whether eradication is possible. In a 1995 survey, managers for The Nature Conservancy preserves ranked the likelihood of control “medium” to “low.” On two preserves, managers successfully reduced field bindweed populations (Youtie, 1994; Swarz, pers. comm.). Youtie successfully halted the spread of the species through herbicide application while Swarz controlled the weed with tillage and competitive species plantings. Swarz believes that the species will always exist as a minor component of the preserve.

Field bindweed must be managed for several years to bring it under control. Field bindweed control entails chemical applications, discing or hand-pulling on a regular basis (perhaps only once per year), plus yearly monitoring. The herbicide 2,4-D is generally the most effective against field bindweed, but glyphosate can provide some control. Alcock *et al.* (1974) suggest the following as general goals in the control of field bindweed: 1. reduce seed in soil, 2. prevent seedling growth, 3. deplete food reserves in the root system, 4. prevent spread of the weed. With diligence the roots can be removed leaving only the seedlings, however, even with intensive management field bindweed will persist as seed for several years. Three to five growing seasons are required in agricultural settings to eliminate all seedlings (Callihan *et al.*, 1990).

A long-term perspective is important for a noxious perennial weed where total eradication is not a realistic short-term goal. When the above-ground biomass of field bindweed is destroyed, the massive root system forms a new shoot and reserves are thus depleted. If the above-ground portion of the weed is continually destroyed, the root eventually starves and dies. However, if the above-ground portion is allowed to regenerate and feed the root system, the plant can continue to flourish. The key to implementing a successful control program is to continue treatment even after it appears the infestations are significantly reduced. Hoeing or hand-pulling in conjunction may be helpful but may also encourage the germination of dormant seeds or further promote vegetative growth by breaking up and spreading the plant (Callihan *et al.*, 1990).

CONTROL WITH MOWING, DISKING, AND PULLING

Tilling may be useful for ridding infestations at sites previously used for agriculture, or which are otherwise very disturbed. For small areas this may be done using hand-held tools, but for large areas machinery is required. If you decide to pull field bindweed it should be done frequently (see below for information on timing of cultivation). Mowing is unsuccessful because plants can be missed and it encourages ground-hugging growth (Callihan *et al.*, 1990). Repeated cultivation is required for field bindweed control because plants can regenerate from roots as deep as 1.5m (Bakke & Gaessler, 1945). According to Bakke *et al.* (1939), concentrations of food reserves in field bindweed roots were substantially higher at soil depths of 1.8-2.4m.

Before the widespread use of herbicides, farmers sometimes disced their fields as much as twenty times per year, starting as soon as field bindweed leaves appeared (Wiese & Rea, 1959). Muenscher (1955) suggests that fields be tilled/cultivated every 4-6 days. Frazier (1943b) and Callihan *et al.* (1990) suggest every 14 days. In orchards, field bindweed is controlled well with only periodic discing (Cox, 1915). Swarz had success using only one cultivation per season (see “TNC Case Study” below).

For best results, the cultivator should be capable of cutting 15cm below the soil surface. Cultivators such as rod weeders or shar duckfoot-types with overlapping sweeps should be used (Callihan *et al.*, 1990; Swan, 1980). The timing of cultivation is crucial, especially if there will be only one per year (Frazier, 1943b). Swan (1980) maintains that seedlings should be cultivated or hoed before they are a month old. Almost all current recommendations for cultivation also prescribe some herbicide treatment.

In the last decade, intensive use of tillage has been discouraged because it erodes soil and in some cases encourages weed proliferation (Cousen & Mortimer, 1995). It has long been known that field bindweed may proliferate if broken into small parts (Cox, 1915), and Frazier (1943b) attributes resprouting to undamaged plant parts left underground. Discing may aid field bindweed control when tilling is infrequent (Cousen & Mortimer, 1995). Timmons (1949) found that the number of bindweed seedlings increased with the number of tillage operations in a cropping system. It is not clear, however, if these were actually seedlings or sprouts from severed roots.

TNC Case Study: Chris and Mike O’Brien at TNC’s Thousand Springs Preserve had success controlling field bindweed in an agricultural site undergoing restoration, using a combination of tilling and planting competitive crops. In the first year the field was burned and planted with peas and oats. In the spring, after the crop was harvested, the field was tilled and irrigated to encourage germination of weeds. Glyphosate (Roundup) was applied in October, although this had little effect because it was quickly followed by a killing frost. Native perennial bunchgrass seeds were no-till drilled in late fall and the seedlings emerged in February and March. The native grasses were irrigated and cheatgrass was suppressed using Roundup. Annual weeds were controlled by mowing around the bunchgrasses. Mowing and irrigation continued for only one year. After five years the perennial grasses were well established, the annual weeds continued to persist, and the perennial weeds (such as field bindweed) were minor components. Field bindweed grows most successfully only where there are irrigation leaks and generally does poorly if not irrigated.

CONTROL WITH BURNING

Burning alone is not an effective control method (Callihan *et al.*, 1990). It may be useful in combination with other methods, however.

CONTROL WITH COMPETITIVE PLANTING, RESTORATION, AND SMOTHER CROPS

Light reduction (by smother crops or mulching) decreases field bindweed vigor (Bakke & Gaessler, 1945; Gray, 1915). If light reduction is used as a means of control the area must be continuously monitored for breaks. According to Bakke (1939), light reaching field bindweed must be reduced to below 6548 lux (about 50% shade or more) for three years for control.

In agricultural systems a smother crop such as millet, sorghum, sudan grass, or alfalfa may be effective to control field bindweed if it is sufficiently competitive (Cox, 1915; Wiese & Rea, 1959). Bakke (1939) in Iowa and Derscheid *et al.* (1950a) in North Dakota found alfalfa to be very competitive with field bindweed, although Callihan *et al.* (1990) disagreed. Phillips and Timmons (1954) showed that under arid conditions sorghum and sudan grass were excellent competitors.

It may be difficult to find native species that can outcompete field bindweed. The outcome of competition between species can be complicated and unpredictable, but it appears the competitive balance between field bindweed and other species may depend mostly on soil water status (Seely *et al.*, 1944; Wiese & Rea, 1955; Bakke, 1939). Swarz (pers. comm.) found that field bindweed is more competitive where there are leaks in the irrigation system. Callihan *et al.* (1990) suggest that competitive crops may need to be fortified with an early season nitrogen application, and reseeded/planted where needed. Furthermore, early and mid-spring grazing should be avoided. Beidleman and Knight (1995) (Phantom Canyon Preserve) were unable to establish native species to compete with field bindweed, while Chris O'Brien (see "TNC Case Study" above) at Thousand Springs Preserve successfully established perennial grasses.

In general, species that grow vigorously during the winter and early spring may be the best competitive crops, because they force field bindweed plants to compete for light when it grows later in the season. Wiese and Rea (1955) and Wiese *et al.* (1996) found that winter wheat in the Texas panhandle effectively controls field bindweed because it grows early in the season while most plants are still dormant, and reduces the available water. Likewise, Callihan *et al.* (1990) found that perennial grasses compete well with field bindweed because they grow early in the season and take advantage of the limited moisture. Competitive crops may be most effective in humid/shady areas where solar radiation is diminished and shading has larger consequences (Wilson *et al.*, 1955). This suggests that competitive planting or restoration efforts in low light riparian habitats, where the available light is reduced by tree canopies, may work to control field bindweed.

CONTROL WITH PAPER, MULCH AND PLASTIC

Mulch paper is black or dark and impervious to water. It can be obtained in various weight and widths, with or without perforations, and can be laid in strips. The edges of the mulch should be secured with rocks or soil. Mulching improves the soil because it increases the temperature and moisture and, as a result, nitrification (Muenscher 1955). Small areas of field bindweed may be controlled using paper mulch (Muenscher, 1955). Swan (1980) suggests using straw, paper, wood chips or black plastic and stresses the importance of thorough coverage. Cox (1915) considers paper mulch and organic covers such as beet pulp, apple pomace, straw or manure, to be ineffective.

CONTROL WITH GRAZING

Hogs may eat the tops of field bindweed, and root deeply to eat rootstock, but as noted earlier, too much may distress them. Cattle will not readily graze on field bindweed and poisoning has been reported (Cox, 1915). Sheep have been used in controlling the weed but only eat above ground parts, and only when there is no other vegetation (Latshaw, 1927). Callihan *et al.* (1990), however, found that continuous, intensive grazing with sheep over a period of several years can temporarily suppress field bindweed, but that it is likely to fully recover when grazing ceases.

CONTROL WITH CHEMICALS

General Considerations

Some preserve managers report success controlling field bindweed with herbicides. Youtie (1994) used glyphosate applied from backpack sprayers to control field bindweed, and while her infestations persist, they are not spreading. Meanwhile, O'Brien and O'Brien (1994) found that a very late fall application of Roundup and 2,4-D from a commercial spray rig did little to control field bindweed.

Hand sprayers provide more efficient coverage than large sprayers. Not only do hand sprayers allow more precise application of herbicides, Duncan-Yerkes and Weller (1996) showed that lower spray volumes of glyphosate promoted herbicide absorption through better coverage and increased herbicide/surfactant concentration.

Some of the herbicides mentioned below, including 2,4-D, paraquat (Gramaxone), and picloram (Tordon) are restricted or prohibited in some states (William *et al.*, 1997).

Developmental and Environmental Considerations

Timing is important when applying herbicides, whether you wish to kill the above-ground growth or translocate herbicides to the root system. The time of year, developmental stage of the plants, and rainfall/soil moisture conditions are all important factors to consider (Westra & Barton, 1992).

Herbicides should be applied when they will be most effectively absorbed and translocated to the roots, but before the plants produce seed and new buds. Most researchers suggest that herbicides be applied to field bindweed when the plant is most vigorous. Investigators advise spraying plants just at or during first bloom when the root carbohydrates are at their lowest (Latshaw, 1927; Alcock & Dickinson, 1974; Callihan *et al.*, 1990; Kogan, 1986; Gigax, 1978). In early spring the plant draws from its root and the majority of translocation will be from below to above ground. Once above ground growth is vigorous, translocation is primarily from the shoot to the roots and herbicide application should be done at this stage to ensure it is moved with the sugar to the roots and root buds (Callihan *et al.*, 1990; Dunn & Datta, 1956; Gigax, 1978). In addition, full-grown vines will have a larger surface area to absorb the chemical (Gray, 1917). Application to developing leaves is not effective because photosynthates are transported to these leaves instead of to roots.

Wiese *et al.* (1996) suggest that drought (*e.g.* in the Great Plains) may decrease the effectiveness of herbicides, perhaps because droughts or frost may cause plants to become dormant or semi-dormant (Callihan *et al.*, 1990). Under dry conditions the application can be made later in the summer if the vines become more vigorous (Wiese & Rea, 1959). Callihan *et al.* (1990) suggest irrigating the site one month before herbicide application to encourage vigorous growth. Under moderately rainy conditions field bindweed will be more vigorous and therefore better controlled by herbicides. On the other hand, if it rains too soon after herbicide is applied, the herbicide may be washed off the plant or more rapidly degraded—for example, picloram is more rapidly broken down by microbes when water is abundant (Westra & Barton, 1992). In any case, the herbicide should be applied before seed set.

Where annual rainfall is low to moderate (27-50 cm) plants acquire attributes that deter absorption of herbicides, such as: lower leaf area, thicker cuticles, greater cuticular wax content, slowed biological processes, small leaf/root ratio (Meyer, 1978), and vertical leaf orientation so herbicide rolls off (Currier & Dybing, 1959). Very hairy plants are also difficult to wet with herbicidal sprays (Weaver & Riley, 1982), although Currier and Dybing (1959) found increased absorption of 2,4-D due to pubescence.

There are other factors that may change the effectiveness of herbicides. Plant injury from aphids or physical damage increases penetration. Leaf necrosis can increase penetration but may decrease transport (Currier & Dybing, 1959).

Biotypes; Tolerance And Sensitivity Considerations

Repeated use of the same or similar herbicides can result in herbicide resistant strains of field bindweed, which can be difficult to control (Whitworth, 1964; Whitworth and Muzik, 1967, Wiese and Lavake, 1985). If you plan to use an herbicide it is useful to know if field bindweed strains infesting the area are herbicide resistant. Records of previous herbicide use may be helpful. Be sure to focus more effort on individual plants or populations that are tolerant to herbicides (Duncan & Weller, 1987). Investigators have unsuccessfully tried to correlate the morphology of field bindweed strains with their herbicide resistance (Valentine, 1975; Whitworth and Muzik, 1967).

Specific Herbicides

2,4-D

2,4-D is the herbicides most widely used for field bindweed (Callihan *et al.*, 1990). It is a selective herbicide that will kill most broad-leaved plants (dicots) but which will not damage most grasses and other monocots. Rates of 1.1-1.5kg/ha are advised although the chemical has been used at rates as high as 3.4kg/ha (Schweizer, 1978). Today agronomists apply it frequently in conjunction with other chemicals. As mentioned above, resistant strains of field bindweed have been identified but it is unclear if tolerance to 2,4-D is a widespread problem.

2,4-D applied to a shoot is not readily translocated to other shoots. This suggests that 2,4-D may not work well in very dense patches where some branches are shielded from herbicide application (Williams *et al.*, 1960).

In Bushland, Texas, in the southern Great Plains, 1.1kg/ha 2,4-D applied once per year to 5 week old field bindweed effectively controlled it after two years. Application was done only after heavy rains, and it was important to apply the herbicide only to vigorous plants. 2,4-D was more cost effective than dicamba (only \$40-55/ha at the above rate). There was no difference in efficacy of 2,4-D under tilled or non-tilled conditions, but the cover crop (winter wheat) did better under non-tillage conditions (Wiese *et al.*, 1996).

Application of 2,4-D under drought conditions allowed little control of field bindweed. Control was better after 25cm of rainfall than after severe drought. After rain, 0.84kg/ha provided the best control, 0.6kg/ha

was insufficient, and 1.1kg/ha was wasteful (Derscheid *et al.*, 1950b).

In vineyards in Chile, field bindweed was eliminated after two consecutive applications of 2,4-D at 1.5kg ai/ha (Kogan, 1986).

In the Pacific Northwest, 2,4-D applied at 2.25-3.4kg acid equivalent/ha at bud growth stage or summer fallow in early August reduced field bindweed 60-80% and prevented establishment of seedlings. It was important to apply every year to prevent regrowth. (William *et al.*, 1997).

Dicamba (which is more expensive than 2,4-D) provides better control under drier conditions, and 2,4-D provides better control under wetter conditions (Wiese *et al.*, 1996).

2,4-D In Combination With Other Herbicides Or Competitive Crops

Near Bushman, Texas, the following treatments provided good control (97-100%) of field bindweed at the end of two years:

A. tillage every three weeks and 2,4-D at 1.1kg/ha through the growing season, plus one follow-up treatment to five-week old, vigorous field bindweed. Successful follow-up treatment formulations were: 2,4-D at 1.1kg/ha; 2,4-D at 1.1kg/ha and picloram at 2.2kg/ha; picloram at 0.28kg/ha and 2,4-D at .5kg/ha.

B. no-tillage plus 2,4-D at 1.7kg/ha after harvest in spring and a following applications to five week old vigorous field bindweed. Successful follow-up treatment formulations were: 2,4-D at 0.4kg/ha and picloram at 0.6kg/ha; 2,4-D at 0.4kg/ha and picloram at 0.6kg/ha plus dicamba at 2.2kg/ha; 2,4-D at 1.0kg/ha and picloram at 0.6kg/ha plus picloram at 0.28kg/ha. 2,4-D was the most cost effective under non-tillage situations and Dicamba was the most costly (Wiese *et al.*, 1996).

September treatments were applied in Lincoln, Nebraska, during a period with little rainfall. 2,4-D at 1.1kg/ha plus dicamba at 5.6kg/ha controlled field bindweed by approximately 90% after two years of treatment. Application of 2,4-D at 1.1kg/ha alone reduced infestations by only 73% (Swisher, 1985).

Herbicides were applied once in the fall, and then every spring to small sorghum plots at Arkansas Valley Research Center in Rocky Ford, Colorado. The best control of field bindweed (96%) was achieved using 2,4-D at 3.4kg/ha for one fall application and a mixture of dicamba at 0.28kg/ha plus 2,4-D at 0.56kg/ha for spring applications. However, this mixture and others significantly reduced crop yields after two years (Schweizer, 1978).

In the Pacific Northwest William *et al.* (1997) recommend using Landmaster BW (a mix of 2,4-D and glyphosate) at 0.43 to 0.75kg acid equivalent/ha (54oz/A) when bindweed runners are at least 25cm long. A 1% solution can be used for spot treatments. They recommend tilling should be used after herbicide treatments.

Glyphosate (Rodeo, Roundup, Accord)

Glyphosate alone does not provide consistent control of field bindweed (Callihan *et al.*, 1990). Glyphosate is a non-selective herbicide, but may be applied directly and carefully to undesirable plants. Field bindweed

suffering drought stress and plants grown from seed (instead of vegetative propagules) are more resistant to glyphosate (Dall'armellina & Zimdahl, 1989). Control efficiency may depend greatly on the relative humidity. While 2.24kg/ha glyphosate reduced infestation levels to 24% under conditions of low humidity, in humid conditions control was only to 60% (Westwood & Weller, 1997).

Some biotypes are resistant to glyphosate. In greenhouse investigations, a glyphosate-susceptible biotype was controlled using 1.1kg acid equivalent/ha glyphosate while a more glyphosate-tolerant biotype required 4.5kg acid equivalent/ha to control (Westwood & Weller, 1997).

A single application in the fall in Lincoln, Nebraska demonstrated that 0.84kg/ha glyphosate provided only 50% control but 1.7kg/ha provided 85% control (Swisher & Shea, 1985).

Tests by William *et al.* (1997) in the Pacific Northwest with glyphosate at 3.4 or 4.2kg acid equivalent/A applied at full bloom or early seed stage was effective, especially if the area is tilled 2-3 weeks after treatment. Repeated treatments, and application to fall regrowth may be necessary for complete control.

Growth chamber and greenhouse trials in Indiana studied the effects of adjuvants on field bindweed control. Glyphosate was applied at 1.1kg acid equivalent/ha with and without MON0818 and Tween 20 surfactants at 1% w/v total spray volume. The MON0818 and Tween 20 improved control. The study showed that plants grown in low light, high humidity conditions are more susceptible to glyphosate, while older leaves and those grown under high light conditions absorb less glyphosate. Decreased dosage of MON0818 resulted in higher translocation of herbicide to the roots. Investigators suggest using adjuvant but at a concentration of 0.5%w/v to encourage absorption but avoid damage and subsequent decrease in translocation to the roots (Sherrick *et al.*, 1986).

Dicamba (Banvel)

Dicamba was shown to be more effective than 2,4-D and picloram against field bindweed, but it generally is more expensive. Dicamba is effective against broad-leaved plants, like 2,4-D. It may not be as useful as other herbicides for management of preserves as it can persist in soil and damage other plant species (Callihan *et al.*, 1990).

Dicamba was applied once per year at 2.2kg/ha to vigorous 5-week old plants on clay loam near Bushland, Texas. At the end of the second year the field bindweed was being controlled under both tillage and non-tillage conditions. The researchers suggest that dicamba is more effective under drier conditions, while 2,4-D is more effective under wetter conditions. Tillage had no effect on control of field bindweed and under non-tillage conditions winter wheat, a cover crop, performed better (Wiese *et al.*, 1996).

At Rocky Ford, Colorado, dicamba at 2.2kg/ha provided 93% control after four years. Applications were made once in the fall and every spring for four years. Dicamba was more expensive than 2,4-D (Schweizer, 1978).

Picloram (Tordon) (note: first two entries based upon Down to Earth, a Dow Chemical publication.)

Picloram is a restricted-use herbicide and is registered only on rangeland and permanent pastures and on fallow grainland east of the Cascades. Picloram is known to remain active in soils for a number of years and may contaminate soils to 3m (William *et al.*, 1997) so should not be used in the vicinity of orchards, vines and gardens (Gooding, 1967), or water. Results are generally best if field bindweed is in early bud to full bloom.

In Colorado, field bindweed was controlled with picloram. Herbicide was applied to runners 15-20cm long once during the year. By the second year of application of picloram at 0.12lb acid equivalent/A plus 2,4-D at 1lb acid equivalent/A, control was 55-97%. A treatment of picloram at 0.25lb acid equivalent/A plus 2,4-D at 1lb acid equivalent/A gave 89-100% control. Differences in degrees of control were attributed to rainfall variation. Better control was achieved where more water was available. Less herbicide can be used if the infestations are light, or repeated yearly treatment is planned, while severe infestations may require higher rates (Westra & Barton, 1992).

In an investigation in Lincoln, Nebraska during two very dry years (only 6.68cm of rainfall in 1983 and 3.63cm in 1984) studied the effects of September applications. Picloram at 0.5lb/A provided 90% control after two years (Swisher, 1985).

Quinclorac

Quinclorac kills a variety of annual grasses and some broad-leaved plants, including field bindweed. It was tested in the autumn, on pre-frost, wheat stubble (dry loam soil in North Dakota) (Ahrens, 1991). The field bindweed plants were 15-25cm long. The tests were conducted under extremely variable conditions (air temperature 17 and 21°C, 25 and 72% relative humidity, wind 6-13 and 5-16km/h) and it was unclear if the variable weather had any effect. The control was approximately 76% with quinclorac at 0.5lb/A plus dicamba at 0.25lb/A and a crop oil surfactant Sun-It at .25G. The wheat injury was 22%. The best average control (86%) was quinclorac at 0.375lb/A plus glyphosate at 0.38lb/A plus 2,4-D at 0.67lb/A with Sun-It surfactant at 0.25G (the wheat injury was 13%). Quinclorac was not used alone.

Paraquat (Gramoxone)

Contact herbicides such as paraquat kill only tissue that they contact (“chemical mowing”), and should only be used for short-term control of field bindweed (Callihan *et al.*, 1990).

BIOLOGICAL CONTROL

General

Many parasitic organisms have been under investigation for control of field bindweed and one has been approved, but none have yet proven useful. Several insect and mite species in North America and Eurasia attack field bindweed but are not effective control agents. The prospective biocontrol agents themselves are heavily parasitized, do not feed exclusively one species, or simply do not cause sufficient damage to field bindweed (Callihan *et al.*, 1990). Many other species have been collected from field bindweed in Canada and the U.S. and a list of these may be found in Weaver and Riley (1982). Species that may be useful in the future are listed below.

Insects

Tyta luctuosa has been tested and approved for release in parts of the US. Caterpillars of this European moth may defoliate field bindweed in the latter part of the growing season (Callihan *et al.*, 1990). However, in Maryland, *T. luctuosa* populations were unstable due to either mortality or dispersal (Tipping & Campobasso, 1997). First released in 1987, as of 1995 self-sustaining populations had not been established (Rees *et al.*, 1996)

Aceria malherbae is a gall forming mite whose larvae and adults feed on buds and leaves of field bindweed. Released in Texas in 1989 and established there, but its impacts are unclear to date.

Chelymorpha cassidea Fabr. is the Argus tortoise beetle. Both adults and larvae feed on the leaves of many members of the Convolvulaceae. It is native to the U.S. and occurs in Canada. In New York it was observed feeding on field bindweed and *C. sepium* to the point of complete defoliation while leaving other plants such as rye and corn were untouched (Selleck, 1979). Attempts to extend its range from eastern North America to the western plains in the 1970s were unsuccessful (Julien & Griffiths, 1998).

Fungi (potentials)

An extensive list of fungal species found on field bindweed in Canada is given in Connors (1967).

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