USGS Weeds in the West project:
Status ofIntroduced Plants in Southern Arizona Parks

Factsheet for:

*Tribulus terrestris* L.

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**Tribulus terrestris L.**

puncturevine, punctureweed, goatshead, tackweed, Mexican sandbur, bullhead, burnut, ground burnut, caltrop, land caltrop

**family:** Zygophyllaceae

**synonymous names of the species:**
- the first name in each species list is the current and synonymous name used by Kartesz (1994).
- the name in bold type occurring within each species list indicates the plant name used within these documents, which is also the name provided in the southern Arizona NPS exotics database ‘soaraz~1.xls’ (Holden 1996).

*Tribulus terrestris L.*

no synonymous names

**species taxonomy**


(A glossary is provided at the end of this section for the plant terminology used in this section.)

**life strategy:** a C4, summer annual; ephemeral. Reproduces by seed. In tropical areas, this plant develops woody roots and becomes perennial. 2n=12, 24, 36, 48.

**structure:** prostrate spreading radially, generally less than 3.3 ft. (1 m) in diameter, herbaceous annual plant; mat forming.

**roots:** deep taproot (to 8.5 ft. (2.6 m)); slender, branched, often somewhat woody, with a network of fibrous roots.

**stems:** prostrate stems up to 8 ft. (2.4 m) long. Stems highly branched, green to reddish-brown, and spreading radially from the crown along open ground; can be more or less erect when shaded or competing with other plants. Stems are silky or appressed-hairy, sharply bristly to glabrous.

**branching:** radially spreading stems (from the crown); the stems highly branched.

**stipules:** stipules leaf-like, subulate, 2-3 mm long.

**leaves:** cotyledons oblong, 0.2-0.6 in. (5-15 mm) long, creased down the center, slightly indented at the tips. Leaves opposite; even-pinnate compound, approximately 0.4-2 in. (1-5 cm) long, with 3-7 leaflet pairs per leaf; and having a small extension at the rachis tip. Leaflets elliptic or oblong, 0.1-0.6 in. (3-15) mm long, with more or less oblique bases; lower leaflet pair unequal in size. Foliage often sparse to moderately silky-strigose to glabrous.

**inflorescence:** peduncled flowers, solitary in axils of leaves.
**Calyx/sepals or phyllaries:** sepals 5 (occasionally 4), caducous. Sepals narrowly lance-ovate, 0.1-0.14 in. (3-3.5 mm) long.

**Corolla/petals:** peduncle reflexed; shorter than subtending leaves. Flowers are axillary, solitary; corolla/petals bright yellow, 0.2-0.6 in. (5-15 mm) in diameter, 0.2 in. (5 mm) or less long. Petals 5 (occasionally 4), deciduous. 5 glands occur between the stamens at the base of the ovary. Flowers perfect. Flowers are open in the mornings, close in the afternoons.

**Gynoecium:** ovary has 5 carpels. Ovary chambers twice the number of petals; a traverse partition separates seeds in each carpel. Style deciduous. Styles connate into a stout column. Stigmas 5.

**Androecium:** stamens twice the number of petals, usually 10. 5 shorter stamens, anthers well below the level of the stigma, opposite the sepals, each subtended by a small gland; 5 longer stamens, anthers at the same height of the stigma, opposite the petals.

**Fruit:** a schizocarp; woody burrs, gray to yellow-tan, hairy, to approximately 0.4-0.7 in. (1-1.8 cm) in diameter, more or less flattened, lobed; separates into 5 (occasionally 4) wedge-shaped, indehiscent nutlets (coccii), each with 2 stout dorsal spines 0.15-0.27 in. (4-7 mm) long and spreading, and several prickles.

**Seeds:** usually 2-5 per nutlet (coccus), remain enclosed within the burrs (coccii).

taxonomic glossary (Harris and Harris 1997):

- **Adnate:** fusion of unlike parts
- **Appressed:** pressed close or flat
- **Caducous:** falling off early compared to similar structures in other plants
- **Canescent:** white or gray in color, due to a covering of short, fine white or gray hairs
- **Connate:** fusion of like parts
- **Cotyledons:** a primary leaf of the embryo
- **Even-pinnate:** pinnately compound having a terminal pair of leaflets or a tendril, thus having an even number of leaflets
- **Glabrate:** becoming or almost glabrous
- **Glabrous:** smooth, hairless
- **Hirsute:** pubescent, with short, stiff hairs
- **Oblique:** having unequal sides, as a leaf base
- **Pedicel:** the stalk of a solitary flower in an inflorescence, or of a grass spikelet
- **Peduncle:** the stalk of a solitary flower or of an inflorescence
- **Perfect:** having both male and female reproductive organs
- **Pinnate:** a compound leaf with leaflets arranged on opposite sides of the rachis
- **Puberulent:** having fine, short hairs
- **Rachis:** the main axis of a structure (as in a compound leaf or inflorescence)
- **Reflexed:** bent backwards or downwards
- **Reticulate:** in the form of a network
- **Strigose:** having straight, stiff, sharp, appressed hairs
- **Subulate:** awl-shaped
- **Tubercle:** a small tuber-like swelling or projection
- **Tuberculate:** having tubercles
There are several native species in the genus *Kallstroemia* (family: Zygophyllaceae) that could be confused with *Tribulus terrestris*: *Kallstroemia parviflora* and *K. californica*; especially when the plants haven’t begun to flowers and fruits aren’t present. They can occur with *Tribulus terrestris* in disturbed areas, especially when disturbance occurs in a more ‘natural’ setting, or they can occur in those same areas alone. They are easiest to distinguish from each other when the fruits have fully matured, the fruits being very different from each other.

*Tribulus terrestris* more often has the smaller flowers that are brighter yellow (versus yellow-orange), although variability within each species and taxa often makes these generalities deficient for proper identification. Also, there are some general and subtle differences in the leaves (leaflet number, shape, and hairiness), and getting to know each plant well seems to be the best remedy for proper in-the-field identification. Below are descriptions of the taxa; see glossary above for definitions of terminology.
**Kallstroemia parviflora**: spreading stems, branched, to 3.3 ft. (1 m) long, mat forming. Leaves are 0.4-1.2 in. (1-3 cm) long; with 3-5 pairs of leaflets, 0.3-0.4 in. (7-10 mm) long, acute at both ends, hirsute beneath, glabrous above. Stipules 0.2-0.3 in. (6-7 mm) long, linear lanceolate; persistent. Flower pedicels 0.4-0.8 in. (1-2 cm) long; up to 1.6 in. (4 cm) in fruit. Sepals approximately 0.2 in. (5 mm) long, hirsute, persistent. Petals orange-yellow, often fading, 0.2-0.5 in. (6-12 mm) long, 0.1-0.2 in. (2-4 mm) wide; deciduous. Fruit 0.2 in. (5-6 mm) wide; carpels bluntly tuberculate on backs; beak 0.2 in. (4-6 mm) long, strongly conic at base, columnar (Kearney and Peebles 1960, Shreve and Wiggins 1964). Occurs in Navajo to Mohave counties, south to Greenlee, Cochise, Santa Cruz, and Pima counties; 1000-5000 ft.

**Kallstroemia californica var. californica**: spreading stems, branched, to 4-24 in. (1-6 dm) long. Leaves 0.6-2.4 in. (1.5-6 cm) long; with 4-7 pairs of leaflets, broadly elliptic, 0.2-0.4 in. (4-10 mm) long; obliquely obtuse at base, obtuse or rounded at apex; strigose-canescent or tardily glabrate above, most of the hairs appressed. Stipules linear-subulate to ovate, 0.05-0.1 in. (1.5-3 mm) long; usually caducous. Flower pedicels 0.6 in. (1.5 cm) long or less. Sepals narrowly lance-ovate, 0.1-0.2 in. (3-4 mm) long; usually deciduous in fruit. Petals orange-yellow, 0.2 in. (4-6 mm) long; deciduous. Fruit 0.1-0.2 in. (3-4.5 mm) in diameter, 0.1 in. (3-3.5 mm) high, puberulent; carpels with sharp tubercles, often to 1.5 mm long, on backs; beak 3 mm long, conic at base, glabrous in fruit (Kearney and Peebles 1960, Shreve and Wiggins 1964). Occurs in south and southwestern Arizona, Graham to Yuma counties; 7000 ft. or lower.

**Kallstroemia californica var. brachystylis**: spreading stems, branched, to 4-24 in. (1-6 dm) long. Leaves 0.6-2.4 in. (1.5-6 cm) long; with 3-5 pairs of leaflets, broadly elliptic, 0.2-0.6 in. (6-15 mm) long; obliquely obtuse at base, obtuse or rounded at apex; strigose-canescent or tardily glabrate above. Stipules linear-subulate to ovate, 0.05-0.1 in. (1.5-3 mm) long; usually caducous. Flower pedicels 0.6 in. (1.5 cm) long or less. Sepals narrowly lance-ovate, 0.1-0.2 in. (3-4 mm) long; usually deciduous in fruit. Petals orange-yellow, 0.2 in. (4-6 mm) long; deciduous. Fruit 0.1-0.2 in. (3-4.5 mm) in diameter, 0.1 in. (3-3.5 mm) high; carpels with low, rounded tubercles, on backs, these sometimes sharper; sides of carpels strongly reticulate (Kearney and Peebles 1960, Shreve and Wiggins 1964). Occurs in central and northern Arizona, Apache, Coconino, and Yavapai counties, south to central Arizona; 7000 ft or lower.

**biology**

growth and reproductive strategy:

*Trichostema lanatum* is a C4, summer annual, reproducing by seed; it is prostrate and mat-forming. *Trichostema lanatum* plant material from California was found to be diploid; 2n=24 (Heiser and Whitaker 1948).

Generally, *Trichostema lanatum* has a considerable seed dormancy lasting over fall and winter months (Washington State Noxious Weed Control Board 2002) with some seeds staying dormant for longer periods of time. Its seedlings emerge in the early spring through summer, often in flushes following increased soil moisture (California Department of Food and Agriculture, EncycloWeedia 2002). It germinates after the start of the monsoon rains, on any type of barren soil, in southern Arizona (Parker 1972). In Washington and Australia, it germinates in the late spring to early
summer, when necessary soil moisture conditions are met (Squires 1979, Washington State Noxious Weed Control Board 2002).

It is a prostrate mat-forming plant with trailing stems, although can be more ascending when light competition exists on a site (Holm et al. 1991, Yolo County Resource Conservation District 2002). Seedlings develop a deep root system in a few weeks; flowers may be produced within 3 weeks, fruits/burrs within 6 weeks (California Department of Food and Agriculture, EncycloWeedia 2002, Washington State Noxious Weed Control Board 2002). Tribulus terrestris roots can develop nitrogen-fixing nodules (Athar and Mahmood 1985, California Department of Food and Agriculture, EncycloWeedia 2002). Athar and Mahmood (1985) observed that plants having root nodules had more lush green healthy growth and greater dry weight versus stunted growth in plants without nodules.

Boydston (1990) reports that flowering occurred within 3-4 weeks of emergence when temperatures were consistently above 68°F (20°C), regardless of planting date. Tribulus terrestris flowers March through October in Arizona, although primarily from July to August (Parker 1972). Once the plant begins to flower, it is continuous throughout the plant's life (Reddi et al. 1981). Tribulus terrestris flowers are cross-pollinated by insects (foragers include: Coleoptera, Diptera, Hymenoptera, Lepidoptera, Thysanoptera) (California Department of Food and Agriculture, EncycloWeedia 2002, Washington State Noxious Weed Control Board 2002) along with being self-pollinated, which occurs at the end of each flower's receptive period (within one day) (Reddi et al. 1981). Self-pollination is accomplished when the petals begin to close and push the stamen inward toward the stigma, the longer anthers making direct contact; the potential of this system is 100% seed set (Reddi et al. 1981). Fruits mature in approximately 2 weeks, and subsequently split apart into segments soon afterward (Holm et al. 1991). Plants continue to reproduce and produce fruit until the cool season begins. Boydston (1990) reports during trials in Washington, fruit/burr production stopped in October when average temperatures were under 68°F (20°C)

Squires (1979) reports that the plant can be killed by frost or drought. At senescence, the fruits/burrs often remain on the plant or the soil surface (California Department of Food and Agriculture, EncycloWeedia 2002). In India, it was observed that seeds may still germinate in the fall, yet the seedlings fail to establish due to declining seasonal temperatures (Pathak 1970). In tropical regions under suitable conditions, Tribulus terrestris develops woody roots and becomes perennial (California Department of Food and Agriculture, EncycloWeedia 2002, Holm et al. 1991).

seed production:

Tribulus terrestris plants typically bear numerous fruits/schizocarps/burrs (averaging 200-5000 per plant) (California Department of Food and Agriculture, EncycloWeedia 2002).

Boydston (1990) reports that seeds planted in May, June, July, and August subsequently produced 5600, 5200, 3600, and 200 burrs/plant, respectively. Although, fruit/burr production seemingly responds to temperatures during a season’s growth, enabling greater production for a longer period of time in warmer years (Boydston 1990). Each fruit/burr usually contains 5 nutlets (cocci), each nutlet (coccus) can contain 2-5 seeds (Boydston 1990).

seed dispersal:

Each fruit section (coccus) has 2 sharp divergent spines and several other spines and warty protuberances enabling the Tribulus terrestris fruits to easily attach to
animals and humans and to stick onto vehicle tires (cars, farm, airplane), subsequently facilitating long distance dispersion and spread (Ernst and Tolsma 1988, Ridley 1930, Squires 1979, Whitson 1992). Holm et al. (1991) points out that due to the architecture of the schizocarp/fruit, the large and small spines are arranged at different angles with at least one of the spines always pointing upward no matter how the fruits/burrs fall from the plant, and can easily imbed into feet, hooves, or tires. After getting caught or imbedded into the hooves, feet, and wool of livestock and other animals, the fruits/burrs are subsequently broken off as the animals try to rid themselves of the irritation (Ridley 1930). Furthermore, they can stick to the shoes and clothing of people, and the fur and feathers of animals (California Department of Food and Agriculture, EncycloWeedia 2002).

*Tribulus terrestris* fruits/burrs are also a contaminate of seed, feed, and wool of livestock (Johnson 1932 in Gould and DeLoach 2002).

Foy et al. (1983) report that *Tribulus terrestris* "presumably" was unintentionally imported into the United States on the tires of military planes returning from the Sahara Desert region; and has been further spread on this continent on the tires of aircraft and cars.

seed longevity:

Buried *Tribulus terrestris* seed can remain viable for several years (California Department of Food and Agriculture, EncycloWeedia 2002), staying dormant in the soil for 4-5 years (Whitson 1992).

**ecology**

origin and history of introduction:

*Tribulus terrestris* is native to southern Europe (GRIN 2000, Parker 1972), Africa, temperate and tropical Asia (Afghanistan, Armenia, Azerbaijan, China, Cyprus Sinai, Georgia, Iran, Iraq, Israel, Japan, Jordan, Kazakhstan, Kyrgyzstan, Lebanon, Mongolia, Russian Federation (Ciscaucasia, southeast Western Siberia), Saudi Arabia, Syria, Tajikistan, Turkey, Turkmenistan, Uzbekistan, India, Pakistan), and north Australia (GRIN 2000); it was introduced here from the Mediterranean (California Department of Food and Agriculture, EncycloWeedia 2002). Squires (1979) comments that *Tribulus terrestris* probably originated in the Saharan region, and spread into the Mediterranean region.

*Tribulus terrestris* was accidentally imported from the Mediterranean into the United States on livestock (Andres and Goeden 1995 in Gould and DeLoach 2002, Washington State Noxious Weed Control Board 2002). It was first reported in California in 1903 (Davidon 1903 in Squires 1979, PRIDE 2002).

ecological distribution / habitat:

*Tribulus terrestris* occurs widely throughout the world from latitudes 35°S to 47°N (Holm et al. 1991). As a weed, it occurs in the subtropics and warm temperate zone (Holm et al. 1991). It frequently concentrates at low elevations in coastal areas (Holm et al. 1991).

In its native area: Within its native range in Eurasia, from the central Russian steppe through Mongolia, Manchuria, Germany, Poland, and the countries bordering the Mediterranean (Squires 1979) it is present at elevations ranging from near sea level to above 3,280 ft. (1000 m) (Squires 1968 in Squires 1979).
On the North American continent: *Tribulus terrestris* is found throughout California to Wyoming, to eastern United States, and south to central Mexico (California Department of Food and Agriculture, EncycolWeedia 2002). *Tribulus terrestris* habitat is disturbed places, along city streets and roadsides, railways, cultivated fields and orchards, barnyards and pastures, fallow fields, lawns and yards, playgrounds, waste places, open sandy sites, and walk ways (California Department of Food and Agriculture, EncycolWeedia 2002, Hickman 1993, Holm et al. 1991, Parker 1972).

In Arizona, *Tribulus terrestris* is found to 7000 ft. (2134 m) (Parker 1972).

**climatic requirements and limitations:**

*Tribulus terrestris* is adapted to warm, temperate regions (Washington State Noxious Weed Control Board 2001) and is prevalent in areas having hot summers, on dry soils (California Department of Food and Agriculture, EncycolWeedia 2002). *Tribulus terrestris* requires relatively high temperatures for growth (Washington State Noxious Weed Control Board 2001), and is intolerant of freezing temperatures (California Department of Food and Agriculture, EncycolWeedia 2002, Squires 1979).

In Australia in places where *Tribulus terrestris* is a major weed, the daily maximum temperatures in summer are above 84°F (29°C) (Squires 1979).

In a database covering the northwestern United States, *Tribulus terrestris* occurs in areas having a mean minimum July temperature of 67°F (19.4°C) and a mean maximum July temperature of 73°F (22.8°C), and a mean minimum January temperature of 17°F (-8.3°C), and a mean maximum January temperature of 24°F (-4.4°C) (Rice 2002).

*Tribulus terrestris* occurs in areas with a mean annual minimum precipitation of 11 in. (28 cm) and a mean annual maximum precipitation of 15 in. (38 cm) (Rice 2002).

*Tribulus terrestris* seedling establishment was observed to be poor on sites that were shaded (Pathak 1970).

**germination:**

Most newly matured *Tribulus terrestris* seeds are dormant and require an after-ripening period of approximately 6-12 months. Ernst and Tolsma (1988) report that dormancy of seeds was very high in both fresh seeds and 3-6 year old seeds. Squires (1968 in Squires 1979) reports that freshly harvested seeds have a germination rate of 10%, and dry-stored 6-month-old seeds have a germination rate of 84%. Imbibition of water differed in dormant versus non-dormant seeds; measurements taken at one hour and periodically through one day of imbibition showed dormant seeds had approximately half of the water content of non-dormant seeds (Ernst and Tolsma 1988). The largest seed within a nutlet (coccus) is usually the first to germinate; the remaining seeds may germinate or remain dormant depending on moisture availability (California Department of Food and Agriculture, EncycolWeedia 2002); this large seed is usually positioned near the basal end of the burr (coccus) (University of California 1998).

Pathak (1971 in Squires 1979) reports that *Tribulus terrestris* germination is inhibited by low temperatures, low light intensities, and wet soil. The optimum temperature range for germination to occur is 81-95°F (27-35°C). In Australia, germination occurs when the maximum air temperature is approximately 75-81°F (24-27°C) (Squires 1979). During trials, *Tribulus terrestris* emergence was initiated when average soil temperatures reached 59°F (15°C) for at least 2 weeks and approached 68°F (20°C) (Boydston 1990). After initial emergence occurred,
emergence was multipeaked with no relationship existing with temperature for the remainder of the summer (Boydston 1990). In subsequent years, emergence occurred and peaked at similar times regardless of the age of the seed, indicating environmental stimuli influencing emergence (Boydston 1990).

*Trihus terrestris* seedlings emerge during early spring through summer, often in flushes following increased soil moisture (California Department of Food and Agriculture, EncycloWeedia 2002, Mirsa 1962 in Holm et al. 1991). During field observations in Botswana, *Trihus terrestris* was observed to germinate and emerge following a rainshower having more than 0.04 in. (10 mm) of precipitation (Ernst and Tolsma 1988). Maximum germination occurred after a series of heavy rains, facilitating a 35% germination rate, with continued germination of seeds lasting for another 4 months (Ernst and Tolsma 1988).

On sandy soils, seedlings emerge from depths to approximately 5 cm (less on heavy soils) (California Department of Food and Agriculture, EncycloWeedia 2002). Squires (1968 in Squires 1979) reports that seeds buried more than 4 in. (10 cm) deep in sandy soils, can successfully emerge.

Germination was irregular in *Trihus terrestris* seeds, whether seeds remained in the fruit (cocci) or were isolated (Ernst and Tolsma 1988). In greenhouse trials, the highest germination rate was achieved by isolated seeds with a maximum of 66.9%, and a mean of 37.3±25.1% (ranging from 68/59°F (20/15°C) up to 95/86°F (35/30°C), in 5°C increments, alternating day/night temperatures). Seeds that remained in the fruits rarely germinated synchronously (Ernst and Tolsma 1988). Ernst and Tolsma (1988) add that because of this pattern, direct competition for water and nutrients is avoided.

soil preferences:

*Trihus terrestris* grows best on dry, sandy soils, but can tolerate most soil types (California Department of Food and Agriculture, EncycloWeedia 2002, Washington State Noxious Weed Control Board 2001). In Australia, *Trihus terrestris* is found on sandy and silty, and on saline soils (Squires 1979). In India, *Trihus terrestris* is found primarily on loose and compact sandy loam soils, and reportedly grows on sand dunes in the desert regions (Pathak 1970). It also thrives on loose, blown soil by field margins (Holm et al. 1991). Plants are typically more robust on sites without compacted soils (Pathak 1970), yet can grow on compacted soils, such as those found alongside unsurfaced roads and in playgrounds (Holm et al. 1991). It also can grow in heavier soils, especially when fertile and moist (Holm et al. 1991).

During tests in India, soil moisture was observed to average 3.54-6.74%, and occasionally lowered to 1.8% during *Trihus terrestris*’s life (Pathak 1970). Water holding capacity of soils of acceptable habitat for *Trihus terrestris* range between 35.36-44.9%, with compact soils having lower capacities (Pathak 1970). Additionally, the plant was observed to grow on soils of low nitrogen (Pathak 1970).

Measurements of *Trihus terrestris* taken during trials in India uncovered factors affecting the plant’s success; that is, dry weight and the plant’s seed output was influenced by the amount of organic matter in the soils (ranging between 1.07-3.94% on tested sites). Exchangeable soil calcium influenced dry weight of the shoots and the plant’s seed output. And, soil moisture of the soil with the presence of organic matter and exchangeable calcium influenced the dry weight of the shoot and the plant’s seed output (Pathak 1970).
As stated previously, waterlogged sites may cause poor seedling establishment, whereas it was observed that plants were abundant on arable and well-drained sites (Pathak 1970).

Competitive abilities:

Due to its ability to extract soil moisture from great depth in the soil, *Tribulus terrestris* competes well in crops (Holm et al. 1991).

There is also research demonstrating that seedling growth of *Pennisetum typhoides* is inhibited by root extracts of *Tribulus terrestris*; root extracts were most harmful when followed by leaf and stem extracts (Sen et al. 1969 in Holm et al. 1991).

*Tribulus terrestris* is sensitive to competition; typically, where perennial plants are maintained *Tribulus terrestris* does not become problematic (Squires 1969). In India, it was noted that *Tribulus terrestris* does not grow in continuous patches, and chooses a sunny location on a site (Pathak 1970). When it is observed in continuous patches on a site, the competition is low on the site (Pathak 1970).

Why it does well as an exotic:

*Tribulus terrestris* is capable of massive population increases over short periods of time, when conditions are favorable (Squires 1979, Washington State Noxious Weed Control Board 2002).

Boydston (1990) notes that erratic and continuous germination of *Tribulus terrestris*, its seed dormancy enabling seed to germinate over several years from one reproductive effort, and its ability to flower rapidly after emergence makes control difficult. As with other weedy species, it insures not all seeds germinate during favorable conditions, in the event a mass failure occurs. Germination of *Tribulus terrestris* seed is quick under suitable moisture and temperature conditions (Squires 1979). And, *Tribulus terrestris* fruits only 10 days old potentially have viable seeds (Johnson 1932 in Squires 1979). Germination after sufficient rain may only yield about 35% germination of seeds; Ernst and Tolsma (1988) suggest that this heterogeneity of seed germination may reduce intraspecific competition for light and nutrients on a site.

As stated previously, the seeds of *Tribulus terrestris* are viable in soil for up to 4-5 years (making eradication difficult) (Yolo County Resource Conservation District 2002).

*Tribulus terrestris* plants have deep, and somewhat woody, taproots; the plants are able to obtain moisture and to grow under conditions too rigorous for most plants (Holm et al. 1991). Its large root volume has a tremendous ability to remove water from the soil at very high moisture tension levels (Davis et al. 1965 in Holm et al. 1991). Also, it was found during trials in Texas that its water requirements are much lower than other plants (sorghum, alfalfa), needing 212 lbs. (96 kg) of water to produce 2.2 lbs. (1 kg) of dry biomass (Davis and Wiese 1964 in Holm et al. 1991).

*Tribulus terrestris* plants potentially produce many thousands of seeds.

Also, its long-distance method of dispersion enable the plant to move almost anywhere.

Effect on natural processes/description of the threat

No information was found on *Tribulus terrestris*’ impacts to natural areas. A few examples of how it impacts life in general:
*Tribulus terrestris* is listed as a regulated and restricted noxious weed in Arizona, causing impacts to crops and animals.

*Tribulus terrestris* fruits (with their sharp, stout spines) cause considerable nuisance in public areas. They also can seriously injure grazing animals (Squires 1979).

**known general distribution**

**United States:**


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**Species distribution in Arizona by county**

[Diagram of Arizona counties with distribution of *Tribulus terrestris* marked]

**Arizona**, by county:

found throughout the state, 7000 ft. or lower (Kearney and Peebles 1960, McDougall 1973, Parker 1972).

**National Park Service, southern Arizona group:**
Casa Grande Ruins National Monument
source listing species’ presence in park:

no sources found

Chiricahua National Monument
source listing species’ presence in park:


Coronado National Memorial
source listing species’ presence in park:


Fort Bowie National Historic Site
source listing species’ presence in park:


Montezuma Castle National Monument and Montezuma Well unit
source listing species’ presence in park:


Organ Pipe Cactus National Monument

source listing species’ presence in park:


Saguaro National Park

source listing species’ presence in park:


Tonto National Monument

source listing species’ presence in park:

no sources found

Tumacacori National Historical Park

source listing species’ presence in park:


Tuzigoot National Monument

source listing species’ presence in park:

no sources found
**Weeds in the West Project**

While completing distribution mapping between Spring 1999 through Spring 2001 for the USGS Weeds in the West project in the southern Arizona National Park Service management units, *Tribulus terrestris* (goatshead, puncture vine) was found in the following parks (Guertin 2001):

- Casa Grande Ruins National Monument
- Chiricahua National Monument
- Coronado National Memorial
- Fort Bowie National Historic Site
- Saguaro National Park
- Tumacacori National Historical Park

**control methods and management strategies**

**Competition:**

As stated previously, *Tribulus terrestris* does not become problematic in perennial plants; it is sensitive to competition (Squires 1969 *in* Squires 1979). Therefore, planting competitive vegetation can help control infestations (California Department of Food and Agriculture, EncycloWeedia 2002).

**Hand labor:**

Removal of plants with fruits/burrs and repeated cultivation to prevent seed production and fruit/burr formation can help control infestations (California Department of Food and Agriculture, EncycloWeedia 2002). *Tribulus terrestris* plants should be howed off below the crown at the root, and if plants have produced fruits before a cultivation effort is made, subsequent to the effort the plants and fruits should be collected and burned (Muenscher 1980, Washington State Noxious Weed Control Board 2002).

Repeated cultivation just after plant emergence is an effective control (Washington State Noxious Weed Control Board 2002).

**Mowing/Mechanical:**

Frequent light cultivation in areas with *Tribulus terrestris* seedlings may be effective (Squires 1979). On more mature plants, shallow cultivation to sever the taproot just below the soil surface is suggested (Holm et al. 1991).

**Grazing:**

Holm et al. (1991) notes that there may be several different toxic agents in *Tribulus terrestris*. The species has been reported to have toxic levels of nitrate in its tissues (Ragonese 1955 *in* Holm et al. 1991). Also, *Tribulus terrestris* foliage is toxic to livestock when consumed in quantity, especially for sheep (California Department of Food and Agriculture, EncycloWeedia 2002); this is caused by an unknown toxin which causes liver damage, and photosensitivation along with other symptoms which can likely cause death especially in young animals (Holm et al. 1991).

The spiked fruits/burrs can cause injury to animals, causing reduced grazing in pastures (Holm et al. 1991).

**Herbicides**
Picloram used as a pre-emergent can give adequate control. Young Tribulus terrestris plants may be sprayed with amitrole, chlorsulfuron, or 2,4-D (Washington State Noxious Weed Control Board 2002).

Rice (1992) lists 2,4-D, MCPA, MSMA, atrazine, bromoxynil, chlorsulfuron, dicamba, glyphosate, norflurazon, oryzalin, oxyfluorfen, simazine, tebuthiuron, trifluralin for puncture vine.

Parker (1997) lists 2,4-D, MSMA, amitrole, bromacil & diuron, chlorsulfuron, norflurazon, paraquat for puncture vine.

Colorado Natural Areas Program (2000) lists dicamba, picloram, and glyphosate as providing excellent control, and 2,4-D as providing good control of Tribulus terrestris.

Cautions and considerations: Herbicides, as with all management / control methods, take careful planning and attention to detail for a particular site (climate/weather, soils, topography, vegetation or lack thereof, sensitive areas, land use, target plant and infestation characteristics) and the goals to be accomplished on the site.

A major consideration when using herbicides is the sensitivity and hazard to other non-target species and organisms in the area (Callihan et al. 1995, Horowitz 1996). Many of the herbicides are 'non-selective' and useful for agricultural operations, but not necessarily intended for natural environments. Even the 'selective' chemicals can harm other plants when not applied properly or when used in places where other native plants are vulnerable to their mode of action (Horowitz 1996). Improper application and/or application rates can harm many other species, along with affecting water quality; the eventual accumulation of these compounds in underground and aboveground water bodies (Callihan et al. 1995, Horowitz 1996). Also, to be considered is the potential resistance a biotype may develop to some of these compounds over time (Horowitz 1996).

The information provided here is meant to give a glimpse of what has been learned, and found effective. It might not necessarily be the best approach in the Sonoran Desert; generally the environments reported on are not desert lands as little research has been done in natural environments of the Sonoran Desert to date. Nor do the same application or herbicide use laws apply across state borders in all cases. Contacts / specialists' names or offices are provided in the following section for follow up and gathering of more information pertinent to a specific environment or site.

Table 1 offers information on the herbicides in this section.

**Biological controls:**

*Tribulus terrestris* is controlled by introduced weevils (Hickman 1993) native to India, France, and Italy (Washington State Noxious Weed Control Board 2002) and brought into California. They are the stem weevil (*Microlarinus lypriformis*) and the seed weevil (*Microlarinus lareynii*), and were introduced in 1961 as a biocontrol agent (Gould and DeLoach 2002). Both of these weevils have established in California and Arizona; substantial success has been obtained in nonirrigated areas, with a partial success overall (Gould and DeLoach 2002). In areas of Texas and New Mexico, success is being defined as 'complete' with *Tribulus terrestris* difficult to find, although years of plentiful precipitation or irrigation, along with parasites and predators of the weevils, have limited complete eradication (Gould and DeLoach 2002).
In Hawaii, these same two weevils were released in 1962 and 1964 with *Tribulus terrestris* being completely eradicated in many areas within 4 years (Davis and Krauss 1966 in Markin et al. 1992).

**Control strategies:**

Control strategies of *Tribulus terrestris* include the removal of fruiting plants, with repeated cultivation to prevent seed production (California Department of Food and Agriculture, EncycloWeedia 2002, Holm et al. 1991).

For best results, control methods would have to eliminate early season to mid-season seedling establishment (April to end of July in Washington) given that these plants are more capable of greater seed production (Boydston 1990). As stated previously, the irregular and continuous germination of *Tribulus terrestris*, its seed dormancy, and its ability to flower rapidly after emergence will make control difficult (Boydston 1990).

**contacts or technical specialists**

**Dr. Francis E. Northam (Ed Northam)**

Noxious Weed Coordinator, Plant Services Division  
Arizona Department of Agriculture  
1688 West Adams Street  
Phoenix, Arizona  85007  
Phone: (602) 542-3309; FAX: (602) 542-1004  
e-mail: ed.northam@agric.state.az.us  
Ed works state-wide primarily with noxious agricultural weeds, yet has also done some work to get non-native invasive plants listed that impact Arizona’s natural environments  
He indicated he would provide, as requested, information regarding:  
- weed biology  
- control/management of weeds

**Dr. John H. Brock**

Professor of Applied Biological Science  
Coordinator of Sustainable Technologies, Agribusiness and Resources (STAR) Research Center  
Arizona State University East  
7001 E. Williams Field Rd.  
Mesa, Arizona  85212  
Phone: (480) 727-1240; FAX (480) 727-1961  
e-mail: john.brock@asu.edu  
Dr. Brock has done:  
- invasive plant work (including control treatments) in essentially all the major vegetation types in Arizona, except the highest elevation types like mixed conifer.

**April Fletcher**, Arizona Interagency Weed Action Group  
U.S. Fish and Wildlife Service  
P. O. Box 1306  
500 Gold Ave.  
Albuquerque, New Mexico  87103  
e-mail: April_Fletcher@fws.gov  
April works region-wide with on-the-ground folks. Arizona Interagency Weed Action Group (IWAG) is an ad-hoc group; working on specific projects identified as species of...
concern by the group. IWAG consists of invasive weed folks from state and Federal resource management agencies.
April is:
- acquainted with control methods for numerous species
- she knows many professionals who are doing control work, so, when she can’t supply an answer, she can usually provide contacts who can.

Jim Horsley, Southwest Vegetation Management Association
Arizona Department of Transportation
2104 S. 22nd Avenue
Phoenix, Arizona  85009
Phone: (602) 712-6135  email: jhorsley@dot.state.az.us
Jim indicated at ADOT they manage and control a number of native and non-native invasive species. Their experience includes
- Centaurea solstitialis (Yellow) and Centaurea melitensis (Malta) star thistle, Onopordum acanthium (Scotch), Carduus nutans (Musk), and Cirsium vulgare (Bull) thistle, Acroptilon repens (Russian), Centaurea biebersteinii / Centaurea maculosa (spotted), and Centaurea diffusa (diffuse) knapweed, Alhagi maurorum (Camelthorn), Halogeton glomeratus (Halogeton), Salsola sp. (Russian thistle, tumbleweed), Linaria damatica (Dalmation toadflax), Cardaria draba (Hoary cress), Tribulus terrestris (Puncture vine), Cenchrus sp. (sandbur), Convolvulus arvensis (Field bindweed), Sorghum halepense (Johnsongrass), Pennisetum ciliare (Buffelgrass), Pennisetum setaceum (Fountain grass), several mustards, Verbascum sp. (mullein), Heterotheca subaxillaris (Camphorweed) and several others.
Jim has
- personal experience statewide
- and, has access to other experts from several states in the southwest.

bibliography


Colorado Natural Areas Program. 2000. Creating an integrated weed management plan: A handbook for owners and manager of lands with natural values. Colorado Natural Areas Program, Colorado State Parks, Colorado Department of Natural Resources, Division of Plant Industry, Colorado Department of Agriculture. Denver, Colorado. 349 pp. Website: http://parks.state.co.us/cnap/IWM_handbook/IWM_index.htm Click on index for appropriate plant family to find species

Davidson, A. 1903. New plant records for the Los Angeles County, Part II. Southern California Academy of Science Bulletin 2, 43.


ExToxNet. 2002. USDA/Extension Service/National Agricultural Pesticide Impact Assessment Program, A Pesticide Information Project of Cooperative Extension Offices of Cornell University, Oregon State University, the University of Idaho, and the University of California at Davis and the Institute for Environmental Toxicology, Michigan State University. Website: http://ace.orst.edu/info/extoxnet/ghindex.html


Website: http://www.ars-grin.gov/npgs/tax/index.html then click on 'simple queries of species data' and search for plant species.


Oregon State University, Weed Science Program. 1998. Table 1. Herbicide classification according to primary site of action. Oregon State University, Extension, Research, and the Department of Crop and Soil Science. Website: http://www.css.orst.edu/weeds/Publications/table1.html


Rice, P.M. 2002. INVADERS Database System, University of Montana, Division of Biological Sciences, Missoula, Montana 59812-4824. Website: http://invader.dbs.umt.edu


additional sources and websites

Cooperative State Research, Education, and Extension Service Website: http://www.reeusda.gov/1700/statepartners/usa.htm
This website brings you to an interface to connect with Cooperative Extension programs throughout the United States; select the desired state, enter a link, often there is a search option in which information on a plant can be searched for.

websites with great plant photos:

http://www.extension.usu.edu/weedweb/photo/PL.htm then find species and select photos under categories (such as 'plant', 'flower', 'leaf', etc)
http://www.naturesongs.com/vvplants/puncturevine.html
http://courses.smsu.edu/pab532f/IDList6_485.htm scroll down to plant and click on image to enlarge
branches with fruit: http://tncweeds.ucdavis.edu/photos/trite03.jpg
leaves and flower: http://www.calflora.net/bloomingplants/puncturevine.html
http://pi.cdfa.ca.gov/weedinfo/puncturefram.html
http://www.psu.missouri.edu/fishel/puncturevine.htm
http://plnt2012.okstate.edu/plantandseedid/Weeds/Weeds.htm and then click on appropriate name
seeds: http://www.oardc.ohio-state.edu/seedid/ then select species

websites with simple plant descriptions and/or photos:

http://www.agf.gov.bc.ca/cropprot/weedguid/puncture.htm
http://mint.ippc.orst.edu/puncturevine.htm
http://plant.cdfa.ca.gov/biocontrol/weeds/83wbc-tribulus.html
http://www.ipm.ucdavis.edu/PMG/WEEDS/puncturevine.html

some websites with great info:

http://www.naturesongs.com/vvplants/puncturevine.html
Table 1. Herbicide information for control of puncture vine.

<table>
<thead>
<tr>
<th>HERBICIDE</th>
<th>TRADE NAMES</th>
<th>CHEMICAL GROUP</th>
<th>USE</th>
<th>MODE OF ACTION</th>
<th>IN SOILS</th>
<th>NOTES</th>
</tr>
</thead>
<tbody>
<tr>
<td>2,4-D</td>
<td>many; some manufacturers are: Benide, Ortho, Rhone Poulenc, PBI/Gordon, Wilber-Ellis, Agrolinz, Combelt, Setre, Lily Miller, Uniroyal, Riverdale, DowElanco, Greenlight</td>
<td>phenoxy</td>
<td>Foliar spray or soil application</td>
<td>Mimic plant’s hormones. Absorbed by foliage and translocated symplastically, and accumulates in areas of high metabolic activity (new growth). Primary mode of action not known, but it affects processes such as cell division and elongation.</td>
<td>Salt formulations are subject to leaching in sandy soils; ester formulations are less water soluble so are less likely to leach. Persistence in warm, moist soils average 1 - 4 weeks.</td>
<td>Selective. Many annual and perennial broadleaf species are sensitive. Drift to nontarget sensitive species can be a problem; use a formulation that is less volatile to aid in prevention. (Labeled sites: lawns, golf courses, parks, etc., non-crop land)</td>
</tr>
<tr>
<td>amino triazole (amitrole)</td>
<td>Amitrole-T, Amizol triazole</td>
<td>Foliar spray</td>
<td>Inhibits chlorophyll formation, and regrowth from buds. Slowly absorbed by foliage; some root absorption in sandy soils. Translocated throughout plant in the symplast and apoplast. Plants turn white or pink after treatment.</td>
<td>Limited activity in soils; persists 2-4 weeks. Broken down by microorganisms. Little photodecomposition.</td>
<td>Nonselective; annual and perennial species. Avoid drift, as most desirable plants are sensitive. Apply to actively growing young weeds for best control; do not apply to drought-stressed weeds. (Labeled sites: field nurseries, ornamental plantings, aquatic weeds, forest plantations, non-crop land)</td>
<td></td>
</tr>
<tr>
<td>Herbicide</td>
<td>Trade Name(s)</td>
<td>Type of Application</td>
<td>Mode of Action</td>
<td>Absorption and Translocation</td>
<td></td>
<td></td>
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<tr>
<td>Atrazine</td>
<td>Aatrex, Atrazine, Atra-Pril, Cheat Stop</td>
<td>Soil application or foliar spray</td>
<td>Inhibits photosynthesis. Absorbed primarily through roots with some foliar absorption; apoplastic translocation; readily translocated. Accumulates areas of high metabolic activity (shoot meristems).</td>
<td>Moderate to strong adsorption to soil particles and organic matter. Leaching generally is limited; may leach in sandy soils, thus groundwater contamination may occur. Seldom found more than 12 in. deep. May persist for more than one season in cold or drought-type soils. Selective. Selectivity based on resistant plants metabolizing the compound to non-toxic materials; also can be caused by position in soil. Many annual grasses and most broadleaf species sensitive. Most in. deep. May persist for more than one season in cold or drought-type soils.</td>
<td>Selective, Selectivity based on resistant plants metabolizing the compound to non-toxic materials; also can be caused by position in soil. Many annual grasses and most broadleaf species sensitive. Most in. deep. May persist for more than one season in cold or drought-type soils.</td>
<td></td>
</tr>
<tr>
<td>Bromoxynil</td>
<td>Buctril, Brominal benzonitrile</td>
<td>Foliar spray</td>
<td>Appears to inhibit photosynthesis and respiration. Absorbed by foliage with little translocation within plant.</td>
<td>Little activity in soils.</td>
<td>Selective. Primarily sensitive to annual broadleaf species. Controls some plants species resistant to 2,4-D. Restricted-use herbicide. (Labeled sites: turf)</td>
<td></td>
</tr>
<tr>
<td>Chlorsulfuron</td>
<td>Glean, Telar sulfonyl urea</td>
<td>Pre-emergent or foliar spray</td>
<td>Primary mode of action is inhibition of cell division in shoots and root; this is accomplished by interference with the enzyme acetolactate synthase. It is absorbed by foliage and roots, and readily translocated throughout the plant.</td>
<td>Leaches readily in well drained soils, as it is not adsorbed strongly. Subject to hydrolysis (in warm, moist soils of low pH) and microbial degradation in soils, with estimated half-life 4 - 6 weeks.</td>
<td>Selective, when used at low rates. Annual and perennial broadleaves are sensitive. But some broadleaved species are extremely sensitive to this compound at low rates. It has a relatively long soil life. (Labeled sites: non-crop land, roadsides, industrial areas, etc.)</td>
<td></td>
</tr>
<tr>
<td>Dicamba</td>
<td>Banvel, Banvel SGF, Banvel II, Clarity, Trooper, Vanquish</td>
<td>Pre-emergent or foliar spray</td>
<td>Mimic plant's hormones. Absorbed by foliage and roots; readily translocated symplastically and apoplastically throughout plant. Acts as an auxin-like growth regulator. Mechanism not known.</td>
<td>Mobile in soils. Leaches readily. Leaching into root zones of trees, etc., can be a hazard. Decomposition by soil microbes. In warm, moist conditions, half-life is 14 days.</td>
<td>Many annual, biennial, and perennial herbaceous broadleaf species, and some woody species are sensitive. (Labeled sites: home and industrial turf, parks, golf courses, non-crop lands)</td>
<td></td>
</tr>
</tbody>
</table>
**diuron**  
*Karmex, Direx*  
substituted urea  
Pre-emergent or directed foliar spray  
Inhibits photosynthesis by inhibiting the Hill reaction. Absorbed mainly by roots, some foliar absorption, and translocated apoplastically through plant.  
Adsorbed to soil on organic matter and clays. Leaching is minimal in clay, increases in sandy soils. Persists several months in soil.  
Used selectively or as complete vegetation killer. When used at low rates, it can be selective; higher rates for general vegetation control. Requires a surfactant for foliar application (plants must be under 2 in. tall). (Labeled sites: field nurseries, non-crop land)

**glyphosate**  
*Roundup, Rodeo, Kleenup, Accord, Honcho, Expedite Grass and Weed, E-Z-Ject, Jury, Mirage, Pondmaster, Protocol, Rattler, Ruler, Silhouette*  
glycine derivative  
Foliar spray  
Absorbed by foliage and translocated symplastically to sites of high metabolic activity in roots and shoots. Inhibits amino acid synthesis. May be washed off if rain occurs within 6 hours.  
Strongly adsorbed to soil and inactivated. Little leaching, no soil activity. Broken down by microorganisms.  
Nonselective. Low volume applications most effective. May be washed off if rain occurs within 6 hours. Rhizome kill often best when applied to mature weeds at time of flowering. Rodeo and Accord require additional nonionic surfactant. Grass control enhanced with addition of ammonium sulfate to spray solution. Retreatment may be necessary. (Labeled sites: turf renovation, nurseries, parks, home garden, industrial landscapes)

**MCPA**  
*many; some manufacturers are: Rhone-Poulenc, Lilly Miller, Wilber-Ellis, Agrolinz, Inter-Ag Corp.*  
phenoxy  
Foliar spray or soil application  
Mimic plant's hormones. Absorbed by foliage and translocated symplastically, and accumulates in areas of high metabolic activity (new growth). Primary mode of action not known, but it affects processes such as cell division and elongation.  
Readily leached in soils. Rapid decomposition by soil microbes; low photodecomposition rate. Persistence in soils under moist conditions is 1 month, in dry conditions is 6 months.  
Selective. Many broadleaf species sensitive. (Labeled sites: turf, non-crop lands)
<table>
<thead>
<tr>
<th>Herbicide</th>
<th>Active Ingredient</th>
<th>Mode of Action</th>
<th>Application Form</th>
<th>Behavior in Soil</th>
<th>Selectivity</th>
<th>Labeled Sites</th>
</tr>
</thead>
<tbody>
<tr>
<td>MSMA</td>
<td>Arsonate, Daconate, Trans-Vert, Bueno, Ansar, Weed-hoe, Weed-E-Rad, Organic arsenical</td>
<td>Foliar spray</td>
<td>Unknown. Suspected to replace phosphorous and interferes with biochemical processes; such as production of ATP. May also interfere with enzyme activity and disrupt membranes. Absorbed through foliage, and translocated symplastically.</td>
<td>Strongly adsorbed in soil. Behaves like phosphate in soil. Resists leaching, but can accumulate.</td>
<td>Limited selectivity. Annual and perennial grasses and some annual broadleaf species sensitive. Best results obtained when air temperature above 80 degrees F. (Labeled sites: turf, non-crop, landscapes)</td>
<td></td>
</tr>
<tr>
<td>norflurazon</td>
<td>Solicam, Evital, Zorial, Predict</td>
<td>pyridazinone</td>
<td>Pre-emergent. Aqueous solution used as soil drench. Inhibits synthesis of carotenoid pigments. In absence of these pigments, chlorophyll is decomposed. Absorbed by roots and translocated to sites of high metabolic activity. Chlorosis occurs.</td>
<td>Adsorbed by organic matter. Does not leach appreciably. Broken down by microorganisms and by photodegradation and volatilization on soil surface.</td>
<td>Selective. Incorporate within 4 weeks of application. (Labeled sites: orchards, non-crop land)</td>
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</tr>
<tr>
<td>oryzalin</td>
<td>Surflan, Weed Stopper, Weed &amp; Grass Preventer</td>
<td>dinitroaniline</td>
<td>Soil application</td>
<td>Inhibits seed germination and root development; mitosis. Little absorption. Severely inhibits root development. Little to no foliar activity; and is not translocated through plant.</td>
<td>Adsorbed in soil. Leaching can occur. Decomposed by microbes and some photodecomposition. Slightly volatile.</td>
<td>Used selectively. Most seedling grasses and some annual broadleaf species sensitive. Kills germinating seedlings, not established plants. (Labeled sites: no information)</td>
</tr>
<tr>
<td>oxyfluorfen</td>
<td>Goal</td>
<td>diphenyl ether</td>
<td>Pre-emergent or foliar spray</td>
<td>Disrupts cell permeability. Absorbed mainly through the shoot (meristematic). Little absorption by roots and translocation occurs in plant.</td>
<td>Strongly adsorbed in soil. Leaching is minimal. Not readily decomposed by microbes or photodecomposition.</td>
<td>Selectivity occurs by compound placement. Requires light for herbicidal activity if applied to foliage. (Labeled sites: no information)</td>
</tr>
<tr>
<td>Herbicide</td>
<td>Brand Names</td>
<td>Type</td>
<td>Method of Application</td>
<td>Site of Action</td>
<td>Persistence and Breakdown</td>
<td></td>
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<tr>
<td>paraquat</td>
<td>Gramonxone, Ortho bipyridylium salt</td>
<td>Foliar spray</td>
<td>Disrupts membranes. High energy free radicals formed by paraquat in plant responsible for herbicidal activity. Rapidly absorbed by foliage and sometimes may be translocated in xylem.</td>
<td>Strongly adsorbed in soil. Is persistent and biologically unavailable. Non-selective. All annual species, top kill of perennials. Use non-ionic surfactant. Thorough coverage important. Toxic to mammals. Restricted-use herbicide. (Labeled sites: non-crop land, nurseries. Not for use in parks, playgrounds, home gardens, schools)</td>
<td></td>
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<tr>
<td>picloram</td>
<td>Tordon</td>
<td>Foliar spray or soil application</td>
<td>Mimic plant’s hormones. Rapidly absorbed by foliage and roots and translocated symplastically and apoplastically to accumulate in areas of high metabolic activity (new growth).</td>
<td>Is highly mobile in soil, with average persistence being two to several seasons after application, depending on application rate and climate. Restricted-use herbicide. Highly phototoxic. Many woody plants, and most annual and perennial herbaceous broadleaved plants are susceptible. Most grasses are resistant. Careful precautions must be made to prevent injury to desired plants. Because of persistence in soils, chances of contamination in non-treated areas must be considered. Do not apply in areas where compound can leach into root zone of susceptible species, or into water supplies. (Labeled sites: no information)</td>
<td></td>
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</tr>
<tr>
<td>simazine</td>
<td>Princep, Aquazine, Caliber 90, Gesatop, Simazine</td>
<td>Soil application</td>
<td>Inhibits photosynthesis. Readily absorbed by roots (little foliar activity), and translocated apoplastically through plant to roots and shoots.</td>
<td>Moderate to strong adsorption to soil particles and organic matter. Leaching generally is limited; but may leach in sandy soils. Little lateral movement. Decomposition by soil microbes. May persist for considerable periods of time depending on soil conditions and application rates. Used selectively or as complete vegetation killer. When used selectively, primarily annual grasses and broadleaf species sensitive. Activation requires considerable soil moisture. Long residual action. Carryover to susceptible species can occur. Resistance has been reported. (Labeled sites: no information)</td>
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</tr>
<tr>
<td>Tebuthiuron</td>
<td>Spike, Sprakil</td>
<td>Substituted urea</td>
<td>Pre- or post-emergent</td>
<td>Inhibits photosynthesis. Absorbed primarily through roots with some foliar absorption; readily translocated.</td>
<td>In dry soils (those receiving less than 40-60 inches per year) persistence is considerable; half-life in wetter soils 12-15 months. No significant lateral movement, nor more than 12 inches deep with surface application.</td>
<td>General vegetation control: including most woody plants. Caution should be taken due to long residual life and strong herbicidal properties. (Labeled sites: non-crop land)</td>
</tr>
<tr>
<td>Trifluralin</td>
<td>Treflan, Trifluralin, Ornamental Weeder, Trilin 5</td>
<td>Dinitroaniline</td>
<td>Soil application</td>
<td>Inhibits mitosis. Microtubule assembly inhibitor. Severely inhibits root development. Little to no foliar activity; and is not translocated through plant.</td>
<td>Strongly adsorbed in soil. Leaching is minimal. Decomposed by microbes or photodecomposition. Slightly volatile. Half life is about 2 months.</td>
<td>Used selectively. Most seedling grasses and some annual broadleaf species sensitive. Kills germinating seedlings, not established plants. Requires soil incorporation after application. Residual activity and carryover to sensitive species possible when used at higher than normal rates. Toxic to fish. (Labeled sites: no information)</td>
</tr>
</tbody>
</table>