Tamarix ramosissima; Tamarix chinensis
Salt cedar; tamarisk

The following description of *Tamarix ramosissima* is adapted from Munz and Keck (1973). *Tamarix ramosissima* is a deciduous member of the Tamarisk Family (Tamaricaceae). It is a glabrous, loosely branched shrub or small tree 1-3 m tall. The branchlets are slender with minute appressed scaly leaves. The leaves are rhombic to ovate, sharply pointed to gradually tapering, and 0.5-3.5 mm long. They are sometimes auriculate but not vaginate or amplexicaul. The margins of the leaves are thin, dry and membranaceous.

The white or pinkish flowers are borne on slender racemes (2-5 cm long) on the current year's branches and are grouped together in terminal panicles. The pedicels are short. The deciduous petals are obovate and 1.5-2 mm long. The bract is ovate. The 5 stamens have the filaments (1.5-2.5 mm long) attached between the lobes of the disc and the anthers blunt to mucronate. The flowers are most abundant in the Northern Hemisphere from April to August but may be found most of the year. Petals are usually retained on the fruits.

The seeds, borne in a lanceovoid capsule 3-4 mm long, are approximately 0.45 mm in length and 0.17 mm in diameter and have unicellular hairs about 2 mm long at the apical end. The seeds have no endosperm and weigh about 0.00001 gram (Wilgus and Hamilton 1962).

There are seven species of *Tamarix* listed as occurring in California (Munz and Keck 1973). The characteristics which distinguish this species from other deciduous species in its genus are its obovate petals, which widen distally, and ovate to subobtuse bracts. Also, it is found in more saline habitats than other *Tamarix* species.

The name *Tamarix pentandra* has apparently also been used for *T. ramosissima* (Munz and Keck 1973), but T. *pentandra* may actually be a synonym of *T. chinensis* (Kartesz and Kartesz 1980). None of the members of this family are native to California and are distinctive in having juniper-like leaves, white or pink flowers, and ovoid seed capsules.

Another species that presents a problem in southwest deserts is *T. chinensis*. *T. ramosissima* and *T. chinensis* are often confused with each other. Each has leaves that are sometimes auriculate but not vaginate or amplexicaul and staminate flowers with filaments that are inserted below the disc. The basic difference in flower morphology is that, while *T. ramosissima* has obovate flower petals which widen distally, *T. chinensis* has oblong-ovate flower petals that are narrowed distally.

Habitat preference also distinguishes the two species. *T. ramosissima* is found invading areas of higher salinity than *T. chinensis*. *T. ramosissima* is more common in standing water such as marshes, oases and lakes or salty river banks and salty steppes. *T. chinensis*, however, establishes most readily along major river drainages.

T. *aphylla* is also an escaped exotic in the Southwest. It is most commonly found among stands of *T. ramosissima* along riverbanks. It is an evergreen tree that flowers during the winter months. Its leaves are vaginate, but its bracts are not. It does not reproduce by seed in California and therefore is not as widespread as *T. ramosissima*. It propagates from root and branch stock (Neill 1985).

Tamarix ramosissima is native from southeastern Europe to central Asia. It was introduced into the eastern U.S. in the 1820s. By the early 1900s, tamarisk had escaped cultivation and had become widespread throughout the southwestern U.S. along riparian areas and springs.

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> "On the California desert, tamarisk is well established along parts of the Colorado and Mojave rivers and at places around and near the Salton Sea ... At many smaller, isolated water sources that are scattered about the desert, the infestation is either fairly recent or is restricted in size by limited water supply or inhospitable growing conditions" (Neill 1983 .

The list of desert water sources in California that have been invaded include Amargosa Canyon, Big Morongo Canyon, Com Spring, Darwin Falls, Piute Creek, Saline Valley, and San Sebastian Marsh (Neill 1983).

Tamarix is widely cultivated as an ornamental. In many places these plants have also been used for windbreaks and erosion control. Beekeepers regard it highly in the production of honey. In some areas *Tamarix* thickets are valued nesting habitat for white-winged doves.

Tamarisk prefers the moist sand along river margins. It grows rapidly on river floodplains in arid and semi-arid climates. In the southwestern United States, it initially naturalized along most major river drainages at lower elevations (Schopmeyer 1974). Now, however, its habitat includes pastures, irrigation ditches, moist lowlands and streambanks. It occupies the niche usually associated with willow and cottonwood.

The plants usually grow where the depth to the water table does not exceed 25 feet, and normally where it is less than 15 feet. Tamarisk has a wide range of tolerance to saline or alkaline soil and water. It has been found growing in Death Valley, CA, where the groundwater contains as much as 5 percent (50,000 ppm) dissolved solids. However, it grows best where the groundwater is little to moderately mineralized (Robinson 1965).

A tamarisk plant may produce many thousand seeds in a single season (Wilgus and Hamilton 1962). These seeds are dispersed by the wind. The pappus hairs on the apex of the seed form a column when moistened.

> "In 5-8 hours after moistening the embryo has usually swollen enough to break the seed coat, the hypocotyl has turned downward and a corona of root hairs has developed around the radicle to anchor the seedling. As the stem straightens the cotyledons separate" (Horton et al. 1960).

Horton et al. (1960) did extensive research on seed germination and seedling establishment of phreatophyte species for the United States Forest Service (USFS). The results of their work are as follows:

> "Tamarisk produces seed abundantly over a long period (April to October). Seeds remain viable for only a few weeks, especially at high temperatures characteristic of Arizona deserts. Fresh seed germinates rapidly, generally in less than 24 hours. Germination is dependent upon saturated soils. Receding spring and summer flows are ideal for germination and seedling establishment. Seedlings grow slowly and are sensitive to drying. In fact, survival is dependent upon saturated soils during the first 2-4 weeks of growth. Seedlings can be submerged several weeks or more, but when small they will be detached from the soil and float away if there is any appreciable current."

Light was found to have no effect on their germination.

> "Early growth is very slow. Top height averages about 2.5 cm at thirty days after emergence and seedlings average only 11 cm tall after sixty days. At this time roots are about 15 cm long. After seedlings become established they can withstand severe drought. When mature, roots occupy the capillary zone above the water table with some roots in the zone of saturation (Schopmeyer 1974).

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> "Seedlings mature rapidly and produce small, pink flowers often by the end of the first year. Under optimum conditions, a desert riparian area containing only a few tamarisk trees can be converted to an impenetrable thicket in less than a decade" (Neill 1983). Tamarisk grows so rapidly, up to one foot per month, and so densely, that native trees are crowded and shaded from direct sunlight and cannot thrive (Neill 1983).

> "Historically, the area and the density of plant growth have increased wherever the species has become established. This effect may be expected to continue wherever area and density of growth have not reached their optimum and wherever new areas become established (Robinson 1965)."

Vegetative surveys of the Bernardo Bridge-San Marcial Reach in the Rio Grande Valley (Texas) were made by the Bureau of Reclamation in 1947 and again in 1955. As part of these two surveys determinations were made, by species, of the cover density and of the height component of the foliage. "In the 1947 survey, cover densities ranged from 1 to 81 percent and averaged 19.1 percent, while in the 1955 survey, cover densities ranged from 2 to 100 percent and averaged 39.3 percent, an increase of more than 100 percent. At the same time the increase of the volume of foliage was over 75 percent" (Robinson 1965).

Horton (1957) made detailed observations of the life history of *Tamarix ramosissima* along the Salt River, east of Tempe, Arizona. He found that the earliest flowers appeared as lateral racemes on old wood of the previous year.

> "Several weeks later the same shrubs began producing terminal panicles on shoots developed since the beginning of the growing season. These shoots often formed on the same branches that produced the spring racemes. A still further stage of flowering occurred as the central stem of the panicle often elongated to develop a secondary panicle after the first one had produced seed."

> "Tamarisk stem tissue (including root crown material) will sprout vigorously and form new plants if buried or partially buried in warm moist soil. In the active growing season nearly all undried stem cuttings of all sizes and from any location in the crown of the original shrub produced roots and formed new plants under greenhouse conditions." (Gary and Horton 1965).

Sprouts, however, do not form from severed root tips (Horton 1960).

> "Sprouting was delayed during the winter period. In some instances, cuttings planted during the late fall and winter months did not sprout for 3 or 4 months. (The drying of cuttings reduced sprouting ability.)" (Gary and Horton 1965).

Tamarix is commonly known as salt cedar because the minute and scale-like leaves are often coated with a salty white bloom.

> "During periods of high humidity, twigs often become laden with droplets of salty fluid. These drops are a result of deliquescence of previously secreted salty bloom rather than from current guttation. The salt is secreted by salt glands imbedded in epidermal pits. The glands are dome shaped and consist of at least two cells which are non-vacuolate and densely filled with granular material" (Decker 1961).

> "It appears that active salt glands are highly turgid and force salt solutions out of their pores under pressure. The glands are primarily desalting organs capable of reducing the salt in the mesophyll cells of the leaves" (Campbell and Strong 1964).

In one experiment, concentrations of all soluble salts averaged 5200 ppm in the upper 20 cm of soil supporting salt cedar. The range of salt concentration was 700-15,000 ppm which is relatively high (low to medium concentrations of soluble salts in soil average in the range of 100-3500 ppm).

> "Tamarisk is a virulent pest in desert riparian areas because it aggressively displaces native trees and shrubs, it withdraws and transpires water from the ground at a high rate, and it is a poor source of food and shelter for desert wildlife" (Neill 1985).
>
> "Invasion of a floodplain by *Tamarix* usually leads to depletion of streamflow, an increase in the area inundated by floods, and an increase in sediment deposition. Salt cedar clogs channels by invading stream banks and sand bars close to the stream. During a flood, the restriction and increased channel roughness cause inundation of areas that normally are not flooded. The damming and ponding effect of dense salt cedar reduces stream velocity and, consequently, its power to carry sediment. Sedimentation is thus accelerated" (Blackburn et al. 1982). On the Brazos River in Texas, for example, some sections have been reduced in width by 71% between 1941 and 1979. Sediment deposits (caused by tamarisk invasion) ranged from 1.2 to 5.5 m deep, average sediment depth was 3.0 m (Blackburn et al. 1982).
>
> "Continued and widespread expansion of tamarisk in stream systems not only increases river sedimentation and causes higher peak flows but consumes large quantities of water. It is estimated that about 2 acre feet of water per acre of phreatophytic vegetation could be saved annually by removing riparian vegetation from floodplains in the southwest U.S." (Blackburn et al. 1982). This is because *Tamarix* has an extremely high rate of evapotranspiration. "Evapotranspiration rates of salt cedar are among the highest of any phreatophyte evaluated in southwestern North America. Denser stands of salt cedar occur where water tables are close to the surface. Annual water losses may total as much as 2.1 cubic meters/square meter" (Carmen and Brotherson 1982).

Tamarisk is a successful competitor with native riparian species, often replacing willow and cottonwood (Neill 1985).

> "It often forms extensive and nearly impenetrable stands along banks and flood plains of streams" (Decker 1961). In 1960 in a quantitative study of vegetation of Glen Canyon in Colorado, a team from the University of Utah wrote: "There are many areas of heavy cover of willow in which the tamarisk has not so far established a foothold, but there are many other areas in which the willow cover has been broken and the tamarisk has occupied sites that are normal habitat of the willow" (Horton et al. 1960).
>
> "Where the two grow together, the willows usually occupy the muddier parts, and the tamarisk the sandy areas ... Tamarisk seedlings are sometimes abundant on wet sand, but willow seedlings are not with them. There is no evidence to indicate that willows will displace *Tamarix* on sandy soil. It is probable that competition between the two will tend to restrict the willows more and more to the muddy parts and yield sandy areas to *Tamarix*, although without competition either one alone might spread more widely into both types of soil" (Christensen 1962).

One example of how quickly tamarisk can establish itself as a dominant riparian species can be seen from records kept on the vegetation of the delta area of Lake McMillan on the Pecos River in New Mexico.

> "There are no records or reports of salt cedar in this area prior to 1912. By 1915 the plants had spread over an area of about 600 acres of delta land. In the next 10 years the plants continued to spread over the delta area until by 1925 they covered 12,300 acres" (Robinson 1965).

> "The same rapidity of infestation was observed in central Utah and the Rio Grande and Pecos river valleys of New Mexico and Texas. By 1961, according to the only comprehensive inventory yet published, tamarisk occupied an estimated 1400 square miles of flood plain land in the western United States (Neill 1983).

Along with crowding out the native riparian flora and increasing the salinity of the soil, *Tamarix* is also a threat to forage production for cattle. Between 1920 and 1960 it was estimated that tamarisk acreage increased in extent from 10,000 to 90,000 acres (Robinson 1965).

Anderson and Ohmart (1976) found that fewer species of birds nest in *Tamarix* than in native riparian vegetation. The average number of bird species found in the tamarisk community from December 1975 to November 1976 was 21. The number of bird species in the cottonwood-willow community averaged 36 during the same time period.

In summary, tamarisk has a major effect on stream sedimentation, bed roughness, water consumption, and native species richness of both plants and animals.

Case History:

> "One tamarisk removal project has been completed, with dramatic success, at Eagle Borax Spring in Death Valley National Monument. Deciduous tamarisk probably was present at this large marsh on the west side of the valley floor in the 1940s or before, but due to grazing by horses it did not proliferate until the mid 1950s. It then spread and grew rapidly during the next decade. By the late 1960s the surface water in the marsh had disappeared, the native grasses and reeds were being replaced by tamarisk, and mesquite trees adjacent to the marsh were slowly losing vigor owing to the competition for ground water.
>
> "After burning the tamarisk cover in 1972 to restore the water level in the marsh, the Park Service began permanent removal by cutting with chain saws and applying systemic herbicide to the stumps. The program was continued intermittently by Park Service employees over the next 10 years and then was completed in 1982 with volunteer assistance. With the tamarisk gone, the recovery of the marsh has been rapid and impressive. The surface water has returned. Use by migratory birds has returned to former levels. The grass and reeds are flourishing, and the grove of mesquite trees is again healthy" (Neill 1983).

Biological monitoring is needed to determine the effectiveness of management practices.

Detailed observations focused on the vegetational changes of the affected area over time will help to determine what method of control would be the most efficient.

Biological monitoring of *Tamarix ramosissima* was begun at Anza Borrego State Park in the spring of 1985. In Coyote Canyon three different plots encompassing 10 square meters will be delineated. The three treatments will be: (1) no *Tamarix*, (2) all *Tamarix*, and (3) a mixed stand of *Tamarix* and natives. The rate of tamarisk infestation will be determined from the plot initially devoid of *Tamarix*. The pioneering characteristics of natives in the area will be assessed from the plot with initially 100 percent cover of *Tamarix*, after the stand has been cut and treated with a systemic herbicide. The changes in the percent cover of natives and their composition will be calculated from the plot initially mixed with *Tamarix* and natives, after the *Tamarix* is selectively removed from the area.

While treating *Tamarix* stands in June and July 1985, M. Jorgenson, State Park Naturalist at Anza Borrego State Park, began another monitoring program to determine the death rate and effectiveness of current control procedures. Monitoring will consist of counting the trees in a site as they are cut and treated with Garlon 34 (a systemic herbicide which breaks down in three days), tagging the perimeter of a stand of 100 stumps, and visiting every six months to count regenerating individuals.

The following are specific areas of research that need study to improve control efforts:
1. Basic research on morphological and physiological features of the plant as they relate to burning and spraying.
2. An evaluation of early-midsummer burning and spraying as means of controlling tamarisk to determine when the plant is most susceptible.
3. Evaluation of potential for biological control of tamarisk.
4. Would revegetation enhance eradication efforts of *T. ramosissima* in California?

This weed does require active management. Researched methods of control are listed below.

Tamarisk is probably the most suitable of "ecological weeds" for investigation of biocontrol. It belongs to a family not native to North America and has only marginal economic use. Its costs, in terms of floodplain management and water consumption, are high, and as will be discussed below, biocontrol agents may be available. However, the U.S. Department of Agriculture must be lobbied to undertake the long and expensive task to developing a biocontrol strategy. Since tamarisk is not an agricultural pest, THE USDA must be specifically encouraged to commit resources.

In an unpublished annual report on biocontrol of *Tamarix* 1969- 1970, researchers reported that

> "the most significant contribution of this research is the demonstration of a significant reduction in *Tamarix* growth by a natural field population of the host specific leafhopper, OPSIUS STACTAGALLUS. This constitutes the first positive evidence of a building block toward an eventual biological control of salt cedar. This evidence, combined with the report of several host specific insects on *Tamarix* in Morocco, offers encouragement to the idea that a combination of several biological agents may be brought into focus to reduce the salt cedar population below the economic level. Because the Tamaricaceae is a small family and the genus *Tamarix* is unique in many physiological characteristics and does not include species of great economic importance to man, it is possible to choose the best combination of biological control agents from the range available and to achieve desired degree of control ranging from slight suppression to stand destruction."

The following is a list of some insect species that feed upon tamarisk with an evaluation of their damaging potential (Gerling and Rugler 1976):

(1) Destroys fruiting bodies: *Corimalia* spp. (Coleoptera: Cureulionidae); *Crastina linnruouri* (Homoptera: Psyllidae).
(2) Causes moderate and long-range damage: *Tuponia* spp. (Heteroptera: Mirdidae); *Opsuis* spp. *Tamaricella* spp. (Homoptera: (Cicadellidae); *Ornativalva* spp. (Lepidoptera: Gelechiidae); *Agelistis* spp.; *Lepidognea tamaricalis* (Lepidoptera: Dryalidae).
(3) Highly damaging insects: Psiloptera spp.; *Steraspis squamosa* (Coleoptera: Buprestidae); *Cryptocephalus* spp.; *Coniatus* spp.; (Coleoptera: Curulionidae); *Opsuis* spp. (Homoptera: Pseudococcidae); *Semiothisa aestimaria* (Lepidoptera: Geometridae).

Campbell (1966) in a paper written for the USFS-United States Department of Agriculture (USDA) entitled "Periodic mowings suppress tamarisk growth increase forage for browsing" found:

> "In many areas of the Southwest, complete eradication of tamarisk is probably not economically feasible. Initial treatment with herbicides or mechanical clearing is costly and retreatment is

> always necessary. Estimates of benefits in water savings following such treatments on a reach or reservoir delta are not always reliable. Tamarisk, however, can be suppressed on flood- plains and reservoir deltas by periodic mowing. In central Arizona, mowings in May, July and September are necessary to keep foliage succulent and within reach of browsing cattle. It is estimated that Bermuda grass and tamarisk resprouts would produce hundreds of pounds of available forage per acre per year on what would otherwise be relatively low-yield sites.
>
> "Tamarisk was killed by frequent foliage removal, although mortality rates varied between treatment years. Mortality increased when tamarisk plants were completely defoliated at frequent intervals. Plants were not killed by one season of mowing. Evapotranspiration was decreased by approximately 50% following mowing treatments. Total hydrolyzable carbohydrate root contents decreased with severity of treatments," an important factor when considering herbicide application.

Horton (1960) researched the feasibility of using a root plow to clear tamarisk stands. His contention was that if shrubs are cut below the surface of the ground when the soil is dry, the stems and branches die before new plants develop from sprouting. This method appeared to be effective, although costly.

> "Some management recommendations to prevent reestablishment of tamarisk by sprouting of several stem portions are: (1) control operations should be done during the growing period when the soil is dry and weather warm; and (2) stems should be left on the surface of the ground and never buried in moist soil" (Gary and Horton 1965).

Uprooting tamarisk stands with a backhoe or tractor and chain has been successful at Chuckwalla Well and Darwin Dry Lake in California. This mechanical means of removal is suitable in marshy areas where the tamarisk will have shallow roots and chemical means of treatment are prohibited. This task is best undertaken during April and May when the plants are flowering and therefore more visible.

Horton et al. (1960) mention that

> "construction of levees to reduce the area flooded during highflows, and regulation of releases from reservoirs to avoid slowly decreasing flow during the seed production season, may also prevent tamarisk invasion of many areas."

In heavily infested areas, control practices will have to extend beyond the initial treatment. Seedlings may continue to sprout for years to come. In combination with the other means of control, removal of saplings by hand is suggested. Until the stem diameter exceeds 3 cm, tamarisk can be pulled up with relative ease while the soil is moist.

Tamarix chinensis

Although *T. chinensis* and *T. ramosissima* occupy two different niches, there has been work done on wildlife enhancement in areas occupied by *T. chinensis* (Anderson and Ohmart 1982) that is worthy of consideration in developing *T. ramosissima* management plans. The site chosen for study was located on the Cibola National Wildlife Refuge, 40 km south of Blythe, California. The area covered 20 ha and supported a mean of 345 trees per ha. When the study began (1973) the site was vegetated with *T. chinensis* and a few widely scattered clumps of willow trees.

The area was initially cleared of *T. chinensis* with bulldozers which pushed the debris into piles. The clearing was done selectively so that the willow stands were left intact. The slash was then burned and the area root-ripped approximately 30 cm below the soil surface. It was subsequently leveled. This activity took place in the spring of 1978.

"Immediately after this treatment in March 1979, there was no sign of any living salt cedar trees. By October 1979, there were 59 salt cedar trees per ha, these having regenerated from rootstock which had not been killed. These trees were chopped off below ground level the following winter. At the same time the area as seeded with *Atriplex lentiformis* (quailbush). This shrub was planted with the intent of enhancing wildlife and to provide competition for any *Tamarix* which might redevelop. *A. lentiformis* germinates in the winter when *Tamarix* is dormant. Treatment in this manner for two consecutive winters resulted in an additional 9 percent reduction in the number of *Tamarix* per ha (see Table 1 below).

TABLE 1: Number of salt cedar trees before clearing and percent reduction in salt cedar at various times after clearing and root-ripping on an experimental plot along the lower Colorado River (from Anderson and Ohmart 1982).

	# *T. chinensis* trees/hectare	Percent reduction
Before clearing		
March 1978	345	0.0
After clearing		
July 1970	0	100.0
October 1979	59	82.9
October 1980	45	87.0
December 1981	29	91.6

In the southwest deserts, root ripping and augering (tillage) are essential in site preparation for revegetation following tamarisk removal (Anderson and Ohmart 1982). A drip irrigation system was also found to be directly correlated with the successful re-establishment of native riparian species. The cost of this project came to a total of $189,634 or $99 per tree, rendering the economics of this method somewhat prohibitive.

This Element Stewardship Abstract would not be complete as a literature and research review without including information on chemical means of *Tamarix* control. However, due to their potentially far-reaching harmful effects on biological systems, chemical procedures should be used only as a last resort, and only after other appropriate methods have been attempted with negative results.

Howard et al. (1983) made the following conclusions from a research project designed to evaluate the effects of fire and 2,4-D as control methods:

"1. Fire in late July effectively combatted salt cedar the initial year following the burn. Burning in September and October did not control saltcedar.
2. Spraying one month after the July burn increased mortality from 64% to 99%.
3. Spraying after the September or October fire was ineffective."

"Triclopyr ester ([(3,5,6-trichloro-2-pyridinyl)oxyl] acetic acid) shows promise as a basal and stump application. "Triclopyr amine was ineffective in controlling salt cedar for all three application techniques, especially the basal bark application. This probably indicates poor penetration and/or translocation of this formulation of triclopyr.

"The basal bark application requires the most spray solution (95 ul/stump) when compared to the cut stump and modified cut stump applications (38 and 86 ul/stump, respectively). The most

> expensive application, however, is the cut stump due to the high concentration of triclopyr included in the spray solution."

Another combination method of control is mowing and spraying. In 1963 and 1964 a study was conducted near Bernardo, New Mexico, comparing single and combination mowing and spraying with the propylene glycol butyl ether (PGBE) ester of 2-(2,4,5 tricholorophenoxy) propionic acid (Silvex), repeated spray applications of Silvex and single applications of mixtures of Silvex and 4-amino-3,5,6 trichloropicolinic acid (picloram) (Hughes 1966).

> "None of the mow spray combinations initiated in 1963 reduced the stand of salt cedar more than 8%, and there were no significant differences between treatments. A follow-up spray treatment of 4 pounds per acre of Silvex in 1964 increased the plant kill up to 60%. Spraying undisturbed salt cedar in June 1964 and respraying in August with 2 pounds per acre of Silvex reduced the salt cedar approximately 40% as did a single application of a mixture of 2 pounds per acre of Silvex and 2 pounds per acre of picloram in June" (Hughes 1966).

Bill Neill, a tamarisk expert in California, explained that the most effective means of tamarisk control is to cut the individuals at ground level with chain saws, hatchets or hand saws and spray the stump immediately with Tordon.

(Silvex has been banned by the EPA because it carries the caustic element 2,4,5-T, also known as Agent Orange. Tordon is banned on federal land due to a lawsuit in Oregon over aerial spraying. The active ingredient in Tordon is 2,4-D.)

Experimentation on the effectiveness of chemical control of salt cedar is extensive. In Arizona, basal and stump treatments with isopropyl ester of 2,4-D at 0.25, 0.5 and 1.0 percent concentration in diesel oil were monitored.

> "Stump treatments at the two higher concentrations have given high percentages of kill, with no difference for the year of age of tree. Basal spray treatments were somewhat less effective.
>
> "In Wyoming, dormant basal spray applications of a mixture of esters of 2,4-D and 2,4,5-T (50:50) to salt cedar trees in November or April reduced the stand 79% and 93% for a 2% and 8% concentration, respectively.
>
> "Work in New Mexico by Whitworth indicated that the propylene glycol butyl ether (PGBE) ester of 2,4-D was effective as a basal spray at 20 ml of herbicide per tree in 0.5 pint of diesel oil per tree. Subsequently higher kills were obtained from treatments with the butoxyethanol (BE) ester of 2-(2,4,5-trichlorophenoxy)
> propionic acid Silvex as compared to the same esters of 2,4-D and 2,4,5-T" (Hughes 1965).

From 1961-1964 Hughes' studies in New Mexico showed basal and stump applications of ester and oil soluble amine formulations of 2-(2,4,5-trichlorophenoxy) propionic acid (Silvex) to be effective means for controlling tamarisk.

> "Trees with trunks 2 inches or larger in diameter were harder to kill than smaller trees and retreatment was often needed. Spraying the lower 2 feet was no more effective than spraying the lower foot. Cutting the larger trees and spraying the stump increased effectiveness" (Hughes 1965).

In 1979, Hollingsworth et al. experimented with a modified root plow that would place herbicides into the subsurface of the soil while severing roots. It was found that

> "one operation, preferably in the spring, which severed the tap root 35-60 cm below the soil surface and simultaneously applied any of several herbicides at the same depth increased salt cedar kill by more than 100% over that of root cutting alone. Residual herbicides, including uracils, substituted ureas, 2,3,6-TBA, picloram, dicamber, and karbutilate, applied with the root plow consistently controlled salt cedar with a single treatment. Phenoxy herbicides showed initial activity against salt cedar but did not persist long enough to satisfactorily kill late sprouting, previously quiescent buds."

Quimby et al. (1977) confirmed the effectiveness of root zone applications of herbicides in a greenhouse evaluation. They found that either soil layering or soil injection of herbicides resulted in a higher mortality rate than stem or foliar applications.

Eradication efforts of *T. ramosissima* at Death Valley temporarily lacks funding but will begin again in October of 1985. This management program is funded for three years at $9700/year. The plan is to cut the tamarisk at ground level with loppers, chainsaws, and brushhooks and treat the stumps with Tordon. This method will be employed with one person sawing and another applying the herbicide to insure safety. They will return to treated sites periodically to cut back resprouts and dig up saplings (Mitchum 1985).

Mark Jorgensen, State Park Naturalist, has been administrating an active management program for controlling *Tamarix* at Anza Borrego State Park. In June 1985, hired seasonal help will cut *T. ramosissima* stands down with loppers, chainsaws, and brushhooks. Immediately following cutting, triclopyr will be applied in a 44.4 percent solution. Triclopyr 44.4 percent is sold by Dow Chemical under the trade name Garlon 3A. It is a systemic herbicide and breaks down in three days. These procedures would ideally be repeated three times during the summer, but lack of funding will prohibit this follow-up work in 1985.

A variety of management methods for *T. ramosissima* have been researched. Among mechanical methods, mowing can be successful, especially if it is followed by the application of a systemic herbicide to the freshly exposed cambium. The use of a root plow also appears to be an effective, although costly, method. Fire as a form of control is recommended in conjunction with herbicide application.

2,4-D (Tordon) and 2,4,5-T (Silvex) have been investigated as chemical control agents and have been proven successful as a treatment applied to freshly cut stumps. However, the use of Silvex or 2,4,5-T (the active ingredient in Silvex) is completely banned by the EPA, and Tordon (active ingredient 2,4-D) is prohibited on federal lands. Apparently, health and safety are jeopardized by skin contact and/or inhalation of these chemicals.

There is some progress in the field of biocontrol for *Tamarix* population suppression by a host specific leafhopper, *Opsius stactagallus*. More research is necessary to determine the feasibility of large scale release of the agent.

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