Introduction, Spread and Areal Extent of Saltcedar (*Tamarix*) in the Western States

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By T. W. ROBINSON

STUDIES OF EVAPOTRANSPIRATION

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CONTENTS

ILLUSTRATIONS

TABLES

STUDIES OF EVAPOTRANSPIRATION

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By T. W. Robinson

ABSTRACT

Saltcedar, the name generally applied to two exotic deciduous species of the genus *Tamarix*, was introduced into this country more than 100 years ago and has, in the last 30 years, become very much of a nuisance plant in the arid and semiarid regions of the Western States. The species are highly water-consuming, salt-tolerant, naturalizing shrubs that have escaped from cultivation and spread rapidly from one stream valley to another.

Saltcedar occurs in 15 of the 17 Western States. Areas infested range from less than 1,000 acres each in Idaho, Montana, Nebraska, and South Dakota, to about 450,000 acres in Texas. Its dense growth along stream channels presents a barrier to flood flows, and thereby increases flood hazards and sediment deposition. The time of awareness of the plant by residents of the region was generally in the 1920's.

The total area of saltcedar growth has increased from an estimated 10,000 acres in 1920 to more than 900,000 acres in 1961. It is possible that by 1970 saltcedar will be growing on 1⅓ million acres. Not only is the growth increasing in areal extent but also in density of growth. The consumptive waste of ground water by the plant is estimated as 40 to 50 thousand acre-feet in 1920, 3.5 million acre-feet in 1961, and possibly 5.0 million acre-feet by 1970.

INTRODUCTION

Since about 1930 saltcedar has become a nuisance plant in the arid and semiarid regions of Western States. In these regions saltcedar is the common name by which the deciduous species *T. pendantra* Pallas and *T. gallica* Linnaeus of the genus *Tamarix* are known. Saltcedar is a highly water-consuming naturalizing shrub that has escaped from cultivation and spread rapidly from one stream valley to another. An aggressive plant, it has not only invaded but has entirely replaced the native vegetation in many areas. The dense junglelike growth shown in figure 1 is typical of its occurrence in a well-established stand. Owing to the rapid spread of the plant, its high water consumption, and the potential flood hazard engendered by it, saltcedar is of concern to the residents of these regions. This concern becomes greater each year as the demand for water increases, the need for reducing flood hazards mounts, and, at the same time, the areal extent and growth density of the plants are increasing.

The genus *Tamarix*, introduced into the Western States from the Mediterranean area, is one of the four genera of the *Tamaricaceae* family native to Africa, Asia, and Europe. Although many species of the genus have been brought into this country, only two have escaped from cultivation to become important in the saltcedar problem.

As a means of evaluating the magnitude of the problem posed by saltcedar, the Phreatophyte Subcommittee of the Pacific Southwest Inter-Agency Committee proposed an inventory of the areas of saltcedar growth. In 1958, the author began to assemble information on the location of areas of saltcedar growth. Although saltcedar was known to have spread widely since about 1920 and to be growing on thousands of acres in the Western States, this report represents the first attempt to map its distribution and areal extent. A brief history also was prepared dealing with the time of introduction and subsequent spread of the plants.

In addition to field mapping, information was collected from all available sources. These include published and unpublished reports, information from Federal and State agencies, and reports by county agents and consulting engineers and from interested individuals. The offices of the State Engineers of Utah and New Mexico and the Colorado Water Conservation Board provided a large amount of data on phreatophyte growth in these States based on partial inventories made under their direction. In Texas most of the information was supplied by the Soil Conservation Service and was based on a general reconnaissance of saltcedar infestation. Vegetative surveys by the Bureau of Reclamation provided information concerning the Gila River, Ariz., and the Colorado River from Davis Dam to the international boundary. Field offices of the Water Resources Division, Geological Survey, located in the Western States, were very helpful in supplying data about their respective States.

FIGURE 1.—Dense saltcedar growth along the Gila River, 40 miles east of Phoenix, Ariz., in the vicinity of Powers Butte, 1958.

The species growing in this country may be divided into the evergreen and deciduous types. The evergreen type generally is represented by the athel tree *T. aphylla* Linnaeus. It has been planted extensively as an ornamental, a shade tree, and windbreak largely in the desert areas of the Southwest, but has rarely become naturalized. It is not a problem plant. Likewise, the deciduous *T. tetrandra* has been widely used as an ornamental shrub, but has nowhere become an aggressive plant.

Originally thought to be confined to the warm and arid Southwest, saltcedar has spread northward since about 1950 into the Great Basin, the Rocky Mountains, and some of the Plains States.

The two species of the deciduous type that have escaped cultivation are *T. pentandra* and *T. gallica*. *T. pentandra* grows profusely along river bottoms throughout the West, but *T. gallica* appears confined to salty soils near the Texas Gulf Coast.

ENTRANCE INTO THE UNITED STATES

Introduction of the species, which are native to the Old World from western Europe to the Himalaya Mountains, into the United States is not of firm record (Bowser, 1958). In discussing its introduction, Bowser notes (p. 13–14) that tamarisk could have been established in Mexico at an early date by Spanish explorers and conquistadors. Inasmuch as these invaders made expeditions into South-Central United States between 1540 and 1750, it could have been established here also.

If tamarisk had been established by the early Spanish explorers, Mexico would have been the center of distribution and it would have been found in abundance there. The sparsity of collection of tamarisk specimens from Mexico, however, does not support this assumption. In the National Herbarium of the Smithsonian Institute, Washington, D.C., there is only one collection of tamarisk from Mexico, and this from the border town of Nogales, while there are many from other Latin American countries such as Argentina, Venezuela, Chile, and Ecuador. Extensive collections of other plant species from Mexico, some very early, some modern, are filed in the Smithsonian Institute.

What appears to be support for the assumption that the tamarisk was introduced into this country by the early Spanish explorers may be found in the journal of Father Escalante (Auerbach, 1943). Father Escalante was one of the early Spanish padres who explored the United States as far north as Utah. According to the translation of his journal, Father Escalante reported tamarisk at Fort Pierce Wash near the Utah-Arizona border in 1776. Dr. E. L. Little, Jr., Forest Service dendrologist, points out (oral commun., 1963) that there is some question concerning the translation of the word "taray" which Father Escalante used to describe the plant he observed.

While "Taray" is defined as tamarisk in the more modern Spanish-English dictionaries published in the United States, it is not so defined in some dictionaries and botanical works published in Mexico. Ramírez (1902) gives two different species under the heading "Taray." In Vera Cruz the legume *Caesalpinia bonducella* Roxb. is called Taray, while in "varios lugares" (other places) *Eysenhardtia amorphoides* H.B.K., also a legume, is known as Taray. Standley (1920), in describing a species of willow *Salix taxifolia* H.B.K., notes that in the State of Durango it is called "Taray" or "Taray de rio" while in Chihuahua it is called "Tarais." *Salix taxifolia* occurs along streams and washes throughout Mexico, south to Guatemala, and in the United States from western Texas to Arizona. Inasmuch as this species of willow was common in much of the country traversed by Father Escalante, it seems probable that when referring to the plant in his journal he would use the local name "taray," meaning willow and not tamarisk.

According to Christensen (1962, p. 53), "*tamarix* was not recorded by the early explorers who traveled on the Green and Colorado Rivers in Utah" in the period from about 1869 to 1875, or by earlier explorers who also crossed these rivers.

The first introduction of tamarisk into the United States appears to have been by nurserymen in the early 1800's. In 1823 according to Horton (1964, p. 2) "tamarisk was offered for sale in New York City by the Old American Nursery operated by Lawrence & Mills," and in 1828 by Bartram's in Philadelphia. During the 1830's it was listed by several nurseries along the eastern seaboard.

Later the U.S. Department of Agriculture began growing tamarisk and in 1868 their annual report (p. 123) listed six species that had been established in the Department's Arboretum Grounds in Washington, D.C. (Horton, 1964, p. 2). Between 1871 and 1890 a large number of collections of tamarisk were made from the plants growing in the arboretum. Apparently many plants were growing there before collections were made outside of Washington. The source of the stock is not known; the plants may have been imported or they may have been obtained from local nurseries.

The earliest authentic record of *Tamarix* in the Western States of which the author is aware is found in the catalogs of early-day nurseries. Bowser (1958, p. 14) notes that California firms listed *Tamarix*, species unknown, as early as 1856. Dr. H. M. Butterfield, agriculturist emeritus, Agricultural Extension

Service, University of California, reports (written commun., 1963) that *Tamarix* was available in California from nursery stock of the Highland Nurseries of New York as early as 1854. Dr. Butterfield, who has an extensive collection of early-day nursery catalogs, has the following to say concerning the early listing of *Tamarix:*

> Some eastern nurseries were listing *Tamarix* before we had records in California. Most of our early introductions into California came from nurseries in New York and other States. The old Downing Nursery at Newburg, N.Y., was taken over by the Saul family and in 1854 the Highland Nurseries operated by the Saul family listed *Tamarix gallica, T. germanica* and one called *T. libanotis* (p. 47 of their 1854–55 nursery catalog). James Saul was sent to California to represent the nursery and was in San Francisco in 1854 and later. * * *

A. P. Smith, of the Pomological Garden and Nursery in Sacramento, in his 1856 nursery catalog (p. 14) listed *T. africana* and *T. gallica.*

The Suscol Nursery, operated by the Thompson Brothers at Suscol, Calif., as early as 1856 on, listed two kinds of *Tamarix* in 1861—African and German (p. 29 of 1861–2 catalog). (Suscol, now abandoned, was located about 6 miles south of Napa, Calif., and 1 mile west of State Highway 29 between Vallejo and Napa.)

James Hutchison, of the Bay Nurseries in Alameda, in his catalog for 1874–75, on page 34 listed *Tamarix gallica,* while R. D. Fox, of the Santa Clara Valley Nurseries north of San Jose, in the 1884 catalog, page 23 listed *Tamarix africana* and *T. chinensis.*

In discussing the species listed in these catalogs Dr. Butterfield points out the uncertainty of the proper names or synonyms given in the early listing. He feels that an opinion on synonyms should be based on what was probably grown rather than on present-day name usage. Because of the similarity in appearance, he thinks *T. africana* may have been confused with either *T. parviflora* or *T. gallica* and that *T. parviflora* has often been confused with *T. africana* and *T. gallica.*

There has indeed been much confusion of nomenclature for the deciduous species. McClintock (1951) has shown that the species common in Arizona and New Mexico is *T. pentandra* Pallas rather than *T. gallica* Linnaeus as formerly thought (Kearney and Peebles, 1942), and this interpretation was accepted in the later work of Kearney and Peebles (1951).

It is apparent that tamarisk stock was available for distribution in the Western States as early as 1854 from nurseries in California, and from the Department of Agriculture Arboretum in Washington, D.C., in the 1870's. Although tamarisk stock was available from the eastern seaboard nurseries as early as 1823, it seems most likely that the role of these nurseries would be as suppliers to the western nurseries, rather than as direct distributors.

Regardless of the possible avenues by which tamarisk may have come to the Western States, the best evidence points to its escape from cultivation in the 1870's. Support for this theory is found in the dates of the early collections. The earliest collection—*T. gallica*—of which the author is aware was in 1877 at Galveston, Texas. *T. tetrandra* appeared as a cultivated plant in 1880 at St. George, Utah. *T. pentandra,* however, may not have arrived until 1890.

Information pertaining to the time and place of specimen collection is valuable in dating the introduction of tamarisk in an area. It is also valuable in following the spread of the plant from one area to another. For this purpose a list of tamarisk specimens collected in the Western States has been prepared, showing the dates of collection in chronological order, the collector, and the locality where collected. The present location of the specimen is given when known. (See table 1.)

TIME OF GENERAL AWARENESS OF SALTCEDAR IN THE SOUTHWEST

After the introduction of saltcedar into the Southwest, a considerable period elapsed before residents generally became aware of its presence. During this period the plants spread and formed stands of such size as to become noticeable. It was in the 1920's when those who lived close to nature—stockmen, farmers, sportsmen—began to realize that a new plant had made its appearance and gained a foothold in the stream valleys of the Southwest. That it was a consumer of ground water was not recognized at that time, nor for nearly 20 years thereafter. No mention is made of saltcedar by Dr. O. E. Meinzer in his classic paper "Plants as Indicators of Ground Water," published in 1927 as U.S. Geological Survey Water-Supply Paper 577, nor in an unpublished paper given before the Geological Society of Washington in 1922 by Professor G. E. P. Smith, of the University of Arizona, who during the period 1915–25 observed and studied plants that were users of ground water.

The earliest eyewitness report of saltcedar on the Gila River in Arizona comes from Ernest Douglas (written commun., 1962) of the Arizona Farmer-Ranchman, Phoenix. He recalls that it was about 1898 when his father, a cowman, brought home a switch of a new plant he had found growing in a sandbar along the Gila River. The switch was stuck in the moist soil at the edge of a ditch that ran by the house; it grew and in a season or two became a considerable clump of saltcedar. The ranchhouse was located about 6 miles north of Gila Bend, Ariz., and about 1 mile from the Gila

TABLE 1.—Tamarix *specimens collected in the Western States (1877 to 1920)*

[Specimens in the National Herbarium of the Smithsonian Institution at Washington, D.C. (a) were examined and identified by Jerome S. Horton, U.S. Forest Service. Specimens in the Arnold Herbarium of Harvard University (b) were examined and identified by Elizabeth McClintock, California Academy of Sciences. Specimens in the Stanford University Herbarium (c). Specimens in the University of Arizona Herbarium (d) and Pamona College Herbarium (e) were examined and identified by Miss McClintock, John E. Flood, Botany Department, Arizona State University, and Jerome S. Horton. Specimens in the California Academy of Sciences (f) were examined and identified by Miss McClintock. Specimens without sufficient floral parts for positive identification are indicated with a question mark]

Date	Species	Collector	Location and Remarks
Apr. 1877	*T. gallica* (a)	J. F. Joor	Galveston Island, Tex. (naturalized).
Sept. 16, 1877	do	L. F. Ward	Galveston, Tex.
Apr. 14, 1880	*T. tetrandra* (e)	Marcus E. Jones	St. George, Utah (cultivated).
1888	T. tetrandra (a)	Mrs. M. L. Nash	Texas.
May 15, 1892	do	J. W. Toumey	Catalina Mts., Ariz.
June 10, 1893	T. pentandra (d)	J. J. Thornber	Brookings, S. Dak. (cultivated).
Mar. 30, 1894	T. tetrandra (a)	M. E. Jones	Harrisburg, Utah.
Apr. 5, 1894	do	do	Beaver Dam, Ariz.
Apr. 9–12, 1894	*T. gallica* (a, d)	A. A. Heller	Corpus Christi, Tex.
May 5, 1894	*T. tetrandra* (e)	M. E. Jones	Silver Reef, Utah.
May 1894	*T. gallica* (a, d)	M. Hapeman	Galveston, Tex.
Apr. 17, 1896	*T. gallica* (a, b)	A. A. and E. Gertrude Heller	Cliff House, San Francisco, Calif.
Apr. 1898	*T. tetrandra* (a)	Mrs. J. M. Milligan	Bonham, Tex.
Apr. 11, 1899	do	W. F. Wight	Stanford Arboretum, Calif.
Aug. 18, 1901	*T. pentandra*? (a)	T. H. Kearney	Tempe, Ariz. (common in river bottoms).
Sept. 22, 1901	*T. gallica* (a)	S. M. Tracy	Galveston Island, Tex.
Apr. 15, 1902	*T. pentandra* (a)	Tracy & Earle	Barstow, Tex.
Apr. 14, 1905	*T. tetrandra* (d)	J. J. Thornber	Thatcher, Ariz.
Oct. 11, 1907	do	—— Blumer	Wilgus Ranch, Chiricahua Mts., Ariz.
July 6, 1909	*T. pentandra* (a)	I. Tidestrom	Kanab, Utah (cultivated).
July 12, 1909	*T. pentandra*? (a)	E. W. Nelson	Winslow, Ariz. (cultivated).
May 23, 1910	*T. pentandra* (d)	J. J. Thornber	Univ. Ariz. campus, Tucson, Ariz.
May 21, 1911	*T. pentandra* (a)	G. L. Fisher	Nara Visa, N. Mex. (cultivated).
1911	*T. tetrandra* (a)	Elmer Stearns	El Paso, Tex. (cultivated).
Sept. 8, 1912	*T. gallica* (a)	G. L. Fisher	Galveston, Tex.
May 21, 1913	*T. gallica* (d)	J. J. Thornber	Univ. Ariz. campus, Tucson, Ariz.
May 22, 1913	*T. pentandra* (d)	do	Do.
1913	do	do	Univ. Ariz. campus, Tucson, Ariz. (5 sheets).
1913	*T. gallica* (d)	do	Univ. Ariz. campus, Tucson, Ariz. (2 sheets).
Sept. 12, 1913	*T. pentandra* (d)	S. B. Parish	Salton Sea, Calif.
Oct. 13, 1913	*T. pentandra* (a)	J. N. Rose and W. R. Fitch	Pecos City, Tex.
Mar. 19, 1914	*T. tetrandra* (f)	John I. Carlson	Agua Caliente, Ariz.
Apr. 1915	*T. africana* (d)	J. J. Thornber	Univ. Ariz., Tucson, Ariz.
Apr. 20, 1915	*T. tetrandra* (f)	B. W. Evermann	Havilah, Kern County, Calif.
May 1916	*T. pentandra* (d)	J. J. Thornber	Univ. Ariz., Tucson, Ariz.
Apr. 11, 1917	*T. tetrandra* (c, e)	I. M. Johnston	Wilmington, Calif.
May 30, 1917	*T. tetrandra*? (c, e)	do	Ontario, Calif.
June 1917	*T. tetrandra* (f)	Marion L. Campbell	Hope, N. Mex.
Apr. 5, 1920	*T. pentandra* (c, e)	Munz & Harwood	Salton Sea, Calif.

River. By 1902, when his family left the ranch, an occasional saltcedar could be seen along the Gila River, but the species was not well established.

The time of awareness of saltcedar appears to have varied from place to place. Although records (Eakin and Brown, 1939, p. 11–18) indicate the presence of a few seedlings growing on the delta of Lake McMillan on the Pecos River, N. Mex., in 1912, it was not until the late 1920's that the growth commanded attention. Mr. L. E. Foster, Superintendent of the Carlsbad Project, describes the conditions in the delta area of Lake McMillan under date of July 20, 1928, as follows (McDonald and Borland, written commun., 1955, p. 51–52): "At the present time, the entire upper end of the reservoir is covered with a dense growth of tamarisk except for a few narrow channels."

In the Rio Grande valley, the time of general awareness was about 1930. The earliest report of saltcedar growth was in 1910 near Mesilla Park, N. Mex. (Thompson, 1958, p. 2). Reports by residents of the valley indicate that the plant was uncommon throughout the 1920's and in the early 1930's.

Dr. Luna B. Leopold (written commun., 1960) of the U.S. Geological Survey, recalls that his father planted a tamarisk in front of their house in Albuquerque, N. Mex., about 1920, and that the plant was rather uncommon. In 1931 his father pointed out a seedling on a road crossing of the Rio Galisteo between Albuquerque and Santa Fe, and remarked that "given time, tamarisk will cover such channels extensively, as it propagates rapidly."

Mr. C. C. McDonald (written commun., 1962) of the U.S. Geological Survey, remembers that in 1923, when his family moved from a farm on the left bank of the Rio Grande west of Old Albuquerque, there was some saltcedar growing along an irrigation canal, but none along the river. The recollection of saltcedar stands out because of the difference between limbs and twigs of willow and saltcedar when used as fishing poles and for whistles. Willow was very common, having been planted for bank protection, but saltcedar was available at only one spot.

Mr. C. L. McGuinness (written commun., 1960), also of the U.S. Geological Survey, reports that his father, a lifetime resident of the Rio Grande Valley, recalls that "as late as October 1931 there were no saltcedars in the vicinity of the 'lakes' southwest of Las Nutrias, N. Mex." Mr. McGuinness, senior, a sportsman, visited this area frequently as he was part owner and used certain of these lakes for duck hunting.

Despite plantings for erosion control in 1926 in the tributary streams Rio Salado and Rio Puerco, and

perhaps in other localities, the plants did not become important in the plant life of the Rio Grande Valley for nearly 10 years. There was no mention of saltcedar in a land-classification report by the Middle Rio Grande Conservancy District (McDonald and Borland, 1955, p. 19) in 1926, although other vegetation was shown. In 1936, the vegetation of the Rio Grande Valley was mapped by the Department of Agriculture during the Rio Grande Joint Investigation (National Resources Committee, 1938). Although saltcedar was present in the valley and was mapped on field sheets, no separate classification was established; it was included under the heading "Trees—bosque."

The author, who was in charge of the ground-water studies in the Colorado portion of the joint investigation, has no recollection of any saltcedar in the San Luis Valley or elsewhere in the headwaters of the Rio Grande in 1936.

In the upper Gila River valley in Arizona, saltcedar may have made its presence known a little before 1920. Mr. Thomas Maddock, Sr. (written commun., 1960), of Safford, Ariz., notes that longtime residents of the Safford Valley date the appearance of saltcedar from the floods of 1916. The floods caused channel shifts of as much as three-quarters of a mile and denuded large areas of native vegetation. Shortly afterwards, saltcedar was observed growing in the area that had been flooded and denuded.

Gillespie Dam on the lower Gila River was completed in 1921. Mr. Thomas Maddock, Jr. (written commun., 1962), reports that by 1929 the lake back of the dam had filled with sediment and a very heavy growth of vegetation had taken place over most of the reservoir area. Much of this vegetation was saltcedar. Water losses from the Gila River were so great that in 1929 the Gillespie Land and Irrigation Co. began the construction of a drainage ditch on the west side of the river to move water from the end of the Arlington Canal to the face of the dam. In 1931 this drain was extended to a point near the Hassayampa River. This effort is perhaps the first known in Arizona to salvage water normally lost by saltcedar through evaporation and transpiration.

Saltcedar appears to have been widely used as hedges prior to 1920. Mr. Thomas Maddock, Jr., recalls a hedge in front of the family home in Williams, Ariz., in 1913. Mr. C. L. McGuinness remembers a well-grown hedge several years old around their house in Albuquerque in 1921. The species is not known. W. W. Hastings of the U.S. Geological Survey recalls a hedge-planting of saltcedar in 1919 at the U.S. Agricultural Experiment Station in Sacaton, Ariz.

Mr. Ernest Douglas (written commun., 1962), who left the lower Gila Valley in 1902, returned in 1925 and "for the next four years edited a paper at Mesa, Ariz., but never heard saltcedar mentioned, though it must have been common along the river bottom." In 1929, after becoming editor of the Arizona Farmer-Ranchman, he noted that saltcedar had become a hard-to-fight nuisance along unlined laterals of the Roosevelt Irrigation District in the Buckeye area and that there were jungles of it along the Gila River. Even then, he writes, no one recognized it as a consumer of precious water.

OCCURRENCE, SPREAD, AND DENSITY OF SALTCEDAR GROWTH

Although the information on the occurrence of saltcedar prior to 1920 is meager, it is sufficient to indicate that the plant did not command much attention in the 43-year period between 1877, when the first specimens were collected in Texas, and 1920. This period of the plant's history contrasts sharply with the next 40 years, when saltcedar was recognized first as a new plant and later as a problem plant. During this latter 40-year period it spread rapidly from one watershed to another and up and down the stream valleys of the Southwest, then northward into the Great Basin and the Rocky Mountains. In 1961, as shown by plate 1, saltcedar was widespread in Arizona, New Mexico, Texas, Oklahoma, Kansas, Colorado, and Utah. Small but well-established areas of growth occur in California, Nevada, Oregon, Idaho, Montana, Wyoming, South Dakota, and Nebraska. So far as could be ascertained, the plant does not occur naturally in Washington and North Dakota.

Data on the rate of spread prior to 1920 is limited to the delta area of Lake McMillan on the Pecos River in New Mexico. There are no records or reports of saltcedar in this area prior to 1912. The first report was of a few seedlings in 1912 (Eakin and Brown, 1939, p. 11–12). By 1915 the plants had spread over an area of about 600 acres of delta land (National Resources Planning Board, 1942, p. 57). In the next 10 years the plants continued to spread over the delta area until by 1925 they covered 12,300 acres.

By 1960 the plants covered an estimated 57,000 acres in the 200-mile reach between Alamogordo Dam and the New Mexico-Texas State line. Concurrent with the increase in total area, there was also an increase in the density and in the cover density (the proportion of an area covered or shaded by the vegetation foliage; usually expressed as a percent). Thus areas of light and medium cover became areas of medium and dense cover. The increase in the areas is shown graphically in figure 2.

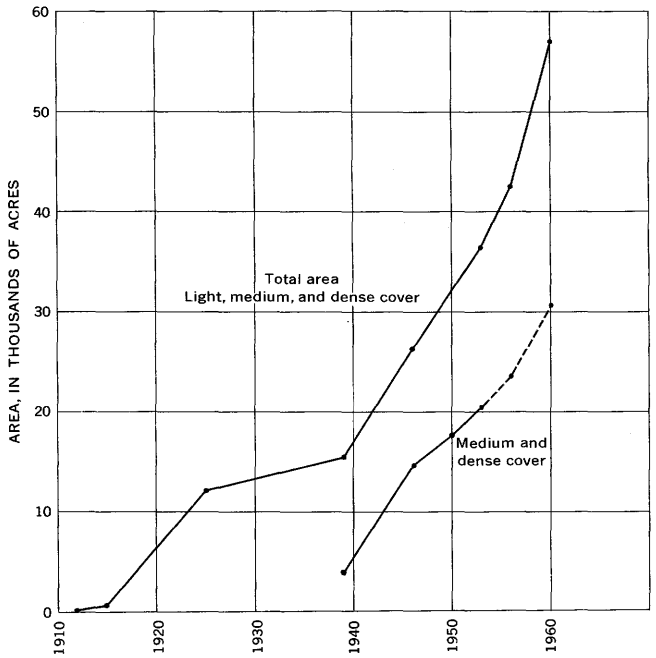

FIGURE 2.—Increase in the area of saltcedar growth and cover density along the Pecos River in New Mexico between Alamogordo Dam and the New Mexico-Texas State line.

The occurrence and spread of saltcedar in the Rio Grande basin of New Mexico has a similar history. Although it was first reported in the area south of Mesilla Park in 1910 (Thompson, 1958, p. 1502–2), most of the available information covers the 80-mile reach from Bernardo Bridge to San Marcial. In 1918 this reach was included in a topographic and land use survey by the New Mexico State Engineer that covered 150 miles of the valley from Cochiti to San Marcial. No mention is made of saltcedar in the description of the land classification. In describing the "timber" classification the survey notes: "The timbered areas are those overgrown with timber or brush, usually cottonwoods, willows or thorn bushes."

A cross-valley profile near San Marcial in 1924 noted the vegetation, but no mention was made of saltcedar. The next survey in point of time was a land-classification survey in 1926 by the Middle Rio Grande Conservancy District. Here again no saltcedar was reported.

According to an unpublished report for the U.S. Bureau of Reclamation (H. R. McDonald and W. M. Borland, written commun. 1955, p. 32–41) dealing with saltcedar infestation in the middle Rio Grande Valley, there was no significant growth of saltcedar prior to about 1926. About that time, erosion was a problem in some tributary streams, and plantings of saltcedar seedlings were made in 1926 and 1927 at several places in the Rio Salado and Rio Puerco basins and perhaps in other localities as an erosion and silt control measure. The plants spread rapidly after the flood of 1929 and by 1936 had covered about 5,500 acres (sum of the planimetered areas of parcels of land shown as saltcedar on the maps of vegetative cover. National Resources Committee, 1938), in the Bernardo Bridge-San Marcial reach. Vegetative surveys of the reach 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. Thus it is possible to make comparisons of area of growth, density of growth, and volume of foliage.

This area of saltcedar in 1947 was 26,300 acres and in 1955 was 24,800 acres. The decrease from 1947 to 1955 was due to clearing about 10,000 acres of saltcedar for cultivation. These data indicate an increase of about 8,500 acres of saltcedar growth in the uncleared lands.

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 in the volume of foliage was over 75 percent.

According to Christensen (1962), there are no records of *Tamarix* at Utah Lake, at Great Salt Lake, or on the Colorado and Green Rivers in Utah prior to 1925. He reports that "the period from approximately 1925 to 1960 was one of rapid spread and increase in importance of tamarix. The greatest degree of invasion occurred during the twenty-year period from about 1935 to 1955."

In the Arkansas River valley of Colorado, Bittinger and Stringham (1963) found a similar history of increase in the area and cover density of saltcedar growth. Comparisons of the areas of saltcedar growth by aerial photographs taken in 1936, 1947, and 1957 show quite clearly the progressive invasion of saltcedar. As an example, in the study reach of the valley the area of phreatophytes, largely saltcedar, increased 520 acres in the 11-year period from 1936 to 1947, or at an average rate of 47 acres a year. In the 10-year period from 1947 to 1957 the average rate of increase was 57 acres a year. Not only was there an increase in area during these periods but also an increase in the cover density. In the aerial photographs in figure 3, taken in 1936 and 1957, the increase in area and cover density in the 21-year period is easily seen.

Concerning the spread of saltcedar in Kansas, Mr. P. H. Berg (written commun., 1962), Project Manager, Bureau of Reclamation, states that:

* * * Because of experience in other reclamation areas in the southwest with saltcedar, we have kept a close watch in our

reservoir areas and on irrigation systems for any new infestations of saltcedar that may occur. Within a short period after we complete a dam or reservoir, scattered plants of saltcedar are observed. Each year we observe a few more plants with more mature ones furnishing seed for new infestations.

It is logical to assume that were data available for other stream valleys they would show a history of saltcedar growth and spread similar to that in the Gila, Pecos, Rio Grande, and Arkansas River valleys.

AREAL EXTENT

The areas of saltcedar growth in the Western States as of 1961 are shown on plate 1. Owing to the small scale of the map, it is not possible to delimit the actual boundaries. Rather the map is diagrammatic, showing the reaches of the streams and included reservoirs, lakes, and playas where saltcedar is known to occur. In compiling the map, the author attempted to visit and observe areas where saltcedar was unreported, but was suspected to be present. However, it was not possible to examine all of them, so there may be some areas of growth that are not shown. Although these are believed to be few, isolated, and small, they do form a seed source from which the growth may spread.

Some observations of saltcedar growth were made at the road crossings of streams, and were limited to the growth seen from the road. The sites of these observations are shown by means of a distinctive symbol on the map. Owing to the aggressive nature of the plant, growth may be suspected for a considerable distance up and down stream from the crossing. Lacking confirmation of this, however, the presence of growth at the crossing only is indicated on the map.

The largest area of saltcedar, 275,000 acres, occurs in the Pecos River basin of New Mexico and Texas. It was estimated by the Geological Survey ground-water office in Albuquerque that in 1960 some 57,000 acres in the New Mexico portion of the basin was infested. In the Texas portion, on the basis of a general reconnaissance of the basin by the Soil Conservation Service in 1959, there was about 218,000 acres (C. A. Rechenthin, written commun., 1963). In this portion of the basin according to Mr. Rechenthin, "saltcedar covers most of the bottom lands from the New Mexico line to a point below Sheffield, * * * is found on many tributary streams such as Salt Draw, Toyah Creek, Tornillo Draw and others * * * and is found extensively on 'gyp' soils in the Pecos, Imperial, Fort Stockton, and Girvin areas."

The cover density, according to J. S. Horton (written commun., 1962) is quite variable, ranging from 5 to 100 percent. The area of dense growth, occurring in the flood plain adjacent to the Pecos River channel, was estimated at about 15 percent of the total area of the Texas portion of the Pecos basin. In the remainder of the area the cover density had decreased in the fall of 1962 to 5 to 15 percent. Horton reports that in these areas the shrubs are suffering and some have died as the result of either increased salinity in the ground water or a declining ground-water level.

A similar condition prevailed shortly after the close of World War II along the Gila River in Arizona for a few miles below Gillespie Dam. Here increased pumpage for irrigation lowered the water table to such an extent that between about 1950 and 1955 much of the saltcedar died. This area of growth is not included on plate 1.

No attempt was made to indicate the cover density of the growth on the map. The cover density, however, as indicated above, is known to range from scattered growth of a few percent to 100 percent. Where growth along a stream was not continuous but occurred at intervals, it is shown by a broken pattern.

On the basis of the assembled information, table 2 was prepared to show the approximate acreage of saltcedar growth by States. The acreage for each State is not presumed to be exact but is considered sufficiently accurate to indicate the magnitude of the growth area in each State. Neither is the total of 900 thousand acres presumed to be exact, but it is believed to be a realistic indication of the area of saltcedar growth in the Western States at the end of the 1961 growing season.

TABLE 2.—*Gross areas of saltcedar growth in the Western States as of 1961*

State	Area (in thousands of acres)	State	Area (in thousands of acres)
Arizona	[a] 118	North Dakota	0
California	[a] 16	Oklahoma	60
Colorado	50	Oregon	1
Idaho	[b]	South Dakota	[b]
Kansas	25	Texas	[c] 450
Montana	[b]	Utah	38
Nebraska	[b]	Washington	0
Nevada	[a] 12	Wyoming	1
New Mexico	155		
		Total (rounded)	900

[a] A vegetation survey by the Bureau of Reclamation in 1961 found there was 53,200 acres of saltcedar in the flood plain of the Colorado River from Davis Dam to the international boundary, of which 38,000 acres was in Arizona, 12,700 acres in California, and 2,400 acres in Nevada. These figures included in the State totals.

[b] Less than 1,000 acres.

[c] A brush survey by the Soil Conservation Service in 1963–64 (Smith, H. N. and Rechenthin, C. A., 1964) found that as of June 1964 there was a total of 523,900 acres of saltcedar, of which 273,000 acres were dense stands (more than 20 percent canopy), and 250,900 acres were light to moderate stands (less than 20 percent canopy).

WATER CONSUMPTION

The term "saltcedar" includes the deciduous species described earlier. Saltcedars are phreatophytes; that is, they depend upon ground water for their water supply. Their occurrence under natural conditions is confined to areas where their roots can reach the water

FIGURE 3.—Aerial photographs, taken in 1936 (upper) and in 1957 (lower), of the Arkansas River valley at the Otero-Bent County line, Colorado. The areas of scattered cottonwood growth of 1936 have been filled in and were dominated by a dense growth of tamarisk in 1957.

table, such as on the flood plains of stream valleys, on deltas, or along the shoreline of lakes and reservoirs. 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. Saltcedars have a wide range of tolerance to saline or alkali soil and water. They have been found growing in Death Valley, Calif., where the ground water contains as much as 5 percent (50,000 parts per million) of dissolved solids. However, it cannot be said they thrive where the concentration of the water approaches the 5 percent limit. Generally they grow best where the ground water is little to moderately mineralized.

Under optimum conditions the annual rate of consumption of ground water by saltcedars is probably the highest of all the phreatophytes. The plants have a low economic value, and hence the water used by them is largely wasted. The term "consumptive waste" (that part of consumptive use that is without substantial benefit to man) aptly describes the disposition of this water.

The annual rate of use of ground water by saltcedar depends upon several factors such as cover density, size of the plants, depth to the water table, and climatic conditions. Use is greatest where the height and density are at a maximum, the water table lies at shallow depth, and the climate is hot and dry.

Studies of the annual rate of use of water by saltcedar show that under favorable conditions it is more than 9 acre-feet per acre. Experiments with plants grown in tanks in the Safford Valley of the Gila River, Ariz., have shown that at 100-percent volume-density the annual evapotranspiration discharge, not including precipitation, ranged from 9.2 acre-feet per acre when the depth to the water level was 4.0 feet to about 7 acre-feet per acre when the water level was at a depth of 8 feet (Gatewood and others, 1950, p. 137). The average annual use of ground water by saltcedar in the Safford Valley, under natural conditions, was 4 acre-feet per acre. The cover density ranged from scattered growth to 100 percent, and averaged 61 percent. At Carlsbad, N. Mex., the annual use of water by saltcedar grown in tanks was 5.5 acre-feet per acre with a 2-foot water level and 4.7 acre-feet per acre with a 4-foot water level (Blaney and others, 1942, p. 202). The average annual use of ground water by saltcedar in the Pecos River valley, N. Mex., was estimated, on the basis of plants grown in tanks, to be 5.0 acre-feet per acre (National Resources Planning Board, 1942, p. 55).

EFFECT ON STREAM REGIMEN

The regimen of a stream on whose flood plain saltcedar has become established is usually affected in three ways. There is (1) a depletion of streamflow, (2) an increase in the area inundated by floods, and (3) an increase in deposition of sediment in the areas of saltcedar growth.

As noted earlier, consumption of ground water by saltcedar is among the highest of all phreatophytes. As a consequence of its draft on the ground-water reservoir, there is a general lowering of the ground-water level throughout the area of growth. Lowered ground-water levels affect streamflow either by reducing ground-water movement toward a gaining stream or by increasing percolation from a losing stream to the ground-water reservoir. In either case the result is the same—a reduction in streamflow.

In a well-established area of saltcedar along a stream, the plants grow so densely that they choke overflow channels and the flood plain, and so form a partial barrier to flood flows. During periods of flood, this restriction and increased channel roughness cause the water to spread out and inundate areas that normally would not be flooded and thus to endanger lives and damage property.

Floodwater is nearly always laden with sediment. The damming or ponding effect of the dense saltcedar growth so reduces the velocity of the water, and thus its power to carry the full sediment load, that much of the sediment is dropped and deposition is accelerated. Substantial deposition of sediment attributed to saltcedar growth has occurred in the Rio Grande and Pecos Rivers in New Mexico and the Gila River in Arizona. Sediment deposition resulting in part from saltcedar growth is common in the delta areas above reservoirs.

FUTURE CONSIDERATIONS

The history of the invasion of saltcedar in the Western States provides a basis for forecasting its future performance and estimating its areal extent and consumptive waste of ground water.

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. At the same time, increased consumptive waste of ground water, increased flood hazards, and continued sediment deposition may be expected.

The increase in area and density will not be at the same rate everywhere, but will vary from place to place according to the availability of growing space and to environmental conditions, such as climate, depth to ground water, and degree of alkalinity or salinity. In the stream valleys that now support extensive growth, such as those in Arizona and New Mexico

where there is little room for expansion, the areal increase will not be large. The density, however, will continue to increase until optimum growth prevails throughout the area. Although no saltcedar was reported in the States of North Dakota and Washington in 1961, it is reasonable to expect the plant to make its appearance in the near future.

If it is assumed that no control measures will be taken to curb the spread and continued growth of saltcedar, some predictions can be made of the magnitude of the growth area and the consumptive waste of ground water.

The area of saltcedar growth at the time of awareness of its presence in 1920 must have been small. The meager data indicate that the growth area was about 10,000 acres. Most of this growth was on the delta of Lake McMillan on the Pecos River, N. Mex. By 1961 the area had increased to about 900,000 acres, or at an average rate of about 22,500 acres a year. Projection of this rate over the 9-year period to 1970 indicates an increase of about 200,000 acres. The average rate of increase, however, is much less than the maximum rate. The two areas for which information is available on the average and maximum rates of spread, the Pecos River valley in New Mexico and the Arkansas River valley in Colorado, show that the maximum rate occurred in the decade 1950 to 1960. Thus an increase of 200,000 acres to a total of 1,100,000 acres in the 17 Western States by 1970 would be a minimum.

In the Pecos River valley the average rate of increase from 1915 through 1960 was about 1,250 acres a year. The rate during the period 1950 to 1960 was double the long-term average, or about 2,500 acres a year.

The saltcedar growth in the Pecos River valley during the 10-year period 1950 to 1960 increased by 25,000 acres, as shown in figure 2. This is 78 percent of the area covered in 1950. In the Arkansas River valley the increase from 1947 to 1957 was about 81 percent of the 1947 area. In the Rio Grande Valley, the increase in the period 1947 to 1955 would have been about 32 percent of the 1947 area, had there been no clearing. Expressed as average rates per year, they are 7.8, 8.1, and 4.0 percent respectively. Projection of these average yearly rates over the 9-year period from 1961 to 1970 indicates an increase in the total area of saltcedar of 325,000 to 650,000 acres.

On the basis of these estimates of the minimum and the average yearly increase in total area of saltcedar growth by 1970, the increase would range from 200,000 acres to 650,000 acres. The average of these projections indicates a probable increase of 425,000 acres, or a total of about 1⅓ million acres by 1970.

The average annual use of ground water by saltcedar in the Safford Valley, Ariz., was 4 acre-feet per acre, and in the Pecos River valley it was 5 acre-feet. On the basis of an average of 4.0 acre-feet for the entire region, the annual draft on the ground-water reservoir in 1961 was about 3.5 million acre-feet and in 1970 would be about 5 million acre-feet. In 1920 the draft probably did not exceed 50,000 acre-feet.

These predictions, as stated earlier, have been made to indicate the magnitude of the saltcedar problem by 1970 and its effect on water supply, under the assumption that the spread and growth of the species will not be curbed by control measures.

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