Phreatophytes

By T. W. ROBINSON

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ABSTRACT

Phreatophytes are plants that depend for their water supply upon ground water that lies within reach of their roots. Although not confined to the arid regions of the Western United States, their occurrence there is more common, more spectacular, and, because of their effect on water supply, more important than it is in humid and subhumid regions. Most phreatophytes have low economic value, and consequently, the water they use and return to the atmosphere without substantial benefit to man is defined as consumptive waste.

Some phreatophytes are widespread throughout the entire West, and others, such as saltcedar, are confined to the river valleys of the Southwest. In all, they waste tremendous quantities of ground water each year. It is estimated that phreatophytes (excluding beneficial species such as alfalfa) cover about 16 million acres in the 17 Western States and discharge as much as 25 million acre-feet of water into the atmosphere annually. Although little has been done so far to prevent this waste, much of the water undoubtedly can be salvaged by converting consumptive waste to consumptive use. There are two basic methods: reducing of consumptive waste by diverting water from the plants to other uses, and increasing the efficiency of water use by substituting beneficial for nonbeneficial plant species. These methods, to be successful, require an understanding of the factors that affect the occurrence and amount of water used by phreatophytes: climate, depth to, and quality of ground water and soil.

More than seventy plant species have been classified as phreatophytes; this report lists information concerning them according to their scientific names. The available information about the phreatophytic characteristics of most of the species is meager, but for eight, pickleweed, rabbitbrush, saltgrass, alfalfa, cottonwood, willow, greasewood, and saltcedar, there are sufficient data to warrant separate discussions. The annual use of water by phreatophytes ranges from a few tenths of an acre-foot per acre to more than 7 acre-feet per acre.

In the Southwest, saltcedar, an exotic plant that develops a junglelike growth, has invaded and choked the normal overflow channels of streams, so as to produce a flood hazard that must be reckoned with. In addition, the ponding effect of the dense growth results in above-normal sediment deposition in the area of growth, and reduced deposition downstream, as was observed at the McMillan Reservoir on the Pecos River in New Mexico.

In the interest of conserving water to meet an ever-growing demand and to reduce flood hazards in the Southwest, more and more attention must be given to the phreatophyte problem.

INTRODUCTION

Since 1927, when O. E. Meinzer's paper "Plants as indicators of ground water" was published as Geological Survey Water-Supply Paper 577, many reports and papers relating entirely or in part to phreatophytes have been released in various forms by the Geological Survey and other agencies. As more data on these plants have become available, a need has developed for a supplement to Meinzer's original list and description of the plants. The need was recognized by the Phreatophyte Subcommittee of the Pacific Southwest Federal Inter-Agency Technical Committee, which proposed the preparation of such a paper. This paper is an attempt to fulfill that need by assembling and discussing the information that is available on phreatophytes. It includes a list of all plants in the desert areas of the Western United States that have been identified as phreatophytes or which there is good reason to class as phreatophytes, together with the available data concerning their occurrence, habits, and annual consumption of ground water. The information was obtained by a comprehensive review of the literature, by consultation with fellow workers, and by field study and observation.

Nearly all the available information and data on phreatophytes are the result of studies and observations that have been made on these plants in the arid areas of the western United States. The reason is twofold; first, it was in the desert areas of the West that Meinzer first observed the plants that he defined and classified as phreatophytes; second, the West by and large is a water-poor region, and attention naturally is focused on water problems including the role of phreatophytes as they affect the water supply. Water-supply problems have increased particularly since World War II, partly because of the increased demand for water, partly because of a decrease in supply as the result of a prolonged drought in the Southwest, and partly because of the spread of one species, saltcedar, a heavy water user, through the stream valleys of the Southwest. (See frontispiece.) It has become increasingly common, when referring to factors affecting water supply, to include the "phreatophyte problem". In fact, it was pointed out by Douglas (1954, p. 8-12) that the word "phreatophyte" is becoming a term that the laymen find convenient for designating a group of destructive enemies that formerly were regarded merely as nuisances.

ACKNOWLEDGMENTS

The author is grateful to many in the fields of hydrology and botany, including the members of the Phreatophyte Subcommittee

of the Pacific Southwest Federal Inter-Agency Technical Committee, and its successor, the Pacific Southwest Inter-Agency Committee, for their helpful criticisms, suggestions, and contributions. He is particularly indebted to two former colleagues in the Geological Survey, Walter N. White and Samuel F. Turner. Mr. White, who did pioneer work in determining the use of ground water by phreatophytes, reviewed the manuscript and made many valuable comments and criticisms. Mr. Turner, as the first chairman of the Phreatophyte Subcommittee, was instrumental in focusing attention on the phreatophyte problem in the Southwest and in preserving data concerning phreatophytes in the minutes of the subcommittee. He was one of the first to study the problem of saltcedars and to obtain data on their use of ground water. His draft of a list of plants that occur as phreatophytes or as hydrophytes formed the nucleus for the list of phreatophytes given in table 1. The author takes this opportunity to express his sincere thanks to these men and also to his associates for the data, information, and assistance they so generously contributed.

USE OF GROUND WATER BY PHYREATOPHYTES

EVIDENCE

Evidence that phreatophytes utilize ground water is provided by diurnal fluctuations of the water level in shallow wells that penetrate below the water table in areas of growth. The water level declines during the day when transpiration is greatest and rises during the night when transpiration is least, the rise or decline beginning at almost the same hour each day. That the daily decline of the water table was due to the withdrawal of ground water from the zone of saturation by phreatophytes was demonstrated by G. E. P. Smith through a series of observations in wells located in phreatophyte areas. Although the observations began in 1916, Smith first described the phenomenon in 1922 (White, 1932, p. 4) in an unpublished paper given before the Geological Society of Washington on November 22.

The depletion of the flow of streams that pass through areas of phreatophytes is further evidence of the use of ground water by phreatophytes.

EFFECT

The effect on the water table of transpiration by saltcedar in the Safford Valley, Ariz., is clearly shown in figure 1. In March, before the saltcedar begins to grow, there is little fluctuation of the water table, but 3 months later, when the growing season is well under way, the daily fluctuations are regular and large. The lowering on June 9, 1944, for instance, was 0.19 foot. In late October, when the growing season draws to a close, the daily fluctuations gradually diminish in amplitude, and finally they disappear altogether.

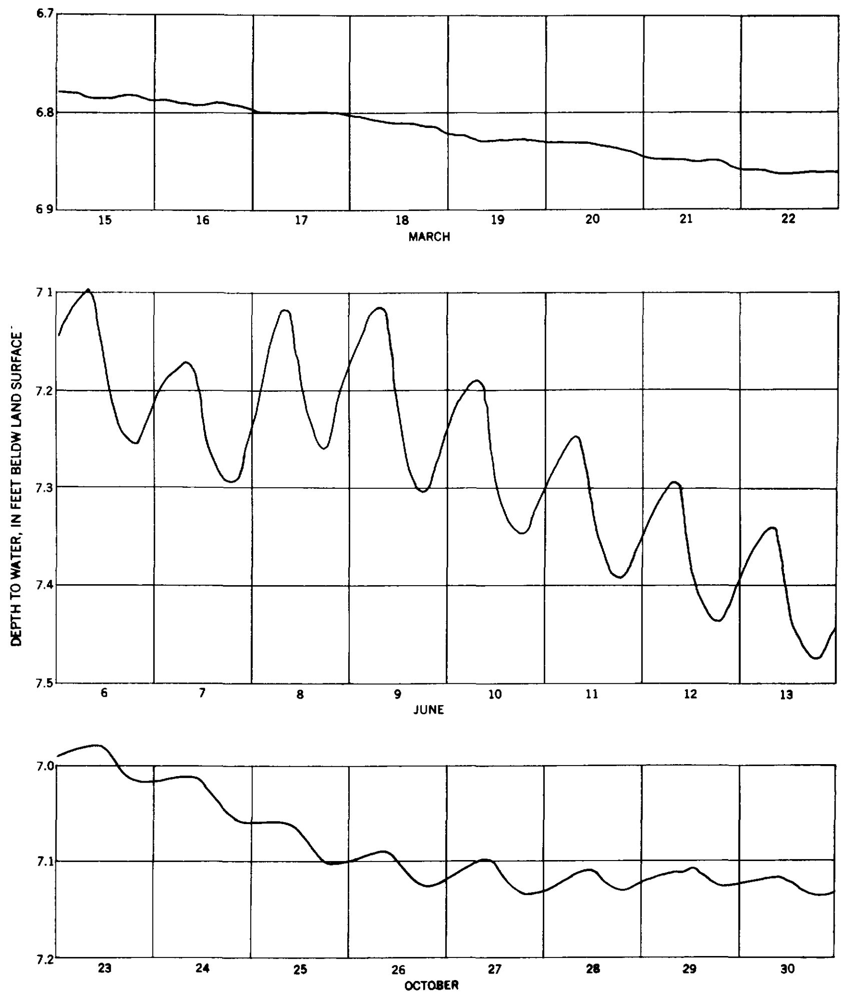


FIGURE 1.—Comparison of fluctuations of the water table as shown in well T-6 in an area of saltcedar growth before, during, and near the end of the growing season in the Safford Valley, Ariz.

During the growing season transpiration also affects the flow of streams that pass through areas of phreatophyte growth, for the plants transpire large quantitues of water, a part of which, if not thus consumed, would reach the streams (White, 1932, p.

95–96). An example is provided by the record of flow of the Gila River near Geronimo in the Safford Valley, Ariz., as shown in figure 2. The period selected, June 6–13, 1944, is the same as for well T-6, shown in figure 1. Well T-6 is about one-eighth of a mile south of the river channel, and the gaging station near Geronimo, where the river was measured, is about 20 miles downstream from the well. The flood plain in this reach of the stream, as well as above and below, is thickly covered with saltcedar. A comparison of the river and well records shows that the diurnal fluctuations in the river are quite similar to those in the well. The transpiration discharge by the saltcedar resulted not only in a marked variation in the daily flow of the stream, but also in a depletion of the streamflow. This depletion was estimated by assuming that the maximum observed rate of discharge is the same as the daily mean rate of discharge under conditions of no depletion. That is to say, if there were no transpiration loss, then the curve obtained by connecting the points of maximum discharge would approximate the probable flow of the stream. Actually, as suggested by Troxell (1936) and demonstrated by Dunford and Fletcher (1947), this method gives results that are too low because it shows only a part of the loss. The drain on the ground-water reservoir adjacent to the stream, lowers the ground-water level below the stage at which it would normally stand if there were no transpiration discharge. Because of the lower ground-water level, the stream picks up less water (or loses more water) in a given stretch than it would if the water table were higher;

MAXIMUM	6.0	6.1	5.9	5.4	5.2	4.7	4.7	4.5
MINIMUM	4.7	5.0	4.6	4.3	3.9	3.8	3.8	3.7
MEAN	5.4	5.4	5.2	4.7	4.5	4.3	4.3	4.0

RATE OF DISCHARGE, IN CUBIC FEET PER SECOND

TRANSPIRATION	1.2	1.4	1.4	1.4	1.4	0.8	0.8	1.0

LOSS THROUGH TRANSPIRATION, IN ACRE-FEET PER DAY COMPUTED AS DIFFERENCE BETWEEN MAXIMUM AND DAILY MEAN RATES OF DISCHARGE

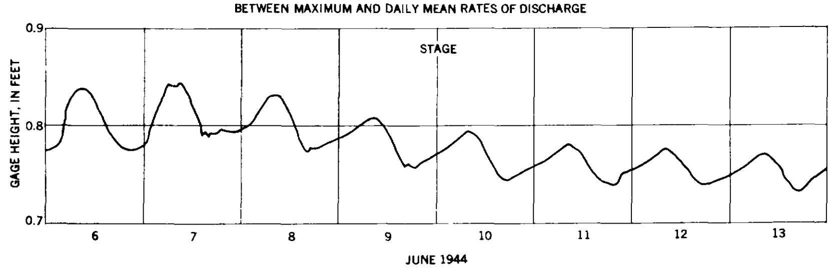


FIGURE 2.—Variation and depletion of streamflow resulting from transpiration by saltcedar, as shown in stage of the Gila River near Geronimo in the Safford Valley, Ariz.

thus, even the high points on the stream graph indicate a flow less than would occur if transpiration had not lowered the water table.

The Green River in its 437-mile course through Colorado and Utah passes through several valleys where the stream is bordered by a total of 40,000 acres of flood plain, much of which is covered with phreatophytes. The average daily depletion in flow for a 21-day period in September 1948, resulting from evapotranspiration on the flood plain area (transpiration by plants and evaporation from the soil) was, according to Thomas (1952, p. 28), 552.4 acre-feet, or 278 cfs. In the 320-mile reach from Linwood, near the Wyoming border, to Greenriver gaging station evapotranspiration losses accounted for 20 percent reduction in flow past the Greenriver gage and a 32 percent reduction in pickup between the two stations.

At the Ouray, Utah, gaging station near the center of the Uinta Basin, where the Green River is bordered by broad flood plains covered with dense vegetation, diurnal fluctuation in stage was clearly shown. Thomas (1952, p. 18-20) computed the reduction in flow on the basis of the differences between the actual stage and a line connecting the points of successive daily maxima, and found it to be about 18 cfs. Similar computation at the Linwood, Utah, gaging station upstream from Ouray, where the river is lined with phreatophytes, indicated a reduction in flow of about 12 cfs.

Phreatophytes occur in the humid Eastern States also, but by 1956 they had not received much attention as such. In those States the line between phreatophytic and nonphreatophytic vegetation is not so sharp, nor is the phreatophyte problem so spectacular or acute as it is in the arid Western States. Nevertheless, the effect on ground water and streamflow is much the same as in the arid States, though proportionately less serious, because of the greater rainfall. Ferris (*in* Wisler and Brater, 1949) described a record from a shallow well near Roscommon, Mich., which shows diurnal fluctuations that are the result of transpiration. At the Bigwoods Experimental Forest in North Carolina, Trousdell and Hoover (1955) found that the water level in shallow observation wells located in uncut stands of loblolly pine declined during the growing season and rose during the nongrowing season. Even more significant was the reversal of the downward trend of the water level that followed cutting of the timber in the 200-foot strip in which one well was located. The water level had declined about 9.5 feet from the beginning of the growing season in early May until the timber was cut on July 21. After cutting, the downward trend halted, and by the end of August, during which 5.66 inches of rain fell, the water level had risen 8.8 feet. During this same period the water level in a well in the uncut stand of timber nearby rose only 0.4 foot. It was found also from a profile of the ground water across the cleancut and uncut strips that the water level was highest in the cleancut strip, lower at the stand edges, and lowest within the stands.

The effect on streamflow in the humid States was demonstrated by experiments in the Coweeta Experimental Forest in the Appalachian Mountains of western North Carolina (Dunford and Fletcher, 1947). The effect of transpiration on streamflow in Maryland is illustrated in figure 3, by the hydrograph of the North River near Annapolis. With the exception that the peaks and troughs occur from 2 to 3 hours later, the diurnal fluctuations are similar to those for the Gila River shown in figure 2. The lag is believed due to differences in the time of the daily variations of temperature and humidity that directly affect the rate of transpiration (fig. 6).

MAXIMUM	3.28	3.28	3.35	3.28
MINIMUM	2.65	2.81	2.74	2.74
MEAN	3.01	3.01	3.05	2.99

RATE OF DISCHARGE, IN CUBIC FEET PER SECOND

TRANSPIRATION	0.53	0.53	0.60	0.58

LOSS THROUGH TRANSPIRATION, IN ACRE-FEET PER DAY COMPUTED AS DIFFERENCE BETWEEN MAXIMUM AND DAILY MEAN RATES OF DISCHARGE

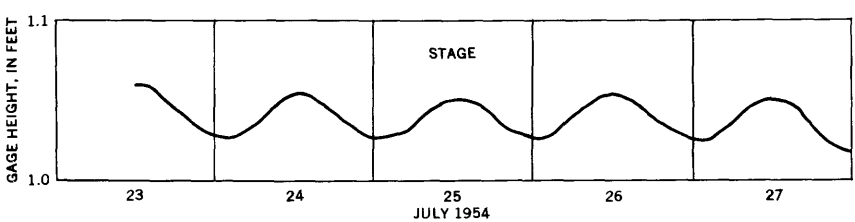


FIGURE 3.—Effect of transpiration on streamflow in a humid region as shown in stage of the North River near Annapolis, Md.

FUTURE CONSIDERATIONS

With the increasing demand for water, it seems certain that more and more attention will be given to a study of transpiration by both phreatophytic and nonphreatophytic plants in the Eastern States, and its effect on water supply. In the humid and subhumid regions, the distinction between these two groups of plants is not so sharp as in the arid regions, and under certain conditions it is difficult to determine whether a plant obtains its water supply from soil moisture or from ground water. The nonphreatophytic plants indirectly affect the water supply of a region by utilizing water in the soil column that might otherwise reach the water table as recharge. Phreatophytic plants, on the other hand, directly affect the available water supply by drawing from the ground-water reservoir as described earlier, thus reducing ground-water storage and related streamflow.

In the Pontiac area of Michigan, for example, planners are considering the practicability of salvaging a part of the evapotranspirative discharge. The annual precipitation in this 9-township area is about 30 inches a year, or 450,000,000 gallons per day (gpd). Of this amount, about one-third leaves the area as streamflow. The remaining 300,000,000 gpd, including 50,000,000 gpd used by man, is discharged by evapotranspiration. An indeterminate but probably substantial part of this is discharged from ground-water reservoirs; the rest is discharged from the soil before it has a chance to descend to the water table (Robinson, 1954).

As explained by Meinzer (1927, p. 82-88), information on the occurrence and habits of phreatophytes and their annnal consumption of ground water is a basic requisite in dealing with water-supply problems in any area where these plants grow on a substantial scale, particularly in the arid regions of the Western United States. In many parts of the regions where phreatophytes are important, man's increasing demand for water already has exceeded, or soon will exceed, the available supply. The supply can be made more nearly adequate by reducing consumptive waste by phreatophytes, insofar as to do so is practical.

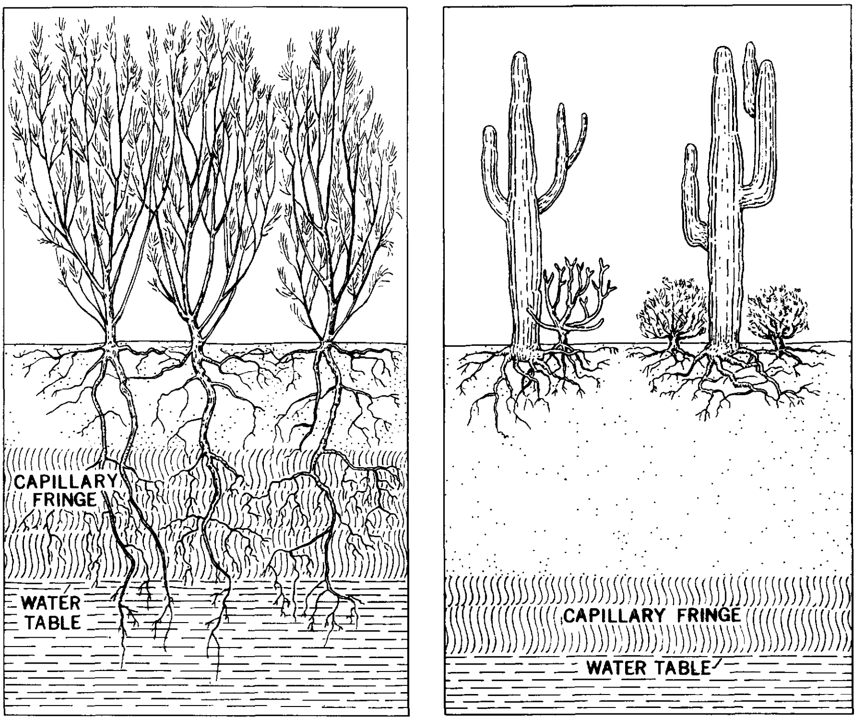
The water consumed by phreatophytes is largely wasted, for most of the plants have a low or negligible economic value. As some of the plants have a high annual water consumption and occupy extensive areas, the amount of water they consume in a given locality may be large. Although the water consumed by phreatophytes is available for salvage, it may not be economically feasible to salvage all the water. In any program involving salvage, however, it is essential to have as much information as possible concerning the occurrence and water requirements of the plants in the area under consideration.

DEFINITIONS

In desert regions in general the flora are sharply divided into two classes depending upon their relationship to the water tables. Such a distinction, although it exists, is less noticeable in regions of greater precipitation, and it may be lost sight of entirely in humid regons. The close association of certain species of desert plants with the water table and the lack of such association in others have been known for many years. The distinction was early recognized by O. E. Meinzer in his work in desert areas, beginning about 1910. Later he gave the name "phreatophytes" to the plants using ground water. The term appeared first in a preliminary mimeographed release of his report entitled "Outline of ground-water hydrology, with definitions," which was issued in revised form as U. S. Geological Survey Water-Supply Paper 494 in 1923. He defined a phreatophyte as "a plant that habitually obtains its water supply from the zone of saturation, either directly or through the capillary fringe." The word is derived from two Greek roots, "phreatos" (a well) and "phyte" (a combining form denoting a plant having a particular characteristic or habitat), and thus means "well plant." The name is apt, for the plants grow where they can send their roots down to the water table, or to the capillary fringe immediately overlying the water table, from which the plant pumps its supply of water, as illustrated in figure 4. In his introduction to Water-Supply Paper 577, Meinzer (p. 1) compares the phreatophytes, with their perennial and secure supply of ground water, with the xerophytes, which occur in desert areas where the water table is out of reach and the vegetation is forced to depend upon the rains for a scanty and extremely irregular water supply. The occurrence of phreatophytes and xerophytes in relation to the water table is shown by figure 4. The name "xerophyte," Meinzer explained, also was derived from Greek roots; it means "dry plant."

In a footnote at the bottom of page 1 of his introduction to Water-Supply Paper 577, Meinzer says:

> The principal ecologic groups of plants that have been recognized by botanists are hydrophytes, which grow in water or at least with their roots in water; the halophytes, which can endure large amounts of salt or alkali in the soil water on which they live; the xerophytes, which are able to survive on very small and irregular supplies of water; and the mesophytes, which are not adapted to endure any of these extremes. In proposing the name phreatophyte, the writer did not imply that this group should find a separate place in the old classification, but rather believed that it would overlap some of the other groups. The term "halophyte" has been used for marsh plants which are more or less intermediate between hydrophytes and



A B

FIGURE 4.—Distinction between phreatophytes (*A*) and xerophytes (*B*) shown by their occurrence in relation to the water table.

mesophytes, but this term could not be used to designate the phreatophytes, without violating its past usage and introducing much confusion.

By definition a phreatophyte gets its water from the water table, and it does under natural conditions. It should be noted, however, that phreatophytes will grow and thrive if water is supplied artificially. Thus phreatophytes may be observed growing along ditches and canals and in irrigated fields, in areas where their roots do not reach the water table but tap irrigation or drainage water. One phreatophyte, alfalfa, an important agricultural plant, is grown extensively by irrigation without regard to the depth to the water table, and there is little doubt that other phreatophytes could be grown in a similar way if it were desirable.

THE HYDROLOGIC CYCLE

The roles that the two principal classes of plants, phreatophytes and xerophytes, play in the hydrology of arid regions can be

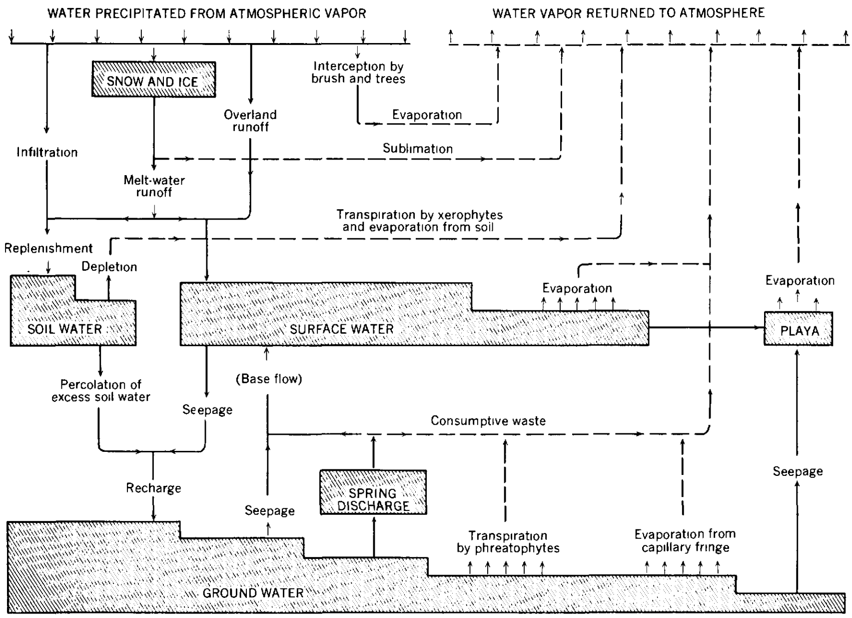


FIGURE 5.—The hydrologic cycle in an undeveloped closed basin in an arid region. (Shaded areas represent water in storage; solid lines, movement as liquid; broken lines, vapor.)

readily understood through consideration of the hydrologic cycle. Figure 5 depicts a simple hydrologic cycle—for an undeveloped closed basin in an arid region. Among other things, the diagram illustrates: (1) the distnction between the soil water for xerophytes and ground water for phreatophytes; (2) the relative positions of the soil-water and ground-water reservoirs in the cycle; and (3) the paths of the movement of water to and from them.

The water in the soil-water reservoir is not directly available to man, for he cannot extract it from the soil in usuable form. It may be available to him indirectly in the products of plant life; as such, however, it does not quench thirst or supply his other everyday needs. Soil water that is excess to the capacity of the soil reservoir eventually becomes available to man by downward percolation as recharge to the ground-water reservoir. In arid regions the excess is generally quite small. Xerophytes, by their draft on soil water during the growing season, reduce the amount of excess that would otherwise percolate to the water table, and so indirectly reduce the amount available to man.

Water in the ground-water reservoir is directly available to man through spring discharge and seepage to streams, or it may be withdrawn by means of wells, tunnels, or ditches. In some localities it is the only available water. This water also is available to phreatophytes which, through their draft on ground water, deplete the ground-water reservoir and correspondingly reduce the amount of water available to man. The transpirative draft by phreatophytes is represented in the diagram as part of consumptive waste. The effect of phreatophytes on the hydrology of arid regions becomes apparent when it is realized that most phreatophytes have a low economic value, are heavy users of water, and occur for the most part on the floors of valleys and the flood plains of streams, where ground water is readily available and where it can be utilized most effectively. Unlike the soil water transpired by xerophytes, the ground water consumptively wasted by phreatophytes is available for recovery and use (p. 25). Man, by reducing the consumptive waste in the area of discharge, may salvage for his use an amount of water equal to the reduction in waste.

PLANTS CLASSIFIED AS PHREATOPHYTES

Meinzer (1927) lists the common names of about 50 phreatophytes of the desert regions of the country, together with the scientific names of the species to which most of them belong. This paper lists, in table 1 and in the discussion that follows, the scientific names of 74 species or subspecies and about 100 common names that are applied to plants that are known to occur as phreatophytes or which there is good evidence to class as phreatophytes. The list is composed of perennial plants that grow in the arid and semiarid regions of the Western United States. No attempt was made to include plants of the Eastern United States or of foreign countries, except as they may occur as phreatophytes in the Western United States also.

The list in table 1 represents our present-day knowledge of phreatophytes, but as the plants listed by Meinzer (1927) have been added to in this paper, so the list here may well be expanded by future work. Additions may come from the group of grass and grasslike plants, for the source of water used by some of the plants in this group is not certain. Additions may come also from exotic plants, as was the case with saltcedar (*Tamarix gallica*), which up to 1927 apparently had not been recognized as a phreatophyte. This plant, imported from the Mediterranean region of western Europe, was not mentioned by Meinzer in 1927, although today it is widespread and presents a serious problem in the river valleys of the Southwest.

The plants have been listed in table 1 as phreatophytes on the basis of observation and field work over a period of years by the author in the Western United States. The list was supplemented by examination of the literature on the subject and by suggestions from workers in the fields of botany and hydrology.

The phreatophytes given in table 1 are listed alphabetically by scientific name. Phreatophytes do not belong to any one family of plants, but consist of many species belonging to different plant families. As a group they do not have much similarity in occurrence, water use, environment, or habits. Their only common characteristic under natural conditions is their typical dependence on ground water.

SCIENTIFIC AND COMMON NAMES

In dealing with phreatophytes, as with any other group of plants, the problem of names is always a vexing one. Scientific names are necessary in order to be exact, and common names are desirable in order to be understood by the layman. For the sake of exactness and clarity, the scientific name and the common name, when it is known, are given in table 1. A scientific name applies to one species of plant and to no other. Unfortunately, this is not true of common names. However, the use of common names is widespread, and more people are familiar with them than with scientific names. In fact, to those who do not have a working knowledge of botany, scientific names mean little. Generally, too, common names are descriptive of the plant to which they apply.

The common names used in this paper are those that have been established through use and are generally accepted, although a common name may refer to several species, or more than one common name may be applied to the same species. Where more than one common name is given, the first is the most generally accepted. Others listed are not so generally used, or perhaps are used only locally. For the convenience of the reader, a finding index of the common names, as used in this paper, is provided on page 76. The index gives the scientific name to which the common name refers.

FACTORS AFFECTING OCCURRENCE OF PHREATOPHYTES

Some phreatophytes are widespread; others are restricted to certain regions or may occur only in small areas. Not all the reasons for the differences in distribution are known, but, on the basis of field observations, there appear to be three important factors that exert a controlling influence on the occurrence and growth of phreatophytes. They are: climate, depth to the water table (or capillary fringe), and quality of the ground water. The character of the soil may be a fourth important factor in some localities.

CLIMATE

Climatic factors, particularly temperature, effectively control the occurrence of some species, whereas others are relatively unaffected by them. Some phreatophytes, such as saltcedar (*Tamarix gallica*), mesquite (*Prosopis*), and baccharis (*Baccharis*), thrive best in a warm climate; others, such as greasewood (*Sarcobatus vermiculatus*), prefer the cold desert areas. In general, saltcedar, mesquite, and baccharis thrive best south of the 37th parallel and below an altitude of about 5,000 feet; greasewood is seldom found south of the 37th parallel except at high altitudes. Willow (*Salix*), cottonwood (*Populus*), and saltgrass (*Distichlis stricta*), on the other hand, have a wide range of climatic tolerance. They grow from Canada to Mexico and at altitudes ranging from sea level to about 8,000 feet.

The effect of climate on saltcedar is striking when the growth and occurrence of the plant in Arizona or New Mexico is compared with that in northern Nevada. Saltcedar plants several years old, growing on the shores of Walker and Pyramid Lakes in the Carson Sink, and in the vicinity of Carson City and Fallon, Nev., (latitude 39° N. and altitude a little above 4,000 feet), are not so aggressive nor do they exhibit the vigorous junglelike growth that is so typical of the plant in the warm river valleys of southern Arizona and New Mexico.

DEPTH TO WATER

As the root systems of some phreatophytes are capable of penetrating to a depth of several tens of feet, whereas those of others are relatvely shallow, the depth to water is a controlling factor in their occurrence. For example, desert saltgrass (*Distichlis stricta*) generally grows where the depth to the water table is less than 8 feet, although it has been observed growing where the depth was as much as 12 feet (Blaney, Taylor, Nickle, and Young, 1933, p. 50). Alfalfa (*Medicago sativa*), however, is a deep-rooted plant whose roots have been traced to a depth of 66 feet, and observed at a depth of 129 feet below the land surface (Meinzer, 1927, p. 55). Mesquite and saltcedar also are deep rooted. Plants capable of developing a deep-root system may grow also where the water table is close to the surface. Typically shallow-rooted plants, however, occur only in areas where the water table is close to the surface.

Extensive studies have been made of the root systems of many cultivated plants, but relatively little is known about the root systems of phreatophytes. A general idea as to depth of root penetration may be inferred from the depth to the water table in the area where the plant is growing. However, this information may not always be reliable, for it is possible that, where the water table lies at great depth below the land surface, plants having a deep and extensive root system may obtain their needed water supply from moisture present in the huge volume of soil and subsoil enveloped by the root system. It is thought that in some localities mesquite with its deep root system may be growing under such conditions. On the other hand, the relation between the occurrence of cottonwood, greasewood, saltgrass, and willow, and the depth to ground water is quite sensitive, and the boundary between areas of growth and of no growth is generally sharp and distinct. An example of this condition occurs in Paradise Valley and Meadow Valley Wash in Nevada (Loeltz, Phoenix, and Robinson, 1949, p. 40 and pl. I; Phoenix, Hardeman, Fox, and Miller, 1948, pl. 2).

QUALITY OF GROUND WATER

The quality of the ground water is a third controlling factor in the occurrence of phreatophytes. Some phreatophytes grow only where the dissolved solids content of the water is low, others will grow only where it is high, and still others have a wide range of salt tolerance. These last may grow where the salt content of the ground water is very low but are more commonly observed growing in areas where it is moderate to high. This apparent preference may be due entirely to the degree of competition offered by other plants.

Willow and cottonwood are good examples of phreatophytes that have a low salt tolerance. Generally, these plants occur in headwater areas, along stream banks, and on the flood plains of rivers (see fig. 28). Greasewood and saltcedar are examples of plants having a wide range of salt tolerance. These plants may be found associated with plants having a low salt tolerance but more frequently they occur where the ground water has a moderate to high salt content. They are also examples of plants that have a high tolerance for certain mineral constituents in the ground water. Greasewood, for example, grows well in areas where the ground water is high in sodium carbonate, which forms the so-called black alkali. In such areas, other phreatophytes generally are not present or occur only sparsely. Saltcedar and saltgrass grow well where the ground water is high in common salt (sodium chloride).

Greasewood is widespread in the Great Basin. It commonly occupies the lower parts of desert valleys and is nearly always present in the vegetation surrounding playas. Saltcedar grows in profusion on the flood plains in the lower reaches of rivers in the Southwest. Relatively few phreatophytes grow only in areas where the ground water is highly saline. Perhaps the best example of a phreatophyte having a high salt tolerance is pickleweed (*Allenrolfia occidentalis*). This plant (fig. 22) is common in the Great Basin, where it fringes barren playas of very alkaline or saline soil.

In table 1, the salt tolerance of the various phreatophytes is indicated in a general way by a numeral, 1, 2, or 3, denoting a qualitative classfication of the type of the ground water used by the plant. This classification is based on the correlation of chemical analyses of water from shallow wells and test holes in areas occupied by different types of phreatophytes with observations of the soil and occurrence and associations of vegetation in the field. The water classes referred to by the numerals are those used by Magistad and Christiansen (1944, p. 9) in classification of standards for irrigation water, namely: (1) excellent to good, suitable for most plants under most conditions; (2) good to injurious, probably harmful to the most sensitive crops; (3) injurious to unsatisfactory, probably harmful to most crops, and unsatisfactory for all but the most tolerant. The classification is not intended to apply to water used for domestic and industrial purposes.

FACTORS AFFECTING THE USE OF GROUND WATER BY PHREATOPHYTES

As described earlier, an individual phreatophytic plant may be considered a pumping plant that obtains its supply of water from the zone of saturation. Depending on the species and density of growth, there may be literally thousands of such pumping plants on an acre of land. Throughout the growing season these plants transpire ground water into the atmosphere. The amount transpired varies with the species. Some species use large amounts of ground water, whereas others use relatively small amounts. The annual use for any given species varies with climatic conditions, depth to water, density of growth, quality of the ground water, and other factors dictated by local conditions.

CLIMATIC CONDITIONS

Most of the elements of climate affect the use of ground water by phreatophytes. Sunlight is, of course, necessary in the process of photosynthesis, essential for plant growth. In addition to sunlight, the elements of temperature, humidity, wind movement, rainfall, length of growing season, daytime hours (which are a measure of sunlight), and altitude influence the use of ground water.

The element that exerts the greatest effect is temperature. It not only controls the length of the growing season, but also the rate of water use during the growing season. For example, it was found in the lower Safford Valley, Ariz. (Gatewood and others, 1950, p. 115) that transpiration by saltcedar practically ceased in the fall when the monthly mean of daily maximum air temperature became less than 73°F and began again in the spring when the mean rose above 73°. Use of water by the saltcedar paralleled closely the seasonal changes in temperature, increasing as the maximum air temperature increased, and decreasing as the maximum air temperature decreased. As shown in figure

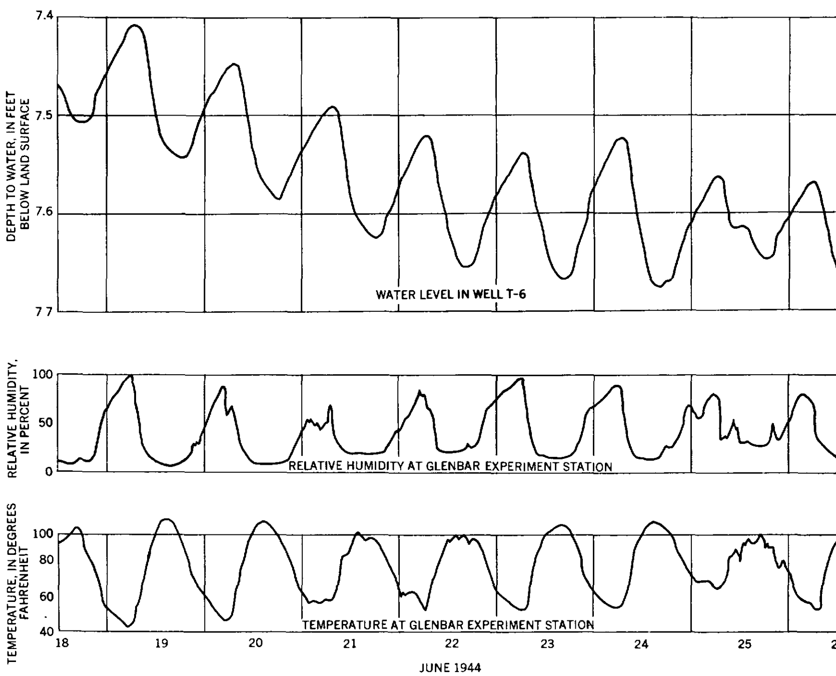


FIGURE 6.—Relation of water-table fluctuations due to transpiration by saltcedar to fluctuation of relative humidity and temperature, in the Safford Valley, Ariz. The ground-water level falls as transpiration increases and rises as it decreases. (After Gatewood and others, 1950, fig. 41.)

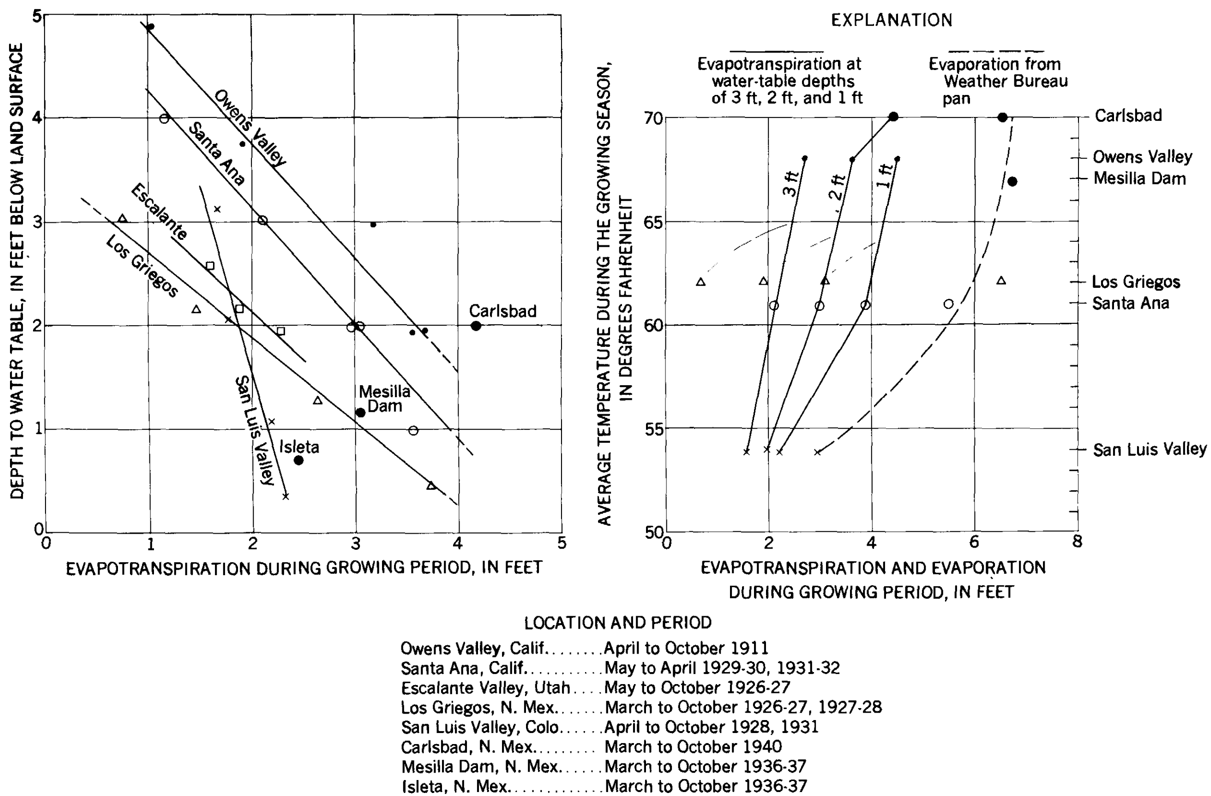


FIGURE 7.—Relation of evapotranspiration of saltgrass grown in tanks to depth to water table and to the average temperature during the growing season.

6, it also paralleled the daily changes in temperature in much the same manner.

The effect of temperature on the seasonal use of water by saltgrass is shown on the right-hand side of figure 7. This illustration, based on experimental data at five locations in the western United States where the average temperature during the growing season ranged from 54° F in the San Luis Valley, Colo. to 70° F at Carlsbad, N. Mex., shows a rapid increase in use with temperature.

The three curves show that for this 16° F rise in temperature there was about a 100 percent increase in use. In other words, the water requirement for saltgrass at 70° F is about twice that at 54° F.

It seems logical to assume that this general relation of increased use of water to increase in temperature holds true for all phreatophytes. The temperature at which appreciable transpiration begins and ceases probably varies with the species, and the ratio for the increase in use with temperature also may not be the same for all species.

The effect of humidity on the use of ground water is in reverse order to that of temperature. The rate of use decreases as the relative humidity increases, and increases as the relative humidity decreases (fig. 6). Thus, other things being equal, the rate of use by a species may be expected to be greater in arid regions than in semiarid or humid regions. A low relative humidity combined with a high air temperature is conducive to a high rate of transpiration and, hence, a high rate of use of ground water. As this combination is usually found only in arid regions, it explains the higher rates of ground-water use observed for phreatophytes growing in desert areas.

Wind movement is effective in increasing water use by keeping the relative humidity low next to the plant leaves. This is accomplished largely by a replacement of the air made humid by transpiration with drier air from the adjacent desert areas. As a rule, in the Western States, phreatophyte areas are surrounded by desert areas having air of very low humidity.

The effect of rainfall in the growing season is to reduce the use of ground water by phreatophytes. This effect was observed in tank experiments with saltcedar in the Safford Valley, Ariz., and also with alfalfa (White, 1932, p. 48-52, figs. 20-22) in the Escalante Valley, Utah. In discussing the effect of rainfall White makes the following statement:

> It was found that rains at this [the growing] season have little or no effect on the water table in plowed fields, in cleared lands, or in fields of sagebrush, but usually are followed by an almost immediate rise of the water table in saltgrass and marshgrass meadows, in willow thickets, and in fields of alfalfa, greasewood, and rabbitbrush.

July 1944	15	16	17	18	19	20	21	22	23	24
CHARACTER OF DAY	Partly cloudy	Partly cloudy	Clear	Partly cloudy	Cloudy	Cloudy	Partly cloudy	Partly cloudy	Cloudy	Clear
TEMPERATURE RANGE, IN DEGREES FAHRENHEIT	105-67	105-70	105-68	103-66	92-68	101-64	99-68	100-67	82-61	98-54
WIND MOVEMENT, IN MILES PER DAY	10	32	28	22	26	12	26	23	20	10
EVAPORATION FROM STANDARD WEATHER BUREAU PAN, IN INCHES	0.304	0.442	0.317	0.456	0.183	0.239	0.279	0.279	0.094	0.339
RELATIVE HUMIDITY, IN PERCENT	44	40	70	67	67	60	60	66	80	58

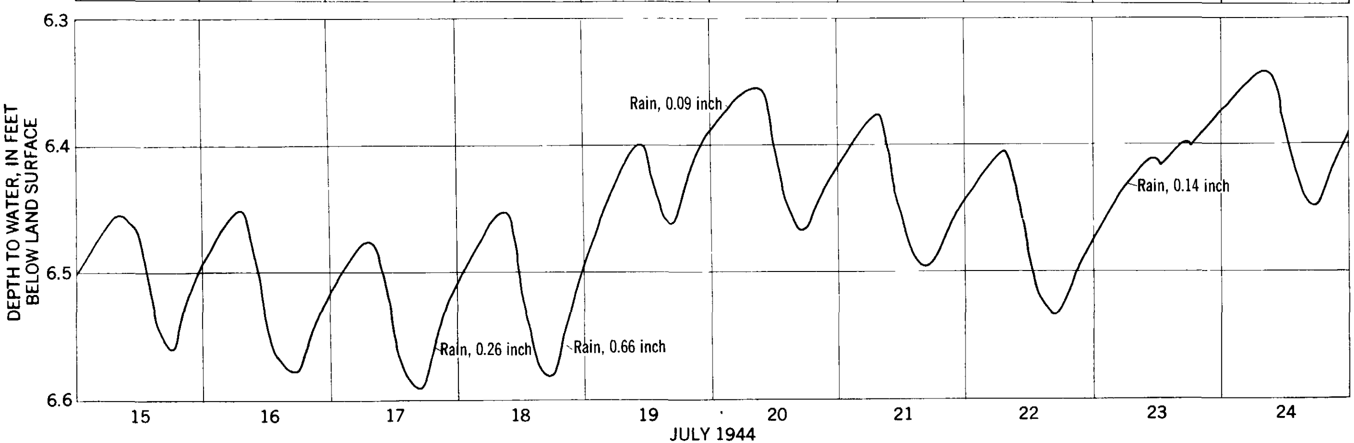


FIGURE 8.—Effect of rainfall on water-table fluctuations due to transpiration by saltcedar. Meteorological data are from Glenbar Experiment Station, 7 miles distant.

In the Safford Valley experiments, it was observed that after light to moderate rains which penetrated the soil only a few inches and did not recharge the ground-water reservoir in the tanks, the draft in the tanks was materially reduced for short periods. The reduction in ground-water draft occurred also in the thickets of saltcedar, as shown in figure 8.

It will be noted in figure 8 that before the 0.26 inch of rain on July 17, the water level had been declining at the rate of about 0.01 to 0.02 foot per day. As a result of the rain the trend was reversed and the water level rose slightly, as shown by the peak and the trough for July 18. The substantial rain of 0.66 inch on July 18 and the light shower of 0.09 inch on July 20 resulted in a rise in water level of about 0.1 foot. That this rise was due to a reduction in draft by the saltcedar from the ground water, rather than recharge from rainfall is indicated by observations of the depth of rainfall penetration at the Glenbar, Ariz., Experiment Station, that follow. On July 18, about 14 hours after the 0.26-inch rain, the depth of rainfall penetration ranged from 0.08 to 0.20 foot and averaged 0.13 foot. On July 19, about 16 hours after the 0.66-inch rain on July 18, the depth of rainfall penetration ranged from 0.26 to 0.55 foot and averaged 0.38 foot. It is apparent from the rainfall-penetration observations that there was no recharge to the water table, even after a total of 0.92 inch of rain had fallen. In most places the line between the rain-wetted soil and the dry soil beneath was sharp and distinct. Although no observations of rainfall or rainfall penetration were made at the site of well T–4, the indications are that they were almost the same as at the Glenbar Experiment Station.

One explanation for the reduced draft of ground water may be that the plant temporarily obtains part of its supply from the increased soil moisture in the top few inches of soil wetted by the rain. Another explanation may simply be a reduced rate of transpiration resulting from the increase in humidity and decrease in temperature that generally follow summer rains. The meteorological conditions on July 19 tend to support this explanation. Very probably, both explanations apply.

Other factors being equal, the use of ground water varies directly with the length of the growing season and daytime hours (sunrise to sunset). It is greatest when they are long and least when they are short. Blaney (1952, p. 61-66) recognizes the effect of daytime hours and adjusts for it in his formula for transferring consumptive-use data from one area to another.

The effect of altitude on use of ground water is largely the result of its effect on temperature and length of growing season. Both decrease as the altitude increases, and hence use of water decreases with altitude.

DEPTH TO WATER

The few data on the use of ground water by phreatophytes indicate that at shallow depths the rate of use decreases as the depth to the water table increases. The left side of figure 7 shows this conclusively in the case of saltgrass for depths to 5 feet. In the case of saltcedar, it has been demonstrated for depths to 7 feet (Gatewood, Robinson, Colby, and others, 1950, p. 137). For depths greater than about 7 feet, the data are meager and not so conclusive. Nevertheless, this relation is inferred to hold true at greater depths. This inference is based largely on the field observation that as the depth to the water increases, the plants become scattered and less vigorous, and gradually diminish in size until they cease to exist altogether. It seems logical to attribute this decrease in vigor and size to a reduction in the ability of the plant to obtain the water necessary for normal growth.

In areas where the capillary fringe extends to the land surface, ground water is discharged by evaporation from the soil and is also transpired by phreatophytes. The two processes, evaporation and transpiration, are closely associated, and it is difficult to determine the quantity of water discharged by each. For this reason, the two are commonly referred to as a single process, evapotranspiration. According to Lee (1942, p. 290), the maximum rate of evaporation occurs with a very shallow water table, decreases as the water table declines, and becomes in effect zero after the water table drops to such a depth that the capillary fringe does not reach the land surface. As many of the data on water used by phreatophytes are actually data on evapotranspiration, it is well to recognize that if the capillary fringe extends to the land surface, the record of use represents both evaporative and transpirative discharge, and if the capillary fringe does not extend to the land surface, the data represents only transpirative discharge. This explains the large difference in annual rate of use reported for a species growing in an area where the water table is shallow and the same species growing in an area where the water table is deep. It illustrates also the unfeasibility of attempting to apply water-use or evapotranspiration data for a shallow water table to an area having a deep water table, or vice-versa.

DENSITY OF GROWTH

The density of growth of phreatophytes, like that of other plants, is not uniform. The number of plants per unit area may from place to place vary from a few scattered plants to a dense junglelike forest.

The height of the plant and the vertical depth of foliage also may differ. These differences in areal and vertical density affect the quantity of ground water transpired. In order to evaluate and compare these differences of plant growth, the volume-density method was developed by the author during an investigation of the use of ground water by phreatophytes in the Safford Valley, Ariz. (Gatewood and others, 1950, p. 23-27). Volume-density is the product of areal density and vertical density, and the computation of it affords a method of comparing on a standard basis one area of growth with another. It affords also a means of applying to field conditions the data obtained from tank experiments.

Density is measured against a growth so thick that any new growth would cause an equivalent amount of old growth to become choked out and die; this is maximum possible density, or 100 percent density. Areal density is the number of plants in relation to the maximum number possible, and vertical density relates the vertical depth of foliage to the maximum possible. It was found in the Safford Valley (Gatewood and others, 1950, p. 27) that the use of water by saltcedar, cottonwood, and baccharis varied directly with the volume density. Thus, it is not sufficient to say that the annual use of water by a certain species is a certain amount; conditions of growth must also be specified. This may be done by describing the foliage in terms of volume density expressed as a percentage.

QUALITY OF GROUND WATER

There is much evidence to indicate that the quality of water affects plant growth and, hence, use of water. In general, plants grow less and use less water as the dissolved-solids concentration of the water increases. The explanation for this is found in the fact that a plant in order to absorb soil water must have a tissue fluid of higher osmotic pressure, and therefore of higher salt content, than the soil water. Thus, plant growth is a function of the ratio of the osmotic pressure of tissue fluid to that of soil water. This relation explains why water of high salt concentration may be unavailable to a particular plant, even though the soil is saturated and the plant needs moisture because that plant is unable, without injury, to build up the salt content of its fluid to the required density. Also plants may be injured or their growth retarded as a result of the toxic effect of salts in the solution (U. S. Dept. of Agriculture, U. S. Salinity Laboratory, 1954, p. 61). According to the Salinity Laboratory,

> The influence of excessive concentrations of specific salts on plant growth is an extremely complex subject involving many fundamental principles of plant nutrition.

Toxicity of water to plants may be a matter of total concentration of large concentrations of common salts, or of small concentrations of particular substances such as boron.

Data obtained in the Safford Valley, Ariz. (Gatewood and others, 1950, p. 77) indicate that the quality of the ground water affected the rate of transpiration of baccharis (*Baccharis glutinosa*). In general it was found that plants were smaller and used less water as the dissolved-solids concentration of the water increased. This observation is substantiated by experimental determinations on the influence of salts on cultivated crops at the U. S. Salinity Laboratory, Riverside, Calif. (U. S. Dept. of Agriculture, 1946, p. 1-25). It was found that some species had a greater tolerance for salt than others. Although specific data are lacking, there is every reason to believe that these experiments and observations apply to phreatophytes in general.

SALVAGE OF GROUND WATER

The ground water used by most phreatophytes has a low beneficial use so far as man is concerned. Although some phreatophytes have ornamental value, furnish cover for game, or are useful to agriculture by providing erosion control, furnishing a limited amount of browse, or serving as windbreaks, most of them have a low economic value. Of the common phreatophytes, only alfalfa is an important agricultural crop.

In referring to the water used by plants, the term "consumptive use" has come into general acceptance to denote the quantity of water evaporated or transpired from an area. It is considered synonymous with the term "total evapotranspiration." The term "consumptive use" makes no distinction as to the nature of the use but includes the water used for the growing of cultivated crops as well as by the uncultivated and native vegetation of forest and rangeland. Some vegetation is essential for man's existence, but some other may benefit him very little or not at all. In order to distinguish between these conditions of use, the term "consumptive use" has been qualified by the addition of the adjectives "beneficial" and "nonbeneficial." As a result, the water used in the growing of cultivated crops and other vegetation of high economic value is referred to as beneficial consumptive use, and that used by weeds or noxious plants is designated nonbeneficial consumptive use.

H. E. Thomas (1951, p. 217) has suggested the general term "consumptive waste" to denote "the water that returns to the atmosphere without benefiting man." When this term is restricted so that it applies only to the water used by plant life, "consumptive waste" may then be applied to the water transpired by plants that have very little utility for man. Used in this manner, the term becomes the opposite of beneficial consumptive use and synonymous with nonbeneficial consumptive use. Under these conditions, consumptive waste is that part of consumptive use that is without substantial benefit to man, and it will be used to mean that in this paper. It is a part of, rather than a complement to, "consumptive use" as that term is broadly defined as synonymous with total evapotranspiration. In describing the water used by phreatophytes, the term is very apt, conveying a concept that is readily grasped by layman and scientist alike.

Ground water that is consumptively wasted by phreatophytes is available for salvage. Salvage, as applied to phreatophytes, is converting consumptive waste of water to beneficial consumptive use. The extent to which consumptively wasted ground water can be salvaged will vary. In some localities it may be possible to effect 100-percent salvage, but in others only a part of the water can be salvaged, and under adverse conditions, none at all. The degree of salvage undertaken or effected probably will depend largely on economics, for in the final analysis salvage is an economic problem.

The water available for salvage in any area is equal to the total water requirements of the nonbeneficial phreatophytes in the area. In the arid western part of the United States, the amount of water consumptively wasted by phreatophytes is very large. Estimates based on incomplete data indicate that the area occupied by these plants in the 17 Western States, the Dakotas, Nebraska, Kansas, Oklahoma, Texas, and States to their west, is nearly 16 million acres, from which phreatophytes may discharge as much as 25 million acre-feet of water into the atmosphere annually (Robinson, 1952a, p. 60). This amount of water is equivalent to about twice the average annual flow of the Colorado River at Lees Ferry, Ariz., or to about 75 percent of the total storage capacity of Lake Mead. The consumptive waste of this quantity of water in the arid and semiarid regions of the West, where the demand for water is on the increase, emphasizes the importance of salvage.

The idea of salvage as applied to phreatophytes is relatively new, and methods are largely in the experimental stage. The data available on methods of salvage are probably fewer than those on any other phase of the phreatophyte problem. Much study is needed to develop methods by which salvage can be accomplished economically.

Salvage may be effected in two ways: lowering the water table beyond reach of phreatophytes by pumping or drainage and subsequently using this water economically; and by substituting plants of high economic value for nonbeneficial phreatophytes. Either operation requires a knowledge of the occurrence and habits of phreatophytes and their annual consumption of ground water.

To be effective, reducing consumptive waste by lowering the water level should be rapid; otherwise, the roots and especially those of the deep-rooted plants may keep pace with the declining water level and keep the plants alive until the water table again becomes relatively stable. Reduction of consumptive waste may be accomplished also by intercepting ground water upgradient from the area of plant discharge and diverting it to beneficial consumptive use. Conveying the water of streams, especially the short mountain streams of the West, through areas of riparian phreatophytes by means of pipes or lined ditches also will reduce consumptive waste.

The method of increasing the efficiency of use through substitute vegetation has tremendous possibilities. Developments in this field have not been great, although some advances have been made. The outstanding example is in the Escalante Valley, Utah, where alfalfa was successfully substituted for an association of greasewood, rabbitbrush, and saltgrass (White, 1932). Before replacement vegetation can be planted, it is necessary to rid the area of existing vegetation. This is not always an easy task, especially where aggressive and tenacious plants such as saltcedar grow. Two methods of clearing have received considerable attention: cutting down or uprooting the plants by mechanical means, and destroying the plants through the use of chemical sprays. Considerably more information is needed concerning the relative cost and effectiveness of these methods.

It may be possible to turn consumptive waste into beneficial consumption by finding a use for wasteful phreatophytes. Such a method would be of particular value in areas where the dissolved-solids content of the ground water is so high as to restrict its usefulness for purposes other than growing the plants already present. A possibility is the use of rabbitbrush as a source of rubber. (See discussion, p. 55.) Also, saltcedar is known to contain tannins, and mesquite is noted for the high quality of the charcoal that it produces. These are some possibilities that could be studied, and there are doubtless many others.

STATUS OF INFORMATION ON PHREATOPHYTES

The considerable amount of information concerning phreatophytes that has become available since Meinzer first introduced the subject in 1927 is still not adequate for intelligent handling of the problem. Little attention was focused on the effect of phreatophytes on the water supply in the Southwestern United States until the early 1940's when increased supplies of water were needed to meet the demands of World War II. Half of the references listed on pages 78–82 were published after 1945.

The greatest advance has been made in determining the annual use of water by different species. Information about common phreatophytes such as saltcedar, greasewood, cottonwood, baccharis, and willow are available for one or two areas, and about saltgrass for several areas in the West. There are few data on the phreatophytes of the Eastern United States. Much more information is needed even for the common phreatophytes, to say nothing of three score others for which there are virtually no data on use of water.

Information on the relation of phreatophyte species to the depth to the water table is scanty, and the available information frequently is conflicting. It is known that some phreatophytes such as saltcedar, mesquite, and alfalfa are deep rooted and that saltgrass is shallow rooted, but there are few data on the limit to which the roots will go in search of water. It has been inferred from observation that the use of ground water by most species decreases substantially beyond a depth of 7 feet, but there is little information to sustain the inference.

Very little is known about the quality of water preferred by most species of phreatophytes or the amount of dissolved solids they can tolerate. It is known that certain plants, such as pickleweed, have a high salt tolerance; others, like greasewood and saltgrass, are less tolerant; and some, such as willow, grow only where the ground water is low in dissolved solids. Also, very little is known of the effect of mineralized ground water on plant growth or the tolerance of any species for any particular mineral in the water.

With the exception of that of alfalfa, the known economic or cultural value of most phreatophytes is low. In fact, many of them are considered harmful and so may be classified as weeds. It should be pointed out, however, that little has been done to determine whether phreatophytes have an economic value. Additional information is needed regarding the value of the plants for food, forage,[1] browse,[2] lumber, erosion control, windbreaks, and other uses.

[1] Vegetable food of any kind consumed by animals.

[2] The tender shoots, twigs, and leaves of trees and shrubs often used and regarded as food for cattle and other animals.

RELATION OF PHREATOPHYTES TO FLOODS AND SEDIMENTATION

Not all the problems concerning phreatophytes relate to water supply; some relate to flood hazards. This is especially true of saltcedar, and to a lesser extent of willow, baccharis, and other densely growing riparian vegetation.

Saltcedar, an exotic plant introduced from western Europe, found the southwestern part of the United States very much to its liking, growing prolifically and spreading rapidly throughout the stream valleys. It is an aggressive and tenacious plant, which in the stream valleys of the Southwest invades and chokes the normal overflow channels, greatly reducing their water-carrying capacity. As a result, in times of flood the water spreads over large areas that normally would not be flooded, endangering lives and damaging property.

The dense river-bottom growth of saltcedar, mesquite, and arrowweed in the 77-mile reach of the Gila and Salt Rivers between Granite Reef and Gillespie Dam in Arizona is an example of a major flood hazard posed by phreatophytes. The Corps of Engineers has recommended the clearing and maintenance of a 2,000-foot-wide channel along the entire distance. In addition to reducing the flood hazard, this clearing would save an estimated 16,600 acre-feet of ground water a year (Turner and Skibitske, 1952, p. 66).

Besides increasing the flood hazard, the damming or ponding effect as a result of the dense growth reduces the velocity of the floodwater. When, as is quite common, the sediment load of the floodwater is high, there is deposition of sediment in the area of phreatophyte infestation as a result of the lower velocity. Such conditions exist along nearly all streams where there is saltcedar infestation, but are particularly prevalent along the Gila and Salt Rivers in Arizona and the Rio Grande and Pecos River in New Mexico. In the Gila River Valley above the San Carlos reservoir, the accentuated valley sedimentation resulting from a dense growth of vegetation on the flood plain was noted by Eakin and Brown (1939, p. 108). The phreatophytes responsible were largely saltcedar and baccharis. In 1954 the writer observed a deposit of silt 4 to 5 feet thick on the flood plain of the Gila River in an area of dense saltcedar growth. This deposit, so far as could be determined, was formed by a single flood a few years earlier.

In the delta above Lake McMillan on the Pecos River, several feet of silt may have been deposited as the result of saltcedar growth. Eakin and Brown (1939, p. 17–18) have attributed the marked decrease in the rate of silting of the reservoir since 1915 to the dense growth of saltcedar in this area. Before 1912, the vegetation in the valley of the Pecos River above Lake McMillan was largely low-growing saltgrass. In the fall of 1912, a few seedlings of saltcedar were observed on the mud flats at the head of the reservoir. By 1915, these seedlings had grown to heights of 3 to 5 feet and, according to the National Resources Planning Board (1942, p. 57), covered an area of 600 acres. The plants continued to spread; by 1939 they were growing on 9,800 acres and by 1950 on 10,160 acres in the delta at the head of Lake McMillan (Pecos River Commission, 1955, p. 10).

The general effect of this saltcedar growth on sediment deposition in the reservoir is shown by the following tabulation prepared by Eakin and Brown (1939, p. 17).

Period	*Length of period (years)*	*Total sediment deposited (acre-feet)*	*Deposits per year (acre-feet)*
1894–1904	10.42	18,000	1,730
1904–1910	6.42	10,000	1,560
1910–1915	4.58	13,400	2,920
1915–1925	10.00	3,500	350
1925–1932	7.00	1,500	215

The average rate of silting in the 21.42 years of record before 1915 was 1,933 acre-feet per year, as contrasted with 294 acre-feet per year in the 17-year period after 1915. The increasing effectiveness of the saltcedar in desilting the flood water is shown by a decrease in the average yearly rate of silting from 350 acre-feet in the 10-year period 1915-25 to 215 acre-feet in the 7-year period 1925-32.

The desilting effect produced by the screen of saltcedar growth suggests the possibility of using such a method of desilting to prolong the effective life of reservoirs. It must be pointed out, however, that such a method would have a high water cost. The average streamflow depletion by saltcedar above Lake McMillan in the 6-year period May 1934 to July 1940 has been computed as 54,300 acre-feet per year (National Resources Planning Board, 1942, p. 56). This is nearly three times the average annual rate of evaporation (19,100 acre-feet) from Lake McMillan and its auxiliary diversion reservoir, Lake Avalon. The use of saltcedar for desilting, then, evolves into a question of economics, that of balancing the additional effective life of the reservoir against the annual water use by the plants. A further consideration is the question of whether the higher flood levels caused by the phreatophyte growth and the sedimentation can be tolerated.

In order to reduce water losses resulting from inundation and ponding caused by the sedimentation in the area of phreatophyte growth, it has been found necessary to construct conveyance channels at the head of McMillan reservoir on the Pecos and Elephant Butte reservoir on the Rio Grande.

PHREATOPHYTES IN WESTERN UNITED STATES

Those plants of the Western United States that are known to occur as phreatophytes, or which, from available information, can with good reason be classified as phreatophytes, are listed in table 1. Some of the plants may not occur everywhere and at all times as phreatophytes. For example, wirerush (*Junius balticus*) may be found in some areas growing as a hydrophyte, with its roots in water. *Juniperus scopulorum,* or Rocky Mountain juniper, generally occurs in the mountains, where, if there is a water table, it lies at great depth. However, the plant grows as a phreatophyte in two areas of shallow water table in Nevada. The line between hydrophytes and phreatophytes, and phreatophytes and xerophytes, is not sharp but appears rather to be a gradual transition. Thus, there are some plants that may occur as both hydrophytes and phreatophytes, a large group that occur as true phreatophytes, and then a group that may occur as both phreatophytes and xerophytes. The fact that a phreatophyte may occur also as a hydrophyte or as a xerophyte is noted in the table, when this information is known.

The list of plants, including the available data on them as phreatophytes, is given alphabetically, by scientific name, in table 1. For eight common phreatophytes, alfalfa, cottonwood, greasewood, pickleweed, rabbitbrush, saltcedar, saltgrass, and willows, there is considerably more information than could be included in the table. Discussions of these plants are given under separate headings, according to genus, after table 1.

FIGURE 9.—Camelthorn (foreground), a native of Asia, and saltcedar (background), native to Western Europe and the Mediterranean region, growing side by side in the flood plain of the Little Colorado River near Holbrook, Ariz. Photograph by A. I. Johnson.

FIGURE 10.—A typical dense growth of batamote (*Baccharis glutinosa*) on the flood plain of the Colorado River near Blythe, Calif. Height about 8 feet.

TABLE 1.—*Phreatophytes in Western United States*

[The quality of the ground water with respect to its suitability for crop growth is indicated by numerals as follows: 1, excellent to good; 2, good to poor; 3, poor to unsatisfactory. The use of ground water, including precipitation, unless otherwise stated is presumed to be for a plant growth of 100-percent volume density (Gatewood and others, 1950, p. 23–27)]

Scientific name	*Common name*	*Occurrence as a phreatophyte*	*Relation to ground water* — *Depth to water below land surface (feet)*	*Quality*	*Use (acre feet per acre)*	*Remarks*
Acacia greggii A. Gray.	Catclaw, devilsclaw, uña de gato.	Southern California to western Texas.		1		Uses more water than mesquite (McGinnies and Arnold, 1939, p. 236). Forms thickets along streams and washes.
Acer negundo Linnaeus.	Boxelder	Canada to Oklahoma and Arizona.				Occurs in moist places and along streams, chiefly in mountains. Observed in the flood plain of the North Canadian River near Oklahoma City, Okla. Widely used as a shade tree.
Alhagi camelorum Fischer.	Camelthorn	Arizona				Introduced into Southwestern United States from Asia Minor. Poor browse plant. Observed growing as a phreatophyte along Little Colorado River between Holbrook and Winslow, Ariz., in localities where the depth to water ranged from 4 to 6 ft. Aggressive and thicket forming, root system deep and extensive (Van Dersal, 1938, p. 45). (Fig. 9.)
Allenrolfea occidentalis (S. Watson) Kuntze.	Pickleweed, iodinebush.	California to western Texas	1-20	3		For additional information see page 49 and figure 22.
Alnus	Alder				5.3	Occurs along streams, river bottom land, and other wet sites. The use of 5.3 ft. (Blaney and others 1933, p. 112) was for the period May to October 1932 in Coldwater Canyon, altitude 2,400 ft., San Bernardino Mountains, Calif., where alder constituted 82 percent of the vegetation.

Anemopsis californica (Nuttall) Hooker and Arnott.	Yerba mansa	Southern California, southern Nevada to Utah and Texas.	Shallow	3		Used by Pima Indians as a herbal remedy. Common in saline and wet lowlands.
Aster spinosus Bentham.	Spiny aster	Arizona				Identified as phreatophyte in bottom land of lower Safford Valley, Ariz. (Gatewood and others, 1950, p. 24).
Atriplex canescens (Pursh) Nuttall.	Fourwing saltbush, chamiso, chamiza.	South Dakota to Oregon, south to Mexico	[1]8-62	1–2		Tolerates alkali. Valuable browse plant. Useful in erosion control. Taproots 30–40 ft deep (Van Dersal, 1938, p. 65). May not always occur as a phreatophyte. (Fig. 21.)
hastata Linnaeus.		Oregon and California to Kansas and New Mexico.		3		Occurs in saline soils, especially around alkaline lakes, in salt marshes, and in other water-soaked soils (Bidwell, and Wooten, 1925, p. 9).
lentiformis (Torrey) Watson.	Quailbrush, lenscale, Nevada saltbush.	Southern Utah and Nevada to California and Sonora, Mexico.	6-15	3		High tolerance for alkali and saline soil (Benson and Darrow 1954, p. 121; Magistad and Christiansen, 1944, p. 10). Fair browse plant. Reaches height of 10 ft where water table is shallow (Kearney and Peebles, 1951, p. 259).
Baccharis emoryi A. Gray.	Emory baccharis	Texas to southern California and southern Utah.		2		
glutinosa Persoon.	Batamote, seepwillow, watermotie, waterwillow.	Colorado and Texas to California and Mexico.	2-15	2	[2]4.7	Evapotranspiration for plants grown in tanks ranged from 10.3 ft with water level at 2 ft, to 4.6 ft with water level of 6 ft. Safford Valley, Ariz. (Gatewood and others, 1950). (Fig. 10.)
sarothroides A. Gray.	Broom baccharis, desertbroom, rosinbrush.	Southern California, Arizona, southwestern New Mexico.				Occurs along streams in draws, in canyon bottoms and wet alkaline sites (Dayton, 1931, p. 160).
sergiloides A. Gray.	Squaw baccharis, waterweed.	Arizona, southern California, southern Nevada, southwestern Utah.		2		Occurs as a phreatophyte in lower Safford Valley, Ariz. (Gatewood and others, 1950).
viminea Crandolle.	Mulefat	Southwestern Utah, southern California, Nevada, Arizona.				Useful in erosion control.

TABLE 1.—*Phreatophytes in Western United States*—Continued

Scientific name	*Common name*	*Occurrence as a phreatophyte*	*Relation to ground water:* *Depth to water below land surface (feet)*	*Quality*	*Use (acre feet per acre)*	*Remarks*
Bigelovia hartwegii, probably *Aplopappus heterophyllus* A. Gray.	Rayless goldenrod					Will grow in dry places but thrives where ground water is within reach (Meinzer, 1927, p. 31).
Celtis reticulata Torrey.	Hackberry, cumaru, kom.	Arizona			(3)	A large tree that may reach 3 ft in diameter and 50 ft in height (Bryan, 1925). Usually occurs along streams.
Cercidium floridum Bentham.	Blue palo verde	Southwestern Arizona, southeastern California.				Common along washes, canyons, valleys, alluvial plains, grassland at sites where ground water is plentiful (Judd, 1954, p. 3–9). (Fig. 14.)
Chilopsis linearis Sweet.	Desert-willow	Western Texas to southern Nevada, Arizona, southern California.	To 50			May not always occur as a phreatophyte (Bryan, 1925).
Chrysothamnus pumilus (Nuttall).	Rabbitbrush	Mud Lake, Idaho				For additional information see page 53.
nauseosus consimilis (Greene).	Rubber rabbitbrush.	Nevada, Utah, Idaho, Wyoming.		2–3		For additional information see page 53.
nauseosus graveolens (Nuttall).	do	Montana, Idaho, Utah, Nevada, New Mexico.	2.5–15	2–3		Do.
nauseosus mohavensis (Greene).	do	Northern California, Nevada.		2–3		Do.
nauseosus oreophilus (A. Nelson).	do	Wyoming, Colorado, Utah				Do.
nauseosus viridulus	do	Colorado to Oregon; Nevada, New Mexico.				Do.

Cowania stansburiana (Torrey).	Vanadium bush	Arizona, Idaho, Utah				Used as an indicator of vanadium-uranium deposits by prospectors in the Colorado Plateau. Able to grow in highly mineralized ground and to absorb large amounts of uranium (Cannon, 1952). (See fig. 11*A*.)
Cynodon dactylon (Linnaeus) Persoon.	Bermuda grass	Arizona, southern California.		1–2	[4]2.85–2.35	Not everywhere a phreatophyte, but uses ground water where it is available. Valuable in erosion control and as forage. A subtropical plant introduced from the Old World, probably India.
Dalea spinosa Gray.	Smoketree, smokethorn.	Southeastern California, southwestern Arizona.				Its persistent occurrence in gravelly and sandy washes suggests it depends upon ground-water underflow and occurs as a phreatophyte. (Fig. 12.)
Dasiphora fruticosa Linnaeus.	Bush or shrubby cinquefoil.	Locally in Idaho but widespread in Oregon, Washington, Utah, Nevada and Arizona.	Shallow			Occurs as a phreatophyte in Pahsimeroi Valley, Idaho (Meinzer, 1927, p. 60). Grows on subalpine meadows, along streams, about cold springs in peaty, sandy, or clayey loams.
Distichlis spicata (Linnaeus) Greene.	Seashore saltgrass	Western United States				See pages 56-59.
stricta (Torrey) Rydberg.	Saltgrass, or desert saltgrass.	All Western States (Hitchcock, 1951 p. 178).	2–14	1–3		Do. (Fig. 24.)
Elymus condensatus Presl.	Giant wildrye	All Western States except New Mexico (Dayton, 1940, p. G52).	1–12	1–2		Fair forage. Killed by overgrazing. Extensive root system. (Fig. 13.)
triticoides Buckley.	Creeping wildrye	Western United States		1–2		Good forage. Frequently cut for hay. Associated with giant wildrye along Humboldt River, Nev. (Dayton, 1940, p. G50).
Eragrostis obtusiflora (Fournier) Scribner.	Mexican saltgrass, alkali lovegrass.	Southeastern Arizona, southwestern New Mexico.	4–15	2–3		Common locally in saline soil near Wilcox, Ariz. (Kearney and Peebles, 1951, p. 87). Observed growing in Sulphur Springs Valley, Ariz., where depth to water table was from 4–15 ft (Meinzer, 1927, p. 23).

TABLE 1.—*Phreatophytes in Western United States*—Continued

Scientific name	*Common name*	*Occurrence as a phreatophyte*	*Relation to ground water*			*Remarks*
			Depth to water below land surface (feet)	*Quality*	*Use (acre feet per acre)*	
***Fraxinus** velutina* Torrey.	Velvet ash, Arizona ash.	Southwestern Utah, southern Nevada, California, Arizona, New Mexico, and western Texas.		1		Prominent stream-bank and canyon tree; restricted to areas with a permanent ground-water supply (Benson and Darrow, 1954, p. 273, 274). Popular as a shade tree in Arizona and California.
***Hedysarum** boreale* Nuttall.	Sweet vetch	Colorado, Utah				Deep tap root (Dayton, 1940, p. W87). Identified as a phreatophyte in Colorado (Cannon, 1953). (Fig. 11B.)
***Heliotropium** curassavicum* Linnaeus.	Heliotrope, Chinese pusley.	Southwestern Utah to southern California.	Shallow	2–3		High tolerance for alkali (Mendenhall, 1909, p. 20). Occurs on moist saline soil (Kearney and Peebles, 1951, p. 710).
***Hymenoclea** monogyra* Torrey and Gray.	Burrobush	Western Texas to southern California.	Shallow	1–2		Occurs largely along streams, washes, and in bottom lands; aggressive, often forming thickets (Dayton, 1931, p. 154). Unpalatable to livestock.
salsola Torrey and Gray.	White burrobush	Utah to Arizona and California.				Occurs in sandy desert.
***Juglans** microcarpa* Berlandier.	Walnut, nogal, butternut.	Arizona, New Mexico	2–20	1		Occurs along watercourses and washes; intolerant of shade (Sudworth, 1934, p. 104). Deep tap root (Van Dersal, 1938, p. 146).
***Juncus** balticus* Willdenow	Wirerush, wiregrass	Western United States			[5]7.8	Grows in wet sites where ground water is shallow, also in shallow ponds. Appears to occur both as phreatophyte and hydrophyte. Deep root system. Fair to good forage.

Juncus cooperi Engelmann.	Desertrush	Southern Utah to California.		2–3		Occurs on the margins of salt marshes and alkaline meadows, common in Death Valley, Calif., along the edge of the playa often associated with saltgrass. (Fig. 20.)
Juniperus scopulorum?	Rocky Mountain juniper; locally "swampcedar."	Nevada	10	1–2		Occurs locally as a phreatophyte in White River and Spring Valleys, Nev. May be a hybrid between *J. scopulorum* and *J. utahensis* (Maxey and Eakin, 1949, p. 26).
Leptochloa fascicularis (Lamarck) A. Gray.	Sprangletop	Western United States		1–3		Occurs along ditches and in moist waste places, often in brackish marshes (Kearney and Peebles, 1951, p. 123); most places in alkali plains (Tidestrom, 1925, p. 83). Often invades rice fields (Davis, 1950, p. 31).
Medicago sativa Linnaeus.	Alfalfa	Western United States	4+	1–2		See pages 59-61.
Phragmites communis Trinius.	Reed, giant reedgrass, carrizo.	Western United States	[1]0–8±	1–2		Occurs also as a hydrophyte in the shallow water of streams, lakes, ponds and marshes. (Fig. 15.)
Picea engelmanni Parry.	Engelmann spruce	Mountain areas of western United States.		1		Requires a good water supply and depends upon ground water in many localities (Meinzer, 1927, p. 63). Shallow root system (Van Dersal, 1938, p. 185).
Platanus wrightii Watson.	Arizona sycamore	Southern Arizona, southeastern and southwestern California, New Mexico.		1		Common along stream and rocky canyons, in foothills and mountains, upper desert, desert grassland, and oak woodland zones (Little, 1950, p. 54). Valuable in erosion control.
Pluchea sericea Coville.	Arrowweed	Texas to southern Utah and southern California.	[1]0–10±	1–2		Occurs along streams and flood plains. Abundant along lower reaches of Colorado River and tributaries. Meinzer (1927, p. 77) suggests arrowweed may grow where depth to water is 25 ft. (Figs. 16 and 18.)

TABLE 1.—*Phreatophytes in Western United States*—Continued

Scientific name	Common name	Occurrence as a phreatophyte	Relation to ground water: Depth to water below land surface (feet)	Relation to ground water: Quality	Relation to ground water: Use (acre feet per acre)	Remarks
Populus	Cottonwood	Western United States		1–2		See pages 61-64 and figure 25.
tremuloides aurea Tidestrom.	Quaking aspen	Mountainous areas of Western United States.		1		Considered a phreatophyte when it grows along streams, around springs, and in other wet areas. Shallow root system (Van Dersal, 1938, p. 197). (Fig. 17.)
Prosopis juliflora (Swartz.)	Mesquite, honey mesquite.	Southern Kansas to southeastern California and Mexico.		1–2		Extensive root development. Reported to penetrate 60 feet below surface (Kearney and Peebles, 1951, p. 402).
velutina Wooton.	Velvet mesquite	Southern Arizona	10+	1–2	[6]3.3	Occurs in bottom lands. Extensive root development. (Fig. 19.)
pubescens Bentham.	Screwbean mesquite, tornillo.	Western Texas to southern Nevada and southern California.				Characteristic of bottom lands along desert streams and water holes of Mojave and Colorado Deserts (Benson and Darrow, 1954, p. 178).
Quercus agrifolia Nee.	California live oak	California	35±	1		Occurrence related to depth to water table (Meinzer, 1927, p. 63).
lobata Nee.	Roble oak	California	10–20			Do.
Salicornia europaea Linnaeus	Glasswort			3		Frequently occurs in salt flats with salts approximating 1.0 percent of weight of soil (Magistad and Christiansen, 1944, p. 10).
rubra Linnaeus.	do	Colorado, New Mexico, Nevada, Utah.		3		Some value as waterfowl feed. In Nevada occurs along edges of channels draining into playas.
utahensis Tidestrom.	do	Utah		3		Occurs on borders of salt lakes and alkaline places.

Salix	Willow	Western United States				See pages 64-66 and figures 26 and 28.
Sambucus	Elder, elderberry	Western United States		1		Eleven species reported to grow in Western United States (Dayton, 1931, p. 147). Grows along streams, in canyons and in moist sites.
Sarcobatus vermiculatus (Hook). Torrey.	Big greasewood	Western United States	60±			See pages 66-69 and figure 27.
Sequoia gigantea (Lindley).	Giant or bigtree sequoia.	California		1		Appears to prefer localities where water table is within reach of its roots (Meinzer, 1927, p. 64) but will grow elsewhere.
Sesuvium portulocostrum	Lowland purslane	Southern Nevada and California.		3		Reported by Mendenhall (1909, p. 20) as a plant that grows on moist alkaline soils. Indicative of ground water but usually of poor quality. Alkali resistant.
verrucosum Rafinesque.	Warty sesuvium, sea purslane.	Southern Arizona, California, and New Mexico.	Shallow	3		
Shepherdia	Buffalo berry	Arizona, New Mexico, Nevada, Oregon, Black Hills.		1		Fruit edible. Grows in moist sites and along streams and river bottoms. One species reported by Meinzer (1927, p. 59) growing as a phreatophyte in Big Smoky Valley, Nev. Occurs also as a phreatophyte in Mason Valley, Nev.
Sporobolus airoides Torrey.	Alkali sacaton	Western United States	[1]5–25±	1–3	[7]4.01–3.45	Most common in the Southwest where it is important as forage; deep, coarse root system. Prefers moist alkali flats. (Dayton, 1940, p. G109). Grows in very saline or saline-alkali soils. Soil salinity may range from 0.3 to 3.0 percent. Grows best in range 0.3 to 0.5 percent (U. S. Salinity Laboratory, 1954, p. 58).
wrightii Munro.	Sacaton	Arizona to western Texas		1–2		Occurs in alluvial flats and bottom lands. Will not grow on highly alkaline soils.
Suaeda depressa Watson.	Seepweed, saltwort	Southwest		3		Browsed when other forage is scarce. Occurs on saline or saline-alkali soils with salt content in first foot as much as 3.2 percent (U. S. Dept. Agriculture, 1954, p. 58).

TABLE 1.—*Phreatophytes in Western United States*—Continued

Scientific name	*Common name*	*Occurrence as a phreatophyte*	*Relation to ground water*: *Depth to water below land surface (feet)*	*Quality*	*Use (acre feet per acre)*	*Remarks*
Suaeda suffrutescens Watson.	Desert seepweed	Western Texas, New Mexico, Arizona		3		Browsed when other forage is scarce. Occurs on saline or saline-alkali soils with salt content in first foot as much as 3.2 percent (U. S. Dept. Agriculture, 1954, p. 58).
torreyana Watson.	Torrey seepweed, iodineweed, inkweed.	Eastern Oregon to New Mexico and California.	14–15	3		Do.
Tamarix aphylla Linnaeus.	Athel tree	Southwest		1–3		See pages 70-75 and figure 29.
gallica Linnaeus.	Saltcedar, French tamarisk	do		1–3		See pages 70-75 and figs. 30, 31, and 32.
Washingtonia filifera Wendland.	Fan palm, California palm	Southern Arizona, California, southeastern New Mexico.		1-3		Highly tolerant to alkali. Generally grows where ground water is at shallow depth (Brown, 1923, p. 112).

[1] Meinzer, 1927.
[2] Average in Safford Valley, Ariz. (Gatewood and others, 1950).
[3] Considerable for full development.
[4] 2.85 with 2-ft water level and 2.35 with 3-ft water level in tanks at San Bernardino, Calif. (Young and Blaney, 1942, p. 50).
[5] 7.8 with water level at 2 ft, Santa Ana, Calif. (Idem, p. 43–45).
[6] Average in the Safford Valley, Ariz. (Gatewood and others, 1950, p. 195).
[7] 4.01 with 2.0 ft water level; 3.45 with 4.0 ft water level, Carlsbad, N. Mex. (Blaney and others, 1942).

FIGURE 11.—"Vanadium bush" (*A*) and sweet vetch (*B*), which have a high tolerance for mineralized ground, are valuable as guides in the search for uranium-vanadium ore deposits on the Colorado Plateau. The "vanadium bush" is able to absorb large amounts of uranium. Photographs by Helen L. Cannon.

FIGURE 12.—Smoketrees (*Dalea spinosa*) in a gravel-filled wash north of Needles, Calif. A typical occurrence of this ashy gray leafless shrub, whose branches all end in spines.

FIGURE 13.—Giant wildrye (*Elymus condensatus*) near Rye Patch Reservoir on the Humboldt River, Nev. The plant had reached a height of 2.5 feet when the photograph was taken in mid-June.

FIGURE 14.—Blue palo verde growing in Centennial Wash, Ariz. Two different species of palo verde are native to Arizona:—blue palo verde (*Cercidium floridum*) which is a phreatophyte, and the foothill palo verde, (*C. microphyllum*) which is not. Photograph by D. G. Metzger.

Figure 15.—Giant reedgrass (*Phragmites communis*), or carrizo as it is known in the Southwest, growing in association with arrowweed (left) along a ditch bank on the flood plain of the Colorado River near Yuma, Ariz. Below, detail of giant reedgrass.

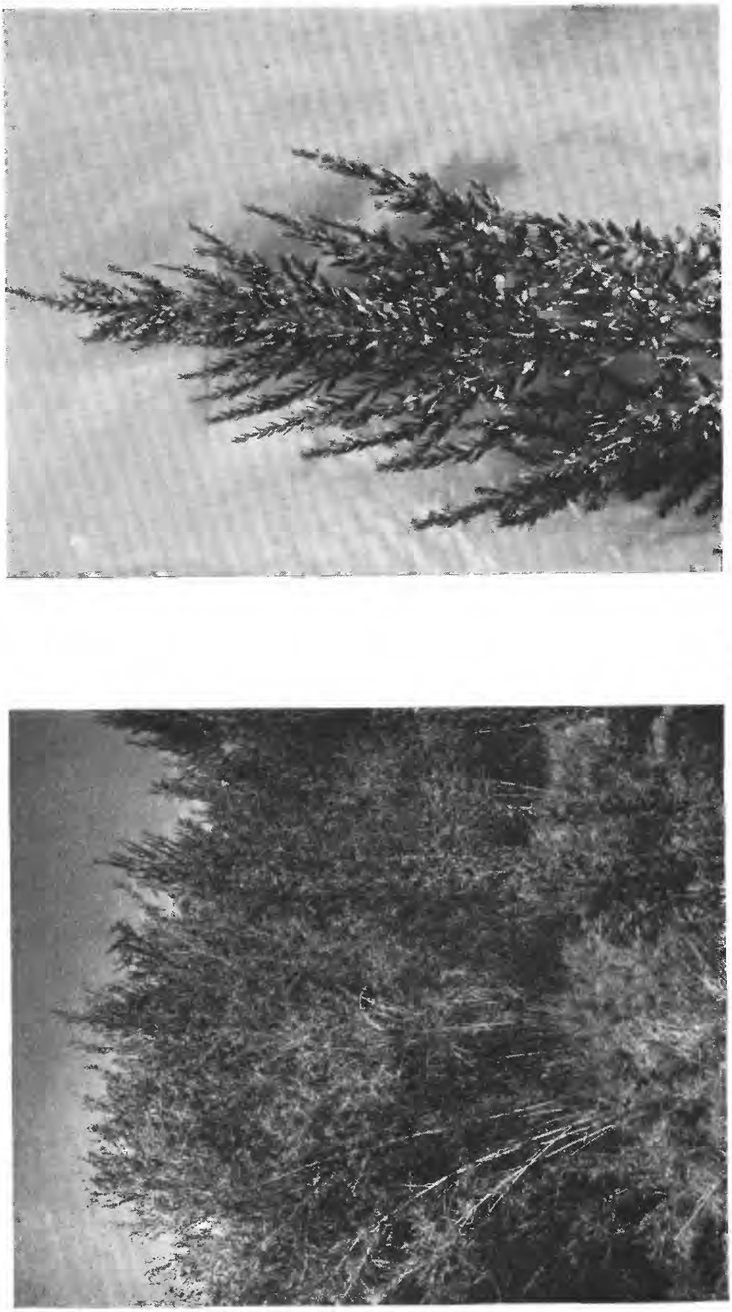


FIGURE 16.—A luxuriant stand of arrowweed (*Pluchea sericea*) growing on the flood plain of the Colorado River near Blythe, Calif. Height about 10 feet. The Indians used its straight stems for arrows.

FIGURE 17.—A grove of aspen (*Populus tremuloides*) marks a spring and seep area in Clear Creek canyon, near Carson City, Nev.

FIGURE 18.— The "devil's corn field" near Stovepipe Wells in Death Valley National Monument, Calif., shows clumps of arrowweed in a sand dune area, the roots having been partially exposed by wind erosion. The capillary fringe is at the land surface here.

FIGURE 19.—A mesquite tree (*Prosopis velutina*) growing along the Gila River near Gila Bend, Ariz. Height 16 feet, spread about 25 feet. Detail view shows its characteristically small leaves and spiney branches.

FIGURE 20.—Desertrush (*Juncus cooperi*) in association with saltgrass (*Distichlis stricta*) on edge of the playa about 5 miles north of Furnace Creek ranch, Death Valley, Calif.

FIGURE 21.—Fourwing salt-bush (*Atriplex canescens*) growing in clumps along the channel of Salt Creek about 3 miles west of Beatty Junction, Death Valley, Calif.

SUMMARY OF INFORMATION CONCERNING EIGHT COMMON PHREATOPHYTES

The information available for eight of the phreatophytes listed in table 1 is more than could be included in the table. This information is presented and discussed, by species, in the following pages.

ALLENROLFEA OCCIDENTALIS — PICKLEWEED

Pickleweed, as mentioned earlier, is one of the most salt-tolerant phreatophytes, actually appearing to thrive on soil of high salt content. It is a succulent, almost leafless shrub (fig. 22) that occurs along the fringes of salt lakes, flats, and playas and in moist saline and alkaline areas. It occurs closely associated with saltgrass and to a lesser extent with greasewood. However, at the inner edge of saline areas, where the salt content of the soil may be too great for saltgrass, pickleweed may be the only plant growing. A typical occurrence of pickleweed associated with saltgrass growing on strongly saline land is shown on the margin of Great Salt Lake in Utah in figure 22. Pickleweed is unpalatable to livestock and is eaten only when other forage is lacking. The upper 3 feet of soil in a pickleweed area generally has a salt content of more than 1 percent—frequently as high as 2.5 percent (Shantz and Piemeisel, 1940, p. 39). In the Tularosa Basin, N. Mex., Meinzer (1927, p. 81) found that, in 10 samples of soil from areas of pickleweed, taken at depths of 1 to 6 feet, the total soluble solids expressed as a percentage of the total dry soil by weight ranged from a minimum of 1.75 to a maximum of 4.20, the sodium chloride or common-salt content being 0.40 to 1.55. Assuming that the soil has a specific gravity of 1.6, a porosity of 40 percent, and is saturated, and that all the salts pass into solution, the soil moisture will range in soluble solids from 70,000 to 170,000 parts per million (ppm) and in common salt from 16,000 to 62,000 ppm.

During April 1953 the author collected a sample of soil in the Malad Valley, Idaho, from a saline flat in which a sparse growth of pickleweed was the only plant, and numerous crystals of common salt were observed on the surface of the soil. At the same time, a soil sample was collected from an area of greasewood growth about a hundred feet distant on the fringe of the saline flat. A comparison of the chemical analyses of the two samples given below shows that the soil from the pickleweed area had a soluble-salt content 55 times greater than that of the greasewood area, and the chloride content was nearly 700 times greater.

FIGURE 22. Pickleweed (*Allenrolfea occidentalis*) associated with saltgrass growing on strongly saline soil on the margin of Great Salt Lake, near Hooper Hot Springs, Utah. Fremont Island in the distance. Photograph by R. J. Brown. Below, detail of its much-branched, fleshy, almost leafless stems.

Chemical analyses of soil samples from a pickleweed and a greasewood area, sec. 21, T. 15 S., R. 36 E., Malad Valley, Idaho

[Analyses by the U. S. Bureau of Reclamation]

	Pickleweed area	*Greasewood area*
Depth of sample — inches	0–4	1–3
Kind of soil	Silty loam	Sandy loam
pH — (1:5 dilution)	8.4	9.7
Percent salt	>3.0	.04
Saturation extract, in parts per million except as indicated:		
Conductivity — micromhos	95,600	1,200
pH	7.5	8.9
Total dissolved solids	75,400	1,350
Calcium	288	8.4
Magnesium	1,700	6.3
Sodium	23,000	279
Potassium	1,340	48
Bicarbonate	71	685
Carbonate	0	0
Sulfate	149	62
Chloride	41,600	60
Boron	.59	1.7

Samples of plant tissue also were collected at the same time and place from the leaf, branch, and root of the pickleweed and a greasewood plant. The analytical results for the pickleweed plant and soil sample are given below, and those for greasewood under the discussion of that plant on page 69.

Chemical analysis of soil from pickleweed area and plant tissue of pickleweed, Malad Valley, Idaho

[Analyses, by U. S. Bureau of Reclamation, in milligrams per gram of soil or plant tissue]

Constituents	*Soil*	*Plant tissue*		
		Leaf	*Branch*	*Root*
Calcium	0.138	12.47	6.84	3.75
Magnesium	.816	7.94	6.64	6.39
Sodium	11.027	20.42	30.36	25.93
Potassium	.641	3.11	7.14	6.80
Chloride	19.987	9.94	37.75	26.64
Sulfate	.072	11.15	5.90	5.11
Boron	.0003	.055	none	tr

Although pickleweed has a high alkaline and saline tolerance, it is not necessarily confined to areas where the ground water has a high content of these constituents. Meinzer (1927, p. 80) reports that in the Tularosa Basin, N. Mex., the dissolved solids in four samples of ground water from areas where pickleweed was growing ranged from 1,670 to 5,500 ppm, and the chloride from 244 to 1,130 ppm. One sample of ground water from the Big Smoky Valley, Nev., had 4,040 parts ppm of dissolved solids and 1,360 ppm of chloride. A chemical analysis of a sample of ground water collected in July 1953 from an uncased well 22 feet deep in an area of pickleweed growth, on the bed of China Lake (sec. 34 T.24 S., R.40 E.) in the desert area of southern California, had a conductance of 3,330 micromhos and dissolved solids of about 2,000 ppm.

The water level in the well stood 5.8 feet below the land surface. A pure stand of pickleweed grew abundantly around the well. Unfortunately, no sample of ground water was collected in the area of pickleweed growth in Malad Valley nor samples of soil from the area of pickleweed growth in China Lake, Calif., to provide a basis for comparison of the quality of the soil and the ground water at the two localities.

Some idea of the concentration of ground water in which pickleweed can grow is furnished by the following chemical analysis of a sample of water collected in April 1957 at Badwater in Death Valley, Calif.

Chemical analysis of ground water from a shallow pit in a seep area of pickleweed growth at Badwater, Death Valley, Calif.

[Parts per million except as indicated]

Conductivity — micromhos	31,600
Dissolved solids	25,600
Calcium	946
Magnesium	93
Sodium and potassium	[1]8,570
Carbonate	0
Bicarbonate	156
Sulfate	3,070
Chloride	12,800
Percent sodium	87
Density—gram per milliliter	1.015

[1] Calculated.

The concentration of this water, which is about two-thirds that of sea water, shows that pickleweed has an extremely high tolerance for alkaline and saline ground water. Pickleweed's wide range of tolerance is indicated by the conductance of the water from Badwater which has ten times the concentration of that from China Lake. In general, the presence of pickleweed in an area is an indication of ground water that is at shallow depth, that contains moderate to high amounts of dissolved solids, especially common salt, and that is probably unsuited for irrigation or domestic use.

CHRYSOTHAMNUS — RABBITBRUSH

According to Dayton (1940, p. B.54), there are about 70 species of the genus *Chrysothamnus* in western North America, to which the name rabbitbrush is commonly applied. The shrub is very widespread, extending from Canada to Mexico and from North Dakota and western Nebraska to California, but is most abundant in the Great Basin. The botanical name *Chrysothamnus* is derived from two Greek roots, *chrysos* "golden" and *thamnos* "a shrub." During the flowering season, from late July to September, the plant is rendered very conspicuous by the profusion of small golden yellow flowers. Because of the similarity of color and size of its flowers, rabbitbrush is often confused with goldenrod.

The genus is both phreatophytic and xerophytic, some species occurring in the lowlands where they draw on the ground water, but others on dry hillsides and slopes where it is apparent that they have no association with the water table. So far as the writer is aware, there has been no attempt to classify the various species with respect to their association with the water table, but a study of this is needed. Generally, a close association with the water table is indicated where the growth of rabbitbrush is vigorous, luxurious, and abundant (fig. 23). In the Great Basin, the phreatophytic species are frequently found associated with greasewood and saltgrass, particularly around playas and on the floors of desert valleys.

Only two species have been identified as phreatophytes. These are *Chrysothamnus nauseosus* and *C. pumilus*. *C. nauseosus* has more than 40 subspecies, or varieties (Hall, 1919, p. 181), but there is evidence to classify only 5 of them as phreatophytes. These are *C. nauseosus consimilis* (Greene), *C. nauseosus graveolens* (Nuttall), *C. nauseosus mohavensis* (Greene), *C. nauseosus oreophilus* (A. Nelson), and *C. nauseosus viridulus*. These forms, however are very common and widespread, covering extensive areas in the Great Basin. *C. pumilus* is reported as a phreatophyte from only one locality, Mud Lake, Idaho (Stearns and others, 1939, p. 68).

The phreatophytic forms of *Chrysothamnus nauseosus* occur in soil that ranges from lightly to moderately alkaline. From this it is inferred that the quality of the ground water used by the plant ranges from good to poor.

Data on the use of ground water by rabbitbrush are meager. White (1932, p. 84) makes the following comment, based on his work in the Escalante Valley, Utah:

> Rabbitbrush is known to consume water. Wells put down during the investigation in fields of rabbitbrush invariably developed a daily water-table fluctuation of considerable amplitude, and although no actual determination was made of the amount of ground water used by rabbitbrush, the assump-

FIGURE 23.—Rabbitbrush, forming the predominant growth in a large area of low-lying land near Carson City, Nev. Average height about 3 feet.

FIGURE 24.—Saltgrass associated with greasewood growing near Battle Mountain, Nev. The light-colored materials on the ground and plant stems are incrustations of white alkali.

tion that it ordinarily consumes at least as much ground water as greasewood is believed to be safe.

The known uses of rabbitbrush are rather unimportant. According to Dayton (1940, p. B54), "Most species of *Chrysothamnus* have little or no forage value . . . but a few rank as fair to good forage for sheep and cattle." By virtue of their deep and extensive root systems, they serve as impediments to wind and water erosion. Indians obtained a yellow dye from the flowers and a green dye from the inner bark.

During World War I, a rubber-plant survey of western North America (Hall and Goodspeed, 1919) revealed that certain species of *Chrysathamnus nauseosus* were a potential source of rubber. The rubber, known as chrysil, is present within the individual cells of the plant, and it is not a latex rubber. The highest rubber content in individual plants was found in two forms occurring as phreatophytes. One, *C. nauseosus consimilis,* from near Gerlach, Nev., contained 6.57 percent rubber and the other, *C. nauseosus viridulus,* from Benton, Calif., contained 5.56 percent rubber. On the basis of field studies and sampling it was estimated that the total amount of rubber in rabbitbrush in all of the Western States was not less than 300,000,000 pounds. The description of the plants and their occurrence given in the estimate show that most of the rubber is present in the forms that occur as phreatophytes in the alkaline valley bottoms of the Great Basin and in the San Luis Valley of Colorado. It is worthy of note also that, in general, the highest rubber content was found in plants growing in alkaline soil, too strong for the standard agricultural crops, and that the rubber-producing kinds of rabbitbrush all have deep taproots with but few main laterals.

In view of the high rubber content of the forms occurring as phreatophytes, their preference for alkaline soils, and the extensive areas occupied by them, it is apparent that they present a unique opportunity for the salvage of ground water. Should the production of chrysil become economically feasible, then much of the ground water now considered wasted by phreatophytic rabbitbrush would become of beneficial consumptive use in view of the value of these plants for their rubber content. Furthermore, for highest rubber content the plants would be grown on wasteland—land where the ground water is too alkaline for growing agricultural crops. Irrigation and the attendant leveling of land and construction of ditches would not be a problem, for the plants would draw on ground water for their supply.

DISTICHLIS — SALTGRASS

The two principal species of the genus *Distichlis* in western United States are *spicata* and *stricta*. *D. spicata*, known as seashore saltgrass, is confined to low-lying lands adjacent to the ocean. It is quite common in the saline soils of the lowlands of the San Francisco Bay area. *D. stricta*, on the other hand, is widespread, growing in all Western States. It is the saltgrass of the desert, and is referred to as desert saltgrass or, usually, just saltgrass. There has been much confusion concerning the two species, for in nearly all the early reports and many of the more recent ones on desert saltgrass cited in this paper, the plant has been referred to as *D. spicata*. However, the description of the habitat and occurrence of desert saltgrass by Chase (Hitchcock, 1951, p. 177-78) leaves little doubt that in most cases the plants referred to as *D. spicata* were in reality *D. stricta*.

Desert saltgrass is quite common in the Great Basin. Shantz and Piemeisel (1940, p. 37) describe it as forming meadows in the lowest parts of valleys between the greasewood-shadscale belt and the pickleweed areas. It does not push out into the salt-encrusted flats so far as pickleweed does. It is commonly associated with rabbitbrush or greasewood (fig. 24), and also alkali sacaton. Saltgrass is a shallow-rooted plant that is generally found where the depth to the water table is less than 8 feet. However, as mentioned earlier, it has been observed growing where the water table was about 12 feet below the land surface (Blaney and others 1933, p. 50).

In much of the area of saltgrass growth, the capillary fringe extends to the land surface so that ground water evaporates directly from the soil. As a result, there is a concentration of alkali salts at and near the surface. Depending upon the quality of the ground water, the concentration of salts in some areas may be small, but in others it may be sufficient to form a crust or an efflorescence as shown in figure 24. According to the U. S. Department of Agriculture (1954, p. 57), the soluble-salt content of the 4-foot soil profile in a saltgrass area is usually high (0.8 to 2.0 percent), the highest content being found in the first foot. Although saltgrass has a high tolerance for salt, it is not confined to saline areas. It will grow where only small amounts of salt are present.

Saltgrass makes fair forage, particularly when the leaves and stems are green. At other times, the leaves are harsh and not relished by livestock.

More work has been done in determining the use of water by saltgrass than has been done for any other phreatophyte. The pioneer experiments were by Lee (1912) in the Owens Valley, Calif. As the result of tank experiments, he found that the evapotranspiration discharge from 54.59 square miles of (salt) grass and alkali lands where the depth to water did not exceed 8 feet was equivalent to a continuous flow of 109 cfs or 2 cfs per square mile. Experiments to determine the evapotranspirative discharge of saltgrass grown in tanks have been conducted by different workers under a wide range of conditions at nine localities in the western United States. The depth to the water table in these experiments has ranged from about ⅓ foot to nearly 5 feet; the altitude from near sea level at Santa Ana, Calif., to more than 7,500 feet at Garnett in the San Luis Valley, Colo.; and the temperature (see fig. 7) from 54°F to 70°F. The location, period of record, depth to water table, and evapotranspiration discharge for these experiments are given in table 2.

The results shown in the tabulation are not always comparable, for the periods of record differed considerably. Some of the periods are for the year, some are for a full growing season, and some are for a part of a growing season. In order to compare the results on as nearly a common basis as possible, the approximate growing season for each locality was determined, and the records that most nearly fit this period were selected. Using these records, curves were drawn to show graphically (fig. 7) the relation of evapotranspiration to depth to the water table, and to the average temperature during the growing season. Considering that the data were obtained by different workers in widely separated areas, and under a variety of conditions, the relations are remarkably consistent. Several relations are readily apparent from figure 7. Within the limits of the curve on the left side of the figure, it may be seen that the evapotranspiration decreases as the depth to the water table increases. It may be seen also that, with the exception of the San Luis Valley, the rate of decrease for the different locations is fairly uniform. The much smaller rate of discharge in the San Luis Valley appears to be due largely to the lower average temperature during the growing season.

The relation of evapotranspiration and of evaporation to temperature is shown on the right-hand side of the figure. The increase of evapotranspiration with an increase in the average temperature during the growing season is evident. The apparent lack of agreement of the results from Los Griegos, N. Mex., may have been the result of a poorly operating water-supply system. Blaney and others, (1942, p. 117) note that difficulty was experienced in main-

TABLE 2.—*Annual or seasonal evapotranspiration of water by saltgrass grown in tanks*

Locality	*Period of record*	*Depth to water (feet)*	*Use (feet)*	*Remarks*
		CALIFORNIA		
Owens Valley	Jan. — Dec. 1911	1.50	4.07	(Young and Blaney, 1942, p. 126.)
Do	Do	1.83	3.74	Do.
Do	Do	2.92	3.35	Do.
Do	Do	3.83	2.05	Do.
Do	Do	4.92	1.12	Do.
Santa Ana	May 1929 — Apr. 1932	1.00	3.56	(Young and Blaney, 1942, p. 44.)
Do	Do	2.00	2.94	Do.
Do	Do	3.00	1.98	Do.
Do	Do	4.00	1.11	Do.
		COLORADO		
San Luis Valley	June — Oct. 1927	.50	1.42	(Blaney and others, 1938, p. 335, 336.)
Do	April — Oct. 1928	.38	2.26	Do.
Do	May — Oct. 1930	.33	2.26	Do.
Do	April — Nov. 16, 1931	.28	2.31	Do.
Do	June — Oct. 1927	1.25	1.49	Do.
Do	April — Oct. 1928	1.17	1.98	Do.
Do	May — Oct. 1930	.79	1.75	Do.
Do	April — Nov. 16, 1931	.98	2.40	Do.
Do	June — Oct. 1927	2.08	1.11	Do.
Do	April — Oct. 1928	2.00	1.69	Do.
Do	May — Oct. 1930	1.92	1.57	Do.
Do	April — Nov. 16, 1931	2.12	1.83	Do.
Do	April — Nov. 16, 1931	3.12	1.69	Do.
		NEW MEXICO		
Carlsbad	Jan. — Dec. 1940	2.00	4.52	(Blaney and others, 1942, p. 210.)
Isleta	June 1936 — May 1937	.65	2.63	(Young and Blaney, 1942, p. 93.)
Los Griegos	Oct. 1926 — Sept. 1927	.42	4.03	(Young and Blaney, 1942, p. 126.)
Do	Oct. 1927 — Sept. 1928	.50	3.87	Do.
Do	Oct. 1926 — Sept. 1927	1.17	2.77	Do.
Do	Oct. 1927 — Sept. 1928	1.33	2.93	Do.
Do	Oct. 1926 — Sept. 1927	2.08	1.51	Do.
Do	Oct. 1927 — Sept. 1928	1.17	3.32	Do.
Do	Do	3.08	.84	Do.
Mesilla Dam	July 1936 — June 1937	2.17	1.89	(Young and Blaney, 1942, p. 99.)
		UTAH		
Escalante Valley	May — Oct. 1926	2.58	1.60	(White, 1932, p. 100.)
Do	May — Oct. 1927	1.94	2.26	Do.
Do	Do	2.17	1.86	Do.
Vernal	April 14 — Oct. 28, 1950	2.00	1.98	(Barrett and Milligan, 1953, p. 11.) Amount does not represent a full year of normal growth.

taining a constant water level in the tanks. The effect of temperature is more fully realized when it is recognized that the evapotranspiration in Owens Valley, average temperature 68°F, for the 7-month period April through October is about 0.6 foot greater than at Santa Ana, average temperature 61°F, for the 12-month period May to April. The longer growing period at Santa Ana was not sufficient to compensate for the higher temperature in Owens Valley.

Comparison of rate of evaporation from a Weather Bureau pan with rate of evapotranspiration in figure 7 shows that evaporation was always greater. For a depth of 1 foot the evapotranspiration ranged from 68 to 75 percent of the pan evaporation, and for depths greater than 1 foot the ratio decreased correspondingly. This fact is of value in estimating evapotranspiration discharge in saltgrass areas, for, if the pan evaporation is known, at least an upper limit can then be placed on the amount of the evapotranspiration, but this tentative ratio needs much more study.

Saltgrass appears to be a phreatophyte that is well suited for such a study, particularly in tank experiments. Because of this and the pioneer work that has been done, saltgrass would be an excellent plant for research on many phases of evapotranspiration.

MEDICAGO — ALFALFA

The genus *Medicago* comprises about 50 species of herbs and small shrubs and is a native of the Old World, probably the Mediterranean, Asia Minor, and the Caucasus Mountains (McKee, 1948, p. 714). *Medicago sativa,* commonly called alfalfa, is by far the most important species. Its first recorded introduction into the United States was in 1739 in what is now Georgia, and its establishment as a crop began about 1850 along the Pacific Coast. It soon became one of the most important hay and forage crops of the Southwest, and later of all the Western States. Today alfalfa is one of the most important forage crops in the United States and is grown in every State.

In the arid Western States alfalfa is quite commonly, though not always, grown as an irrigated crop, but in the humid Eastern States irrigation generally is not necessary. The yield of alfalfa, ranging from about 1½ to 5 tons per acre, is almost directly proportional to the available moisture. The many varieties of alfalfa combine to give it a wide range of climatic tolerance, so that it is successfully grown in both the northern and southern parts of the country, and in the high valleys of the mountains as well as in the lowlands. It grows on a wide range of soils but prefers deep loams; as a rule it does not thrive on acid soils (McKee, 1948,

p. 715). Experiments at the United States Salinity Laboratory at Riverside, Calif., show that alfalfa has a good to strong tolerance for salt (U. S. Dept. Agriculture, 1946, p. 21). Magistad and Christiansen (1944, p. 14) report that it will grow in soil containing as much as 4,000 ppm of white alkali, but will tolerate only a little sodium carbonate (black alkali). It does not thrive on poorly drained soils or where the water table is less than about 4 feet below the land surface.

Alfalfa is a deep-rooted plant and will send its roots to great depth in search of ground water. Meinzer (1927, p. 54) cites three reports of the roots of older plants being traced or reported at depths of 65, 66, and 129 feet. The latter was in a mine tunnel in Nevada, beneath an alfalfa field, where the roots came through crevices in "rotten porphyry."

The available data on the use of water by alfalfa are largely from tank experiments. White (1932, p. 99) found that at Milford, Utah, the use in the 1927 growing season, April through October, was 2.58 feet, the depth to water in the tanks averaging about 3 feet. At the Los Poblanos ranch near Albuquerque, N. Mex., the use of water was 3.7 feet with the water level in tanks at an average depth of 4.5 feet, for the period April 15 to October 31, 1936 (Blaney and others, 1938, p. 373).

During 1948, in the course of consumptive-use studies in the Colorado River area of Utah, two alfalfa tanks were installed at the Vernal, Utah, airport. The tanks were operated during the growing periods of 1948, 1949, and 1950. The soil column, 3.67 feet in length, was held in an inner tank, whose bottom and sides were perforated. This tank was placed in an outer tank, about 3 inches greater in depth and in diameter. The soil column was not saturated at its lower end through contact with a water table. Instead, the soil column was saturated on the first of each month and irrigated on the fifteenth of each month with enough water to simulate irrigation conditions in the area. The use under these conditions was probably less than it would have been with a water table at a depth of 3.67 feet, that is, at the bottom of the soil columns, for the reason that the plants did not necessarily have a constant and unlimited supply of water at all times. The averages of the two tanks for the 3 years were: for the growing period May 17 to October 6, 1948, 3.6 feet, for the growing period May 31 to November 5, 1949, 2.5 feet, and for the growing period April 14 to October 27, 1950, 3.3 feet (Barrett and Milligan, 1953, p. 11).

A review of the characteristics, habits, and tolerances of alfalfa indicate that it has great salvage potentialities through conversion of consumptive waste of ground water to beneficial consumptive use.

Its economic importance as a forage crop, its growth under a wide range of climatic conditions, its tolerance to salts, and its deep root system are factors that make it an ideal plant to substitute for uneconomic phreatophytes. The successful substitution of alfalfa for an association of "greasewood and weeds" in the Escalante Valley, Utah, described by W. N. White (*in* Meinzer, 1927, p. 89-91) is evidence of its value as a salvage plant.

POPULUS — COTTONWOOD

The genus *Populus* includes aspens, poplars, and cottonwoods. According to Dayton (1940, p. B111), approximately 15 species and several varieties of *Populus* are native to the Western United States. This discussion, however, is concerned primarily with cottonwoods, although one species of poplar is included.

Cottonwood trees are widespread throughout the West, being represented in every Western State by one or more of *Populus* species; it is the State tree of Kansas, Nebraska, and South Dakota. The names, both scientific and common, and descriptions of the following list of cottonwoods, including poplars, were taken largely from Sudworth's excellent descriptive material (1934) for these trees in the Rocky Mountain region.

Scientific name	*Common name*
Populus acuminata Rydberg	Lance-leaf or smoothbark cottonwood
angustifolia James	Narrowleaf cottonwood
balsamifera Linneus	Balsam poplar
deltoides Marsh	Eastern cottonwood
fremontii Watson	Fremont cottonwood
sargentii Dode	Plains cottonwood
texana Sargent	Texas cottonwood
trichocarpa Torrey and Gray	Black cottonwood
weslizeni S. Watson	Valley cottonwood, Rio Grande poplar, álamo

Even though specific data on the relation of the above-listed species to the water table are lacking, it is believed that all of them may be classified as phreatophytes. This belief is substantiated by the available literature on the occurrence and habits of the trees. All the species listed have one characteristic in common; they grow along streams or on river bottom lands where ground water is generally at shallow depth and readily available. At least two of the species, *Populus fremontii* and *P. weslizeni,* are known to be true phreatophytes (Meinzer, 1927, p. 58). Present-day information indicates that, as phreatophytes, cottonwoods are much alike. However, future work may show that there are differences in their annual water use, range in depth to water, or chemical quality of the ground water or soil they prefer.

Some of the species listed are widespread in their occurrence; others are quite local. There is also overlapping of species, so that more than one species may be present in a locality. *Populus deltoides* is a large tree of the Eastern United States that extends west into the Plains States. In those States it occupies a belt extending from eastern North Dakota south to eastern Texas. Three cottonwoods, *P. angustifolia, P. sargentii,* and *P. acumenata,* occur in the Rocky Mountain region from Canada almost to Mexico, *P. angustifolia* being the most widespread. *P. sargentii* extends eastward from the mountains into the plains of western Oklahoma, Kansas, Nebraska, and South Dakota. *P. weslizeni* also occurs in the Rocky Mountain region, from central Colorado to Mexico. The poplar *P. balsamifera* prefers the colder part of the Rocky Mountain region from Colorado and Wyoming north to Canada. *P. trichocarpa* grows largely along the Pacific coast in Oregon, Washington and California. *P. texana* is limited to the Panhandle and central part of Texas. *P. fremontii* occurs from western Texas to Nevada, Arizona, and California. It is intolerant of shade, as are most cottonwoods.

Measurements of consumptive use of water by cottonwoods and willows growing in tanks along the San Luis Rey River, Calif., were made by Muckel and Blaney in 1939-44 (1945, p. 54). The average annual use was 5.2 feet with the water table at 4 feet, and 8.1 feet with the water table at 3 feet. Density was 100 percent. Although the trees were dormant during most of the winter months, grass and weeds grew vigorously throughout the year.

As part of the detailed studies of the use of water by bottomland vegetation in the lower Safford Valley, Ariz., cottonwood plants (*P. fremontii*) were grown in tanks. The use of water by the plants during the period October 1, 1943, to September 22, 1944 (Gatewood and others, 1950, p. 138), at 100-percent density was 7.64 feet with the water table at 7.0 feet. In applying the tank data to the areas of cottonwoods in the valley, it was estimated that the annual use for 100-percent volume density was 6.0 feet, including 0.57 foot of precipitation. The water table in the valley ranged in depth from 4 to 30 feet below the land surface.

Information as to the depth that cottonwood will send its roots to the water table is scanty. Meinzer (1927, p. 58) quotes reports of cottonwoods growing where the depth to water was 20 feet. The writer has observed cottonwoods growing in areas where there was reason to believe that the depth to the water table was between 25 and 30 feet. Thirty feet is believed to be near the limit.

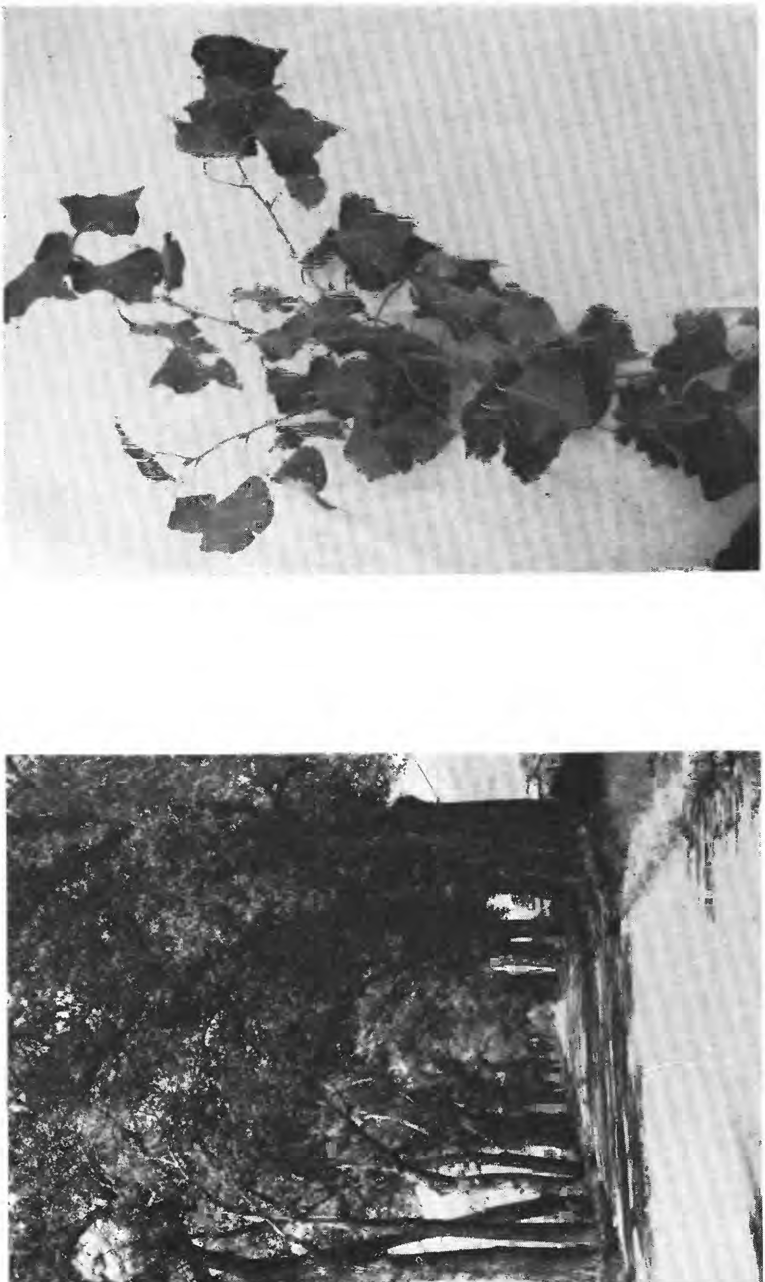


FIGURE 25.—Cottonwood trees planted long ago meet overhead to provide shade along a road east of Carson City, Nev. Right, cottonwood branch and leaves.

Cottonwoods prefer a water of good quality, although they tolerate a water of moderate salinity.

The principal use for cottonwoods has been as shade trees (see fig. 25). They furnish browse for livestock when the leaves are within reach. The tree supplies lumber and veneer that is used principally for boxes and crates and as a source for excelsior and pulpwood.

SALIX — WILLOW

There are about 250 species of willows, practically all native to the North Temperate and Arctic Zones. According to Dayton (1931, p. 15), at least 80 (perhaps considerably more) species occur natively in the Far Western States. Willows are familiar to nearly everyone, for they compose one of the most prominent groups of woody plants that line the banks and flood plains of streams (fig. 28). They grow also in dense stands over moist bottom lands and in mountain meadows. The willow growth on the flood plain of the Humboldt River in Nevada is particularly outstanding. Because of the many species of *Salix* and the difficulty of distinguishing among them, generic reference will be made here except in the few instances when specific data are available.

Most species of willows are believed to be phreatophytes, for they are nearly always associated with moist situations. Sometimes they grow "with their feet in the water," but this is not a normal condition. General observations indicate that most of the willow growth occurs where the depth to the water table is less than 15 feet. Most willows prefer water of good quality and deep fertile soils. They have a low tolerance for alkaline or saline conditions.

Although willows are widespread, there is a dearth of data on the use of water by these plants. In the course of his investigations in the Escalante Valley, Utah, White (1932, p. 41) demonstrated conclusively that willows were using ground water in that area, but he made no determinations of the annual use. Daily water-level fluctuations averaging about 0.3 foot were observed in August 1926 in a water-table well in a thicket of willows. The willows (species not given) were "from 8 to 12 feet high and close together and apparently were putting on an abundance of woody growth as well as foliage." The water table was between 5 and 6 feet below the land surface.

Data on use are available for two localities, Santa Ana, Calif., and Isleta, N. Mex. At Santa Ana, Calif., a single plant of red willow (*Salix laevigata*) consisting of about 20 stems was transplanted to an isolated 6-foot-diameter tank 3 feet deep. The water level was maintained at a depth of 2.0 feet. The total use of water

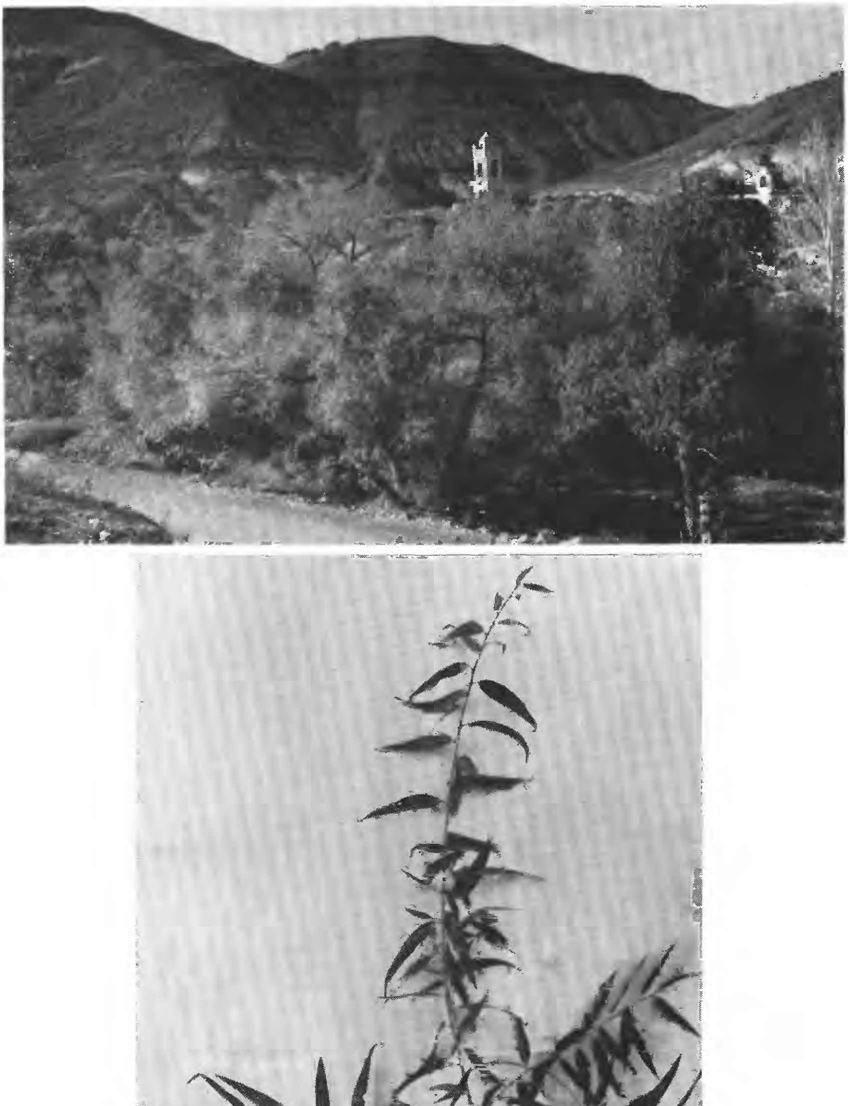


FIGURE 26.—An unusually luxuriant and tall growth of willows line the banks of Grapevine Creek at Scotty's Castle (background) in Death Valley National Monument, Calif., amidst nearly barren hills. Below, typical willow branch and leaves.

in 11 of the 12 months from May 1930 through April 1931 was 4.4 feet (Blaney and others, 1933, p. 65). There were no observations of use during January 1931. The amount used probably is high, because generally the use by an isolated plant is greater than that in a thicket. In an isolated growth the effect of sunlight, temperature, and wind movement on water use is greater than in thicket growth where the conditions are such as to reduce the effect of these factors.

At Isleta, N. Mex., a clump of willows 6 to 8 feet high was transplanted to a 6-foot-diameter tank located in a thicket of the same growth. The water level averaged about 13 inches below the surface. The use of water in the 12 months from June 1936 through May 1937 was 2.54 feet in depth for the area of the tank (Young and Blaney, 1942, p. 93).

Young and Blaney (1942, p. 144) summarize the use of water by willows as follows: "Willows usually grow where the roots extend into the ground-water region, and they appear to use the approximate equivalent of evaporation from a free water surface. Investigations with willows are limited, and this relation may vary for different localities."

Willows are important in erosion control, through stabilizing the soil on the banks of streams and gullies. They also form an important browse plant on the western ranges. In commerce their chief use is in the manufacture of wicker baskets and furniture.

SARCOBATUS — GREASEWOOD

Greasewood (figs. 24 and 27) is probably more widespread and covers more area than any other phreatophyte in the Western United States. It occurs from Canada south to northern Arizona, and it is the dominant phreatophyte of the Great Basin. It is primarily a plant of the cold desert, and so does not thrive in the southern deserts, except at altitudes above 5,000 feet. On the basis of Shantz and Zon's natural vegetation map of the United States, Dayton (1931, p. 2) reports that greasewood covers "19,551 square miles" or about 12.5 million acres in the West. It may occur as pure stands, or, as is quite common where the water table is shallow, in association with two other phreatophytes, rabbitbrush and saltgrass. On higher lands where the water table is at depths of about 10 to 50 feet, it may be found in association with shadscale, rabbitbrush, or sagebrush.

Greasewood is a deep-rooted plant. According to Meinzer (1927, p. 41), greasewood was found growing in the Big Smoky Valley, Nev., where the depth to water was as much as 33 feet; near Grand View, Idaho, H. T. Stearns observed roots of greasewood pene-

FIGURE 27.—A vigorous clump of greasewood (*Sarcobaus vermiculatus*) nearly 8 feet in height growing along Highway 50 west of Grand Junction, Colorado.

FIGURE 28.—Willows and cottonwood (tall trees) line the banks and cover the adjacent lowland of the Carson River in Carson Valley, Nevada.

trating the roof of a tunnel 57 feet below the surface. Shantz and Piemeisel (1940, p. 32) report that near Moab, Utah, along a creek bank where the roots were exposed

> . . . . a greasewood 6 feet tall had roots down 18 feet, a taproot 3 inches in diameter down 6 feet and abundant feeding roots, some 10 feet long, at a depth of 10 to 12 feet.

Although greasewood is a very salt- and alkali-tolerant plant, it is not confined to saline or alkali soils. The range in soil salinity is wide, from 0.05 to 1.6 percent or 500 to 16,000 ppm (U. S. Dept. of Agriculture, 1954, p. 57).

Greasewood also has a wide range in tolerance to alkali, and, although alkali is not necessary for its growth (Shantz and Piemeisel, 1940, p. 33), the plant is characteristic of black-alkali sites. The physical properties of the soil occupied by greasewood have a considerable range. Although it generally grows on fine-textured soils of low permeability, it also inhabits light, sandy soils. It may be seen in sand-dune areas where the ground water is at shallow depth.

Evidence for the wide range of tolerance of greasewood to the soluble solids in both soil and ground water has been shown by Meinzer (1927, p. 81, 82). Ten samples of ground water from areas of greasewood growth in the Big Smoky Valley, Nev., had a range in dissolved solids of 137 to 2,400 ppm, and in chloride of 4 to 501 ppm. The total soluble salts in 11 samples of soil from the same valley, collected at depths of 1 to 6 feet, ranged from 0.81 to 2.19 percent of the total dry soil by weight. If the specific gravity of the soil is about 1.6 and the porosity about 40 percent, the soil extract would range from about 30,000 to about 90,000 ppm in dissolved salts.

A sample of soil from an area of greasewood growing on the fringe of a saline flat in which there was a sparse growth of pickleweed was collected in April 1953 in the Malad Valley, Idaho. For comparative purposes a sample of soil from the area of pickleweed growth was collected at the same time. The chemical analyses of these two samples of soil are given on page 51. On the basis of the analysis, the soil of the greasewood area may be considered a "black-alkali" soil, and that of the pickleweed area a "saline" soil.

Samples of plant tissue for chemical analysis were collected from both the greasewood and the pickleweed (p. 51) plants at the same time and place as the soil samples. The analytical results for the greasewood plant tissue and for the soil sample on a comparative basis are given below.

Chemical analysis of soil from greasewood area and plant tissue of greasewood, Malad Valley, Idaho

[Analysis, by U. S. Bureau of Reclamation, in milligrams per gram of soil or plant tissue]

Constituent	Soil	Plant tissue: Leaf	Stem	Branch	Root
Calcium	0.0034	9.21	8.06	4.74	8.81
Magnesium	.0026	3.16	1.03	.69	.58
Sodium	.1120	69.54	5.29	1.46	1.89
Potassium	.0192	29.15	8.21	2.54	3.24
Chloride	.0238	20.53	2.05	.10	1.16
Sulfate	.0250	10.49	4.22	4.53	8.52
Boron	.0007	.005	none	.02	.005

Data on the use of ground water by greasewood are meager. The only tank experiments of record were made by W. N. White (1932) in the Escalante Valley, Utah. One tank was operated from June to October 1926 and May to October 1927. The record for 1926 was not considered representative, owing to the shock of transplanting to the tank in April and to the fact that the record covered only a part of the growing season. In the 1927 growing season, the evapotranspiration discharge including rainfall was 2.47 feet and excluding rainfall was 2.10 feet (White, 1932, p. 100) with a water table between 1.25 and 2.5 feet below the surface of the tank. As this tank was isolated (White, 1932, pl. 8B), the use likely was higher than if the tank had been in a natural environment of greasewood. The seasonal use of ground water computed from the diurnal fluctuations of water levels in greasewood and greasewood shadscale tracts where the water table stood 5 to 10 feet below the land surface ranged from 0.08 to 0.38 foot. It is difficult to make comparisons between the results of the tank experiment and the results based on diurnal fluctuations. The higher values for the tank experiment may be due in part to the isolation of the tank and in part to the shallower depth to the water table. A difference in the density and vigor of the growth in the tank and around the wells also would affect the use of water, for, as shown by Gatewood and others (1950), the use varies directly with the growth density.

Dayton (1931, p. 39) rates greasewood as an important range browse, although cautioning that, if stock eat too much of it, poisoning may result from the large concentration of oxalate in the edible parts of the plant. Greasewood is of value in erosion control, for in some places on the desert it is the only plant that will grow. In sand-dune areas where the water table is near the surface, greasewood, usually growing in clumps, has a stabilizing effect.

TAMARIX — SALTCEDAR

Tamarix gallica, tamarisk, or saltcedar, is a plant native to western Europe, the Mediterranean region, and western Asia, and was introduced into this country before the turn of the century. According to Bowser (1957, p. 3–5) introduction of the plants into North America is not of firm record. He reports that,

> The first reliable herbarium record indicates that a collection of *Tamarix* was made by J. F. Joor in 1884 on the San Jacinto River, Harris County, Texas, and at that time the species was naturalized completely in that area. In 1877 a specimen identified as *Tamarix gallica* was collected in Fairmont Park, Philadelphia. Heller and Hapeman collected specimens of this species along the ocean near Corpus Christi and Galveston, Texas in 1894, but other collections of the species were made only infrequently until 1915. After that widespread collections of tamarisk were made in the tributaries to most drainage channels throughout southwestern United States indicating that the plants were then established widely in the plant communities. Complete invasion of these nonendemic plants now is evidenced along many natural water courses.

According to Dodge (1951, p. 71), eight species of the genus were introduced by the Department of Agriculture between 1899 and 1915. There is other evidence to indicate that other plants of the genus, species unknown, found their way into this country at a much earlier date. For example, in the historical novel "Death Comes for the Archbishop," the author, Willa Cather, notes on page 228 "old, old tamarisks, with twisted trunks," in the Bishop's garden in Sante Fe. The time of the observations is placed about May 1859. There are between 60 and 75 species throughout the world, of which it is estimated that 40 may occur in the United States. Of these, only two species, *T. aphylla* and *T. gallica* (the latter also referred to as *T. pentandra*), appear to be important as phreatophytes. Both appear to thrive best in the arid regions south of the 37th parallel and below an altitude of 5,000 feet in the southwestern United States.

Tamarix aphylla, commonly known as the athel tree, is the less aggressive of the two. It is a rapid grower and makes a fine shade tree in areas where other trees cannot exist because of saline conditions, and also is much used for hedges and windbreaks in the Southwest. It has been observed to reach heights of more than 40 feet (fig. 29). The species is not known to reproduce by seed (Bowser, 1957, p. 4) and, consequently, the plant does not create the problem of spreading into areas where it is not desired. It differs from *T. gallica* also in that it is not deciduous but retains its leaves and remains green throughout the year. In other respects, it is much like *T. gallica,* for it appears to thrive best under arid or semiarid conditions, has a high tolerance to saline or alkali soil

FIGURE 29.—This handsome specimen of the athel tree (*Tamarix aphylla*) growing along Rillito Creek on the outskirts of Tucson, Ariz., reaches a height of about 40 feet. Detail shows the long fronds that are not shed but remain green throughout the year.

FIGURE 30.—A dense and vigorous growth of saltcedar (*Tamarix gallica*) lines the banks along the dry (April 1954) bed of the Gila River in the Safford Valley, Ariz. This phreatophyte, which infests most stream valleys of the Southwest, is the heaviest known user of ground water. Below, the small delicate fronds that are shed in autumn.

FIGURE 31.—Saltcedar encroachment along the Pecos River about 35 miles upstream from Roswell, N. Mex. In 1953, saltcedar was growing on about 41,000 acres along the Pecos River in New Mexico. Photograph courtesy of Pecos River Commission, 1954.

FIGURE 32.—A vigorous growth of saltcedar along the bank of the Little Colorado River near Holbrook, Ariz. Reports indicate that this growth has taken place since about 1940.

and water, and, when growing under natural conditions, sends its roots to the water table. No data are available on the use of ground water by *T. aphylla,* although it has generally been regarded as about the same as that by *T. gallica.*

Tamarix gallica (figs. 30–32), sometimes called French tamarisk but more commonly known as saltcedar, is an aggressive, naturalizing, and spreading shrub that is native from western Europe to the Himalaya Mountains. Since its introduction into this country, it has spread rapidly and has infested large areas of river bottom and low-lying ground in Arizona, southern California, New Mexico, and Texas. It is a prolific seeder. One small plant has been estimated to bear over 600,000 seeds (Bowser, 1957, p. 6), and the seeds, being light, are readily disseminated by the wind. The seeds germinate rapidly, and, once established, the plant grows rapidly, usually at the expense of other vegetation. An example of the speed and aggressiveness with which the plant spreads is furnished by the record of its infestation along the Pecos River between Santa Rosa, N. Mex., and the Texas State line. Records indicate that before 1912 there were no saltcedars in the Pecos River basin. The first reports of a few seedlings were in 1912 in the McMillan Delta (Eakin and Brown, 1939, p. 11–18). These spread until, in 1915, they covered about 600 acres (National Resources Planning Board, 1942, p. 57). The plants continued to spread, not only in the delta but also up and down stream (fig. 31), so that in 1925 they covered 12,300 acres and in 1939, 13,000 acres. In 1950, the Pecos River Commission, from an aerial survey, found that between the Alamogordo Reservoir and the New Mexico-Texas State line saltcedar covered a total of 31,820 acres, and by 1953, an estimated 36,270 acres (Pecos River Commission, 1955, p. 9–10). Nearly 5,000 acres at the head of Alamogordo Reservoir was not included in the 1953 estimate, so that the total for the Pecos River Valley in New Mexico is about 41,000 acres. The average rate of spread, from 1912, when the first seedlings were observed, to 1953 was about 1,000 acres per year, but for the period 1950-53, excluding the area at the head of Alamogordo Reservoir, the average rate was about 1,500 acres per year. This is an increase of 50 percent in the rate of spread over the 41-year average. Such a rate of spread cannot continue indefinitely, for eventually a saturation point will be reached. It does, however, serve to show the aggressive nature of the plant. Perhaps even more significant is the increase in the area of dense saltcedar growth. In 1939, the area of dense growth was only 490 acres, but in 1950 it amounted to more than 7,715 acres (Pecos River Commission, 1955, p. 10), an average increase of nearly 660 acres per year.

Tamarix gallica[3] is without doubt the outstanding problem phreatophyte of the Southwest because of its aggressive nature and thirst for water. Use of ground water by this plant, at optimum volume-density, is among the highest, if not the highest, of any of the phreatophytes. Data on the use of ground water are available from studies on the Pecos River in New Mexico and the Gila River in Arizona. At Carlsbad, N. Mex., the average use of water during the period January to December 1940 by saltcedar grown in tanks with a 2-foot water level was 5.48 feet, and with a 4-foot water level, 4.68 feet (Blaney and others, 1942, p. 202).

The estimate of average annual use of water by saltcedar in the Carlsbad area of the Pecos River Valley, N. Mex., was 6.0 feet, including an average annual precipitation of 1.0 foot (Natl. Res. Plan. Board, 1942, p. 55).

Intensive studies on the use of water by saltcedar in the Safford Valley of the Gila River, Ariz., during 1943 and 1944 gave the following results:

From tank experiments at 100-percent volume-density, not including precipitation (Gatewood and others, 1950, p. 137):

Use, in feet	*Average depth to water level, in feet*
9.17	4.0
8.42	5.0
7.75	6.0
7.33	7.0
7(?)	8.0

Calculated from the diurnal fluctuations of water levels in wells located in thickets of saltcedar, the use of water was 6.03 feet at 100 percent volume density, not including precipitation, based on the average of 8 wells whose water level ranged from 3.8 feet to 8.5 feet below the land surface and averaged about 6.3 feet (Gatewood and others, 1950, p. 152–53).

Saltcedar is capable of sending its roots to considerable depth in search of water. Tamarisk roots (species unknown) penetrating to a depth of 30 meters (nearly 100 feet) were observed in excavations for the Suez Canal (Renner, 1915).

The uses of *Tamarix gallica* appear to be few. The wood is reported to make good fenceposts and the flowers are a source of honey. The plant is also high in tannins.

[3] Early references to the widespread deciduous species of saltcedar list it as *Tamarix gallica*. Recently a question has arisen as to whether it is *T. gallica* or *T. pentandra*. Except for minute floral differences the two plants are similar. The original name *T. gallica* is retained here.

FINDING INDEX FOR COMMON NAMES

COMMON NAME	SCIENTIFIC NAME
Alder	*Alnus*
Alfalfa	*Medicago sativa* Linnaeus
Arrowweed	*Pluchea sericea* Coville
Ash, Arizona	*Fraxinus velutina* Torrey
Ash, velvet	*Fraxinus velutina* Torrey
Aspen, quaking	*Populus tremuloides aurea* Tidestrom
Aster, spiny	*Aster spinosus* Bentham
Athel tree	*Tamarix aphylla* Linnaeus
Baccharis, broom	*Baccharis sarothroides* A. Gray
Baccharis, emory	*Baccharis emoryi* A. Gray
Baccharis, squaw	*Baccharis sergiloides* A. Gray
Batamote	*Baccharis glutinosa* Persoon
Bermuda grass	*Cynodon dactylon* (Linnaeus) Persoon
Boxelder	*Acer negundo* Linnaeus
Buffaloberry	*Shepherdia*
Burrobush	*Hymenoclea monogyra* Torrey and Gray
Burrobush, white	*Hymenoclea salsola* Torrey and Gray
Butternut	*Juglans micorcarpa* Berlandier
Carrizo	*Phragmites communis* Trinius
Catclaw	*Acacia greggii* A. Gray
Camelthorn	*Alhagi camelorum* Fischer
Chamiso	*Atriplex canescens* (Pursh) Nuttall
Chamiza	*Atriplex canescens* (Pursh) Nuttall
Cinquefoil, bush or shrubby	*Dasiphora fruticosa* Linnaeus
Cottonwood	*Populus*
Cumaru	*Celtis reticulata* Torrey
Desertbroom	*Baccharis sarothroides* A. Gray
Desertrush	*Juncus cooperi* Engelmann
Desertwillow	*Chilopsis linearis* Sweet
Devilsclaw	*Acacia greggii* A. Gray
Elder	*Sambucus*
Elderberry	*Sambucus*
Glasswort	*Salicornia europaea* Linnaeus
Do.	*rubra* Linnaeus
Do.	*utahensis* Tidestrom
Goldenrod, rayless	*Aplopappus heterophyllus* A. Gray
Greasewood, big	*Sarcobatus vermiculatus* (Hook) Torrey
Hackberry	*Celtis reticulata* Torrey
Heliotrope	*Heliotropium curassavicum* Linnaeus
Inkweed	*Suaeda torreyana* Watson
Iodinebush	*Allenrolfea occidentalis* (Watson) Kuntze
Iodineweed	*Suaeda torreyana* Watson
Juniper, Rocky Mountain (locally "swampcedar")	*Juniperus scopulorum*
Kom	*Celtis reticulata* Torrey
Lenscale	*Atriplex lentiformis* (Torrey) Watson
Lovegrass, alkali	*Eragrostis obtusiflora* (Fournier) Scribner
Mesquite	*Prosopis juliflora* (Swartz)
Mesquite, honey	*Prosopis juliflora* (Swartz)
Mesquite, screwbean	*Prosopis pubescens* Bentham
Mesquite, velvet	*Prosopis velutina* Wooton
Mulefat	*Baccharis viminea* Crandolle
Nogal	*Juglans microcarpa* Berlandier
Oak, California live	*Quercus agrifolia* Nee
Oak, Roble	*Quercus lobata* Nee
Palo verde, blue	*Cercidium floridum* Bentham
Palm, California	*Washingtonia filifera* Wendland
Palm, fan	*Washingtonia filifera* Wendland

COMMON NAME	SCIENTIFIC NAME
Pickleweed	*Allenrolfea occidentalis* (S. Watson) Kuntze
Purslane, lowland	*Sesuvium portulocostrum*
Pusley, Chinese	*Heliotropium curvassavicum* Linnaeus
Quailbrush	*Atriplex lentiformis* (Torrey) Watson
Rabbitbrush	*Chrysothamnus pumilus* (Nuttall)
Rabbitbrush, rubber	*Chrysothamnus nauseosus*
Do.	*nauseosus* var. *consimilis* (Greene)
Do.	var. *graveolens* (Nuttall)
Do.	var. *mohavensis* (Greene)
Do.	var. *oreophilus* (A. Nelson)
Do.	var. *viridulus*
Reed	*Phragmites communis* Trinius
Reedgrass, giant	*Phragmites communis* Trinius
Rosinbrush	*Baccharis sarothroides* A. Gray
Sacaton	*Sporobolus wrightii* Munro
Sacaton, alkali	*Sporobolus airoides* Torrey
Saltbush, four-wing	*Atriplex canescens* (Pursh) Nuttall
Saltbush, Nevada	*Atriplex lentiformis* (Torrey) Watson
Saltcedar	*Tamarix gallica* Linnaeus
Saltgrass	*Distichlis stricta* (Torrey) Rydberg
Saltgrass, Mexican	*Eragrostis obtusiflora* (Fournier) Scribner
Saltgrass, desert	*Distichlis stricta* (Torrey) Rydberg
Saltgrass, seashore	*Distichlis spicata* (Linnaeus) Greene
Saltwort	*Suaeda depressa* Watson
Sea-purslane	*Sesuvium verrucosum* Rafinesque
Seepweed	*Suaeda depressa* Watson
Seepweed, desert	*Suaeda suffrutescens* Watson
Seepweed, torrey	*Suaeda torreyana* Watson
Seepwillow	*Baccharis glutinosa* Persoon
Sequoia, giant or big tree	*Sequoia gigantea* (Lindley)
Sesuvium, warty	*Sesuvium verrucosum* Rafinesque
Smoketree	*Dalea spinosa* A. Gray
Smokethorn	*Dalea spinosa* A. Gray
Sprangletop	*Leptochloa fascicularis* (Lamarck) A. Gray
Spruce, Engelmann	*Picea engelmanni* Parry
Swampcedar	*See* Juniper, Rocky Mountain
Sycamore, Arizona	*Platanus wrightii* Watson
Tamarisk, French	*Tamarix gallica* Linnaeus
Tornillo	*Prosopis pubescens* Bentham
Uña de gato	*Acacia greggii* A. Gray
Vanadium bush	*Cowania stansburiana* Torrey
Vetch, sweet	*Hedysarum boreale* Nuttall
Walnut	*Juglans microcarpa* Berlandier
Watermotie	*Baccharis glutinosa* Persoon
Waterwillow	*Baccharis glutinosa* Persoon
Waterweed	*Baccharis sergiloides* A. Gray
Wildrye, creeping	*Elymus triticoides* Buckley
Wildrye, giant	*Elymus condensatus* Presl
Willow	*Salix*
Wiregrass	*Juncus balticus* Willdenow
Wirerush	*Juncus balticus* Willdenow
Yerba mansa	*Anemopsis californica* (Nuttall) Hooker and Arnott

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