Selected Trees and Shrubs Evaluated for Single-Row Windbreaks In the Central Great Plains

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Summary

Twelve years of testing several kinds of trees, shrubs, and grasses shows that effective single-row vegetative barriers for wind erosion control can be grown in semiarid areas without special care or maintenance. Information is provided on growth, survival, efficient water use, and effective wind protection. Climate for the test period is described in terms of the Palmer Drought Index. Redcedar, Russian mulberry, tamarisk, pampasgrass, American plum, Siberian elm, Russian-olive, caragana, and combinations of honeylocust and caragana and honeylocust and redcedar were some of the most promising windbreaks for use for wind erosion control in semiarid areas.

Introduction

Tree and shrub windbreaks to protect crops, livestock, and man have been recognized for a long time (*1*).[2] Windbreaks absorb and deflect wind forces and thereby modify the energy budget and microclimate in their leeward zones. Such modification or shelter effect influences windspeed, air temperature, soil temperature, and atmospheric humidity which, in turn, influence evaporation, plant transpiration, wind erosion, snowdrifting, and crop yields.

The amount and areal extent of shelter provided by any barrier depends on wind velocity and direction, and shape, width, height, length, and porosity of the barrier. Early shelterbelt planters believe the most desirable of those characteristics could only be obtained with wide, multiple-row plantings. Consequently, approximately 40 percent of the windbreaks planted from North Dakota to Texas by the Prairie States Forestry Project immediately after the Dust Bowl Days of the 1930's were 10 rows wide. About 50 percent were 5 to 7 rows wide and the remaining 10 percent were either 3, 4, 11, or 21 rows wide (*12*). Such wide barriers are effective but they waste valuable cropland.

Ideally, a single row of trees or shrubs that attain substantial and uniform height in a short time, retain branches to the ground and provide sufficient year-round density would use the least land and be most desirable.

Despite problems that may develop because single-row barriers have no safety factor against gaps when trees die, windbreaks are being more extensively used now with maximum use of all available land for crops. Single rows of privet are used in vegetable growing areas of New Jersey (*14*). Many single-row

Conversion table—English to metric units

To convert from	To	Multiply by
Feet	Meters	0.3048
Feet	Centimeters	30.48
Inches	Centimeters	2.54
Pounds/ft^3	Grams/cm^3	.01602
Grams/cm^3	Pounds/ft^3	62.46
Miles/h	Meters/sec	.447

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[2]Italic numbers in parentheses refer to Literature Cited, p. 15.

deciduous and coniferous tree barriers have been planted in the Northern Great Plains (*2, 7, 8, 9*). Single rows of willows are used in China (*4*) and single rows of caragana in Canada (*13*). Wind-tunnel studies have shown narrow belts to be nearly as effective as wider belts (*16, 17*), and evidence from abroad (*15*) indicates that field barriers need not be wide to modify microclimate effectively.

This report presents growth, survival, and shelter effect results from studies in the Central Great Plains from 1963 through 1974 to evaluate potentials of various trees and shrubs for use in single-row windbreaks.

Trees and Shrubs Tested

Seven species of deciduous trees, nine of coniferous trees, nine of deciduous shrubs, and two ornamental grasses were tested during the 12 years at one or all three Kansas locations. Common and scientific names of all species tested are given in table 1. Three annual crops—kenaf, sunflowers, and hybrid forage sorghum—also were tested the first 2 years of the study. Results of those tests are in the interim report (*6*) published in 1969.

Location and Climate of Test Sites

Test sites were in Kansas at the Sandyland Experiment Field, St. John, the Garden City Branch Experiment Station, Garden City, and the Colby Branch Experiment Station, Colby. The soils were Pratt loamy fine sands, Tivoli sandy loams, and Keith silt loams at St. John, Garden City, and Colby, respectively. Bulk densities in the tree rows averaged 1.37, 1.25, and 1.23 grams per cubic centimeter at St. John, Garden City, and Colby.

The climate of the areas for the test years is summarized in figure 1 in terms of the Palmer Drought Index (*3, 11*), which measures the cumulative intensity of dry and wet periods for a geographic area and characterizes the weather as in table 2. The drought index shows that all three test sites generally experienced rather dry conditions during most of the 12-year test, 1963 through 1974.

TABLE 1.—*Common and scientific names of species tested*

Common	Scientific
Deciduous trees:	
Mulberry, Russian	*Morus alba var. tatarica* Seringe.
Poplar, Lombardy	*Populus nigra* L. var. *italica* Muenchh.
Elm, Siberian	*Ulmus pumila* L.
Cottonwood, Necklace	*Populus deltoides* Marsh.
Honeylocust	*Gleditsia triacanthos* L.
Cottonwood, Plains	*Populus sargentii* Dode
Russian-olive	*Elaeagnus angustifolia* L.
Coniferous trees:	
Pine, Austrian	*Pinus nigra*
Pine, Jack	*Pinus banksiana* Lamb.
Pine, Pitch	*Pinus rigida* Mill.
Pine, Ponderosa	*Pinus ponderosa* Laws.
Pine, Red	*Pinus resinosa* Ait.
Pine, Scotch	*Pinus sylvestris* L.
Pine, Virginia	*Pinus virginiana* Mill.
Pine, White	*Pinus strobus* L.
Redcedar, Eastern	*Juniperus virginiana* L.
Deciduous shrubs:	
Honeysuckle, Tartarian	*Lonicera tatarica* L.
Lilac, Common	*Syringa vulgaris* L.
Sumac, Skunkbush	*Rhus trilobata* Nutt
Multiflora Rose	*Rosa multiflora*
Spirea, Van Houtte	*Spiraea*×*vanhouttei* (Briot) Zab
Plum, American	*Prunus americana* Marsh.
Privet, Amur North	*Ligustrum amurense*
Tamarisk	*Tamarix gallica*
Siberian peashrub	*Caragana arborescens* Lam.
Ornamental grasses:	
Pampasgrass	*Cortaderia selloana*
Bamboo	*Bambusa arundinacea*

TABLE 2.—*Classes for wet and dry periods, Palmer Drought Index (PDI)*

Index value	Character of weather
≥4.00	Extremely wet
3.00 to 3.99	Very wet
2.00 to 2.99	Moderately wet
1.00 to 1.99	Slightly wet
.50 to .99	Incipient wet spell
.49 to −.49	Near normal
−.50 to −.99	Incipient[1] drought
−1.00 to −1.99	Mild drought
−2.00 to −2.99	Moderate drought
−3.00 to −3.99	Severe drought
≤4.00	Extreme[2] drought

[1]Incipient drought indicates a dry-weather period when the need for moisture is definitely apparent.

[2]Extreme drought indicates a serious, disastrous, dry-weather condition lasting many months or even years.

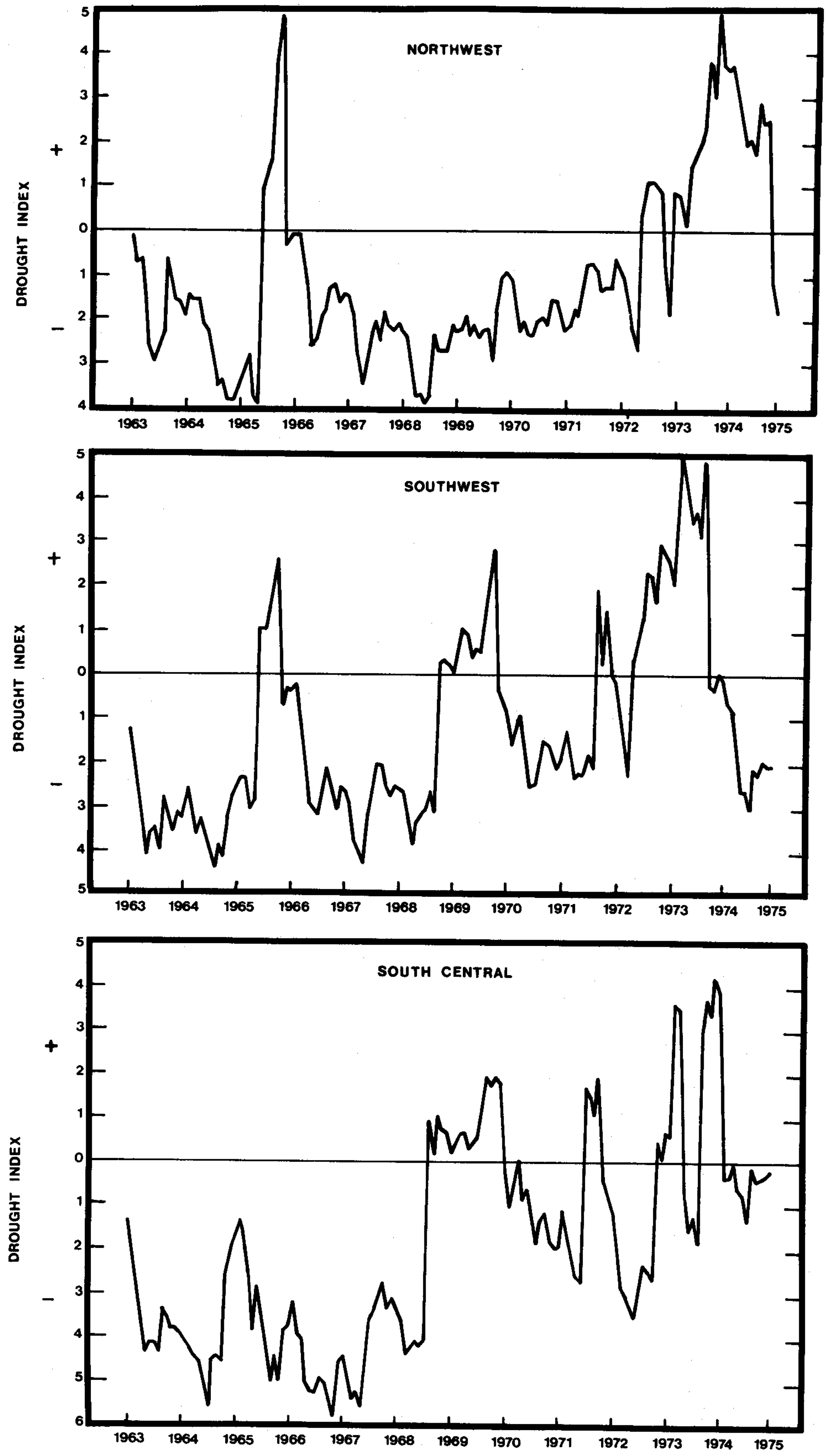


FIGURE 1.—Palmer Drought Index for northwestern (Colby), southwestern (Garden City), and central (St. John) Kansas, 1963-74.

The northwestern area (Colby) was dry approximately 73.6 percent of the time, wet 21.5 percent, and normal about 4.9 percent. That compares with 59.3, 34.3, and 6.4 percent for dry, wet, and normal, respectively, 1931 through 1974.

The southwestern area (Garden City) was dry about 65.3 percent of the time, wet 23.6 percent, and normal 11.1 percent. That compares with 56, 34, and 10 percent for dry, wet, and normal, respectively, 1931 through 1974. The central area (St. John) was dry approximately 70.2 percent of the time, wet 18.1 percent, and normal 11.7 percent—compared with 54.6, 33.5, and 11.9 percent for dry, wet, and normal for the 43 years.

Methods and Procedures

Planting procedure

Initial plantings consisted of 19 species at St. John and 12 at Garden City in 1963, and 23 at Colby the next year. More species were added during the tests and some were dropped after performing poorly. Length of test for each species at each location is indicated by years of growth (figs. 4 and 7).

Bare-root nursery stock of a given species was planted in about 100-foot-long single rows at spacing intervals of 1-foot for grasses and short shrubs; 3 feet for taller shrubs; 4 feet for poplars, cottonwoods, and elms; 5 to 6 feet for cedars and pines; and 6 feet for such taller, bushy trees as mulberry. All plants were planted in a continuous end-to-end row along fence lines at Colby and Garden City (fig. 2) but in six 400-foot rows each approximately 300 feet apart at St. John. Plants were thoroughly watered only once, when planted. They received no supplemental water thereafter. Those that died were replaced each spring for the first 3 years in an effort to establish a continuous barrier; however, the practice was discontinued after 3 years and measurements were continued only on original trees.

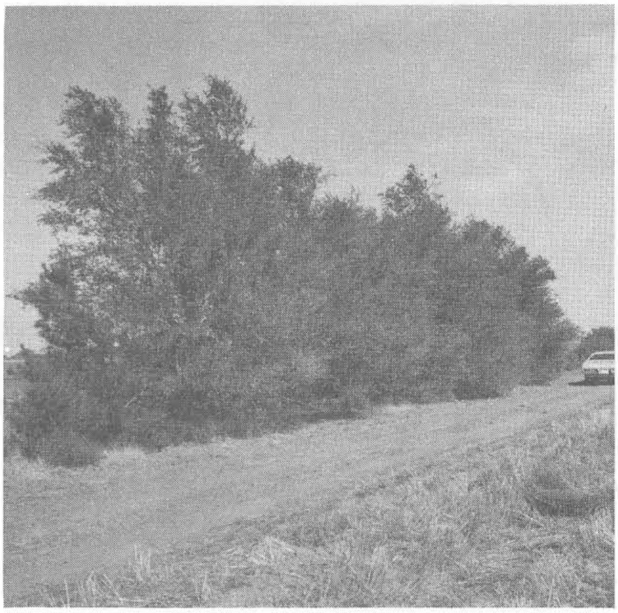


FIGURE 2.—General planting layout at Colby Branch Experiment Station, Colby, Kans.

Care and maintenance

Care and cultivation were minimum to evaluate performance under a condition that might exist on farms where little time or expense could be allotted to maintenance. Sweeps were run along each side of the rows when weeds became a problem, generally two or three times during the growing season. Usually twice a summer some hand hoeing and some rotary tillage with a small garden tractor were done.

Rabbits were a problem the first 3 years, especially at Garden City and Colby, so the trees and shrubs were sprayed anually the first 3 years with the repellent Tetramethylthiurmdisulfide and a sticking agent (Magic Circle Rabbit Repellent, Evans Orchard Supply Company, 305 Delaware Street, Kansas City, Mo.).[3] It was effective when applied early in the winter before rabbits began chewing on trees and shrubs.

Measurements

Height measurements and survival counts were made at the end of each growing season. Gravimetric soil moisture determinations were made each month during the growing season from selected locations at each site from 1965 through 1970 at Colby and Garden City and from 1965 through 1969 at St. John.

Soil samples were taken in tree rows to 42

[3]Trade and company names are included to provide specific information but they imply no endorsement or preferential treatment over products not mentioned by the U.S. Department of Agriculture.

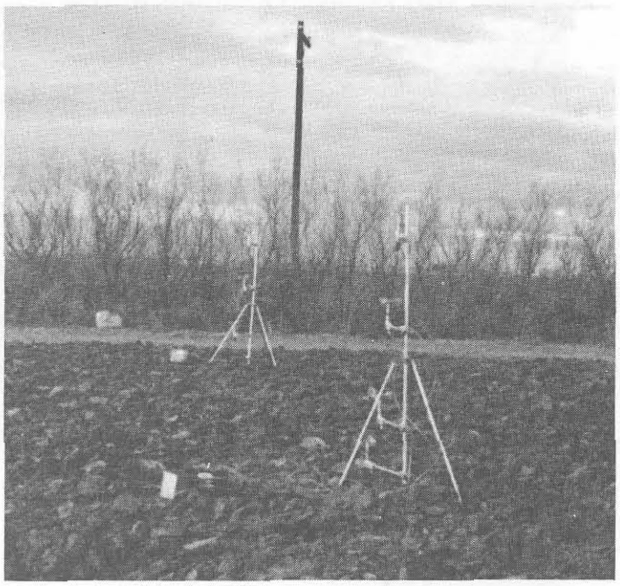


FIGURE 3.—Measuring wind velocities leeward of the tamarisk barrier at the Colby Branch Experiment Station, Colby, Kans.

inches deep in increments of 0 to 6, 6 to 18, 18 to 30, and 30 to 42 inches.

Wind velocity profiles were made windward and leeward of selected planting during late fall when the deciduous trees were defoliated after 4 years of growth and again after 11 years of growth (fig. 3). Velocity reduction patterns, resistance coefficients, and turbulence intensities for the 4-year data were included in the 1969 interim report (*6*). Velocity reduction patterns in the zone from the ground to 6 feet high 10H (H = barrier height) leeward for selected 11-year-old windbreaks are given in this paper. Velocity reduction was calculated from the relation:

Velocity reduction percentage = 100 $(1-U_L/U_o)$

where U_L is the average leeward velocity at given height and U_o is the average open-field velocity for the same height, time period, and elevation. An effectiveness index was also computed by summing the 16 products (velocity-reduction ratio times its leeward H distance), thus:

$$\text{Effectiveness index} = (1 - U_{1_{L_1}}/U_{1_{O_1}})1 + (1 - U_{1_{L_2}}/U_{1_{O_2}})2 + (1 - U_{1_{L_4}}/U_{1_{O_4}})4 + (1 - U_{1_{L_6}}/U_{1_{O_6}})6 + (1 - U_{1_{L_{10}}}/U_{1_{O_{10}}})10 + (1 - U_{2_{L_1}}/U_{2_{O_1}})1 \ldots + (1 - U_{4_{L_1}}/U_{4_{O_1}})1 \ldots + (1 - U_{6_{L_1}}/U_{6_{O_1}})1 \ldots + (1 - U_{10_{L_1}}/U_{10_{O_1}})1 \ldots + (1 - U_{10_{L_6}}/U_{10_{O_6}})10$$

where

$U_{1_{L_1}}, U_{1_{L_2}}, U_{1_{L_4}}, U_{1_{L_6}}, U_{2_{L_1}}, \ldots U_{10_{L_6}}$ are velocities at 1, 2, . . . 10H leeward of the windbreak at elevations of 1, 2, 4, and 6 feet.

In addition, the leeward distance fully protected from wind erosion was determined based on the average ultimate threshold velocity to initiate soil movement [14 miles per hour at 1 foot high (*5*)], assuming that wind velocity varies as the logarithm of height and average surface conditions for a smooth, bare fallow field with level terrain that has a ridge roughness equivalent of about 2 inches (*18*). Those distances are given for wind velocities of 17, 23, and 29 miles per hour at 1-foot elevation. Corresponding velocities at the 50-foot elevation, the reporting height used by many National Oceanic and Atmospheric Administration (NOAA) Weather Stations, also are given to facilitate use of this information.

Precipitation data from each of the three Branch Experiment Station record were used with soil moisture data to examine growth-water use relationships. The Palmer Drought Index (PDI) was calculated by using NOAA published weather records.

Results

Growth and survival

Deciduous trees.—Growth curves and survival percentages for deciduous trees are shown in figure 4 (lower). Siberian elm, Russian mulberry (fig. 5A and B), Plains cottonwood, and Russian-olive all show good growth and survival at Colby. Siberian elm and Russian mulberry were the only trees with adequate growth and survival at Garden City, but Russian-olive, Siberian elm, Russian mulberry, and Siouxland cottonwood had good growth and survival at St. John. Lombardy poplar grew rapidly during the first 4 or 5 years and produced a reasonably good windbreak; however, its high susceptibility to disease and insect attack then caused many trees to die, with complete kill at St. John after only 8 years (fig. 5C).

Deciduous shrubs.—Growth curves and survival percentages for deciduous shrubs are

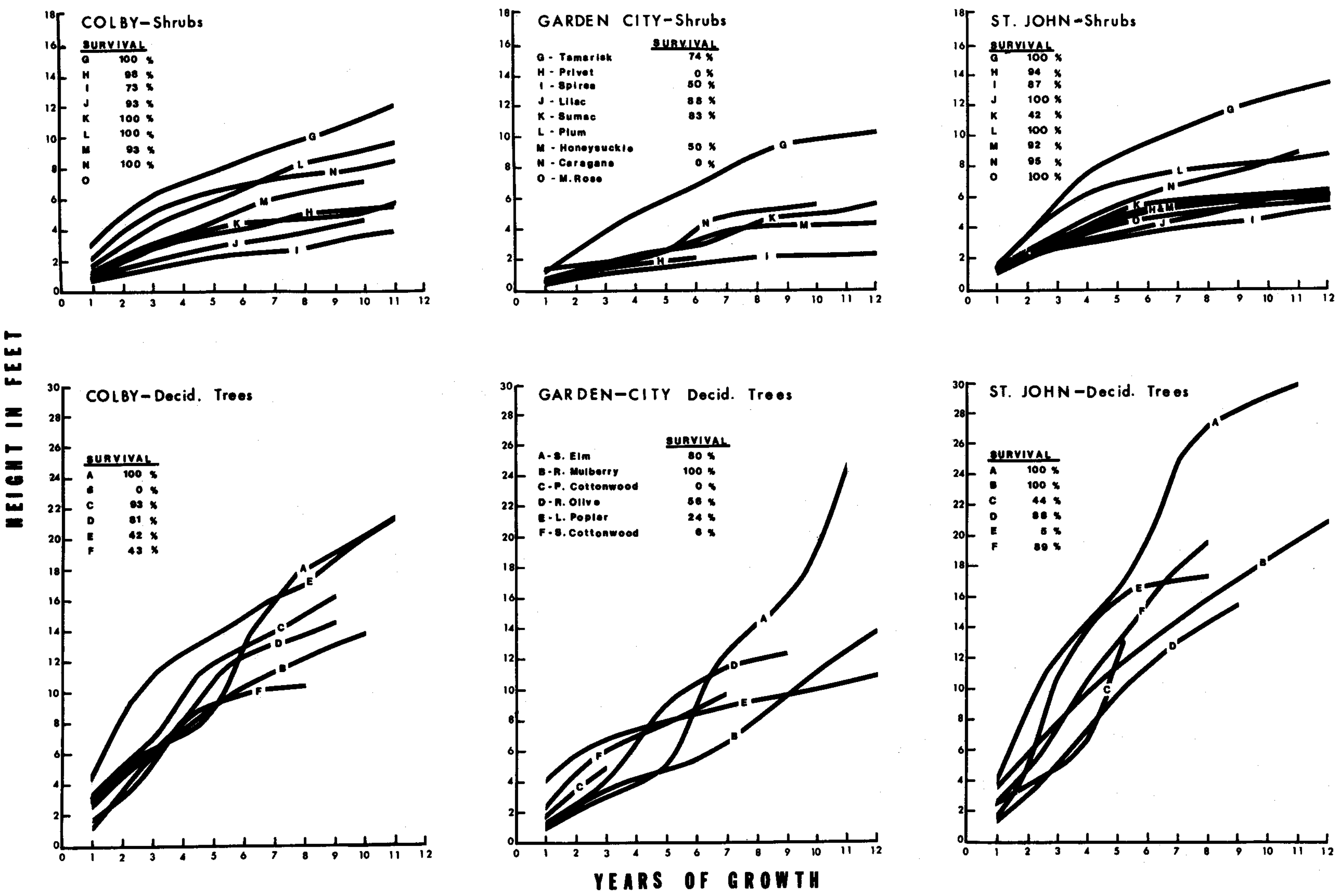
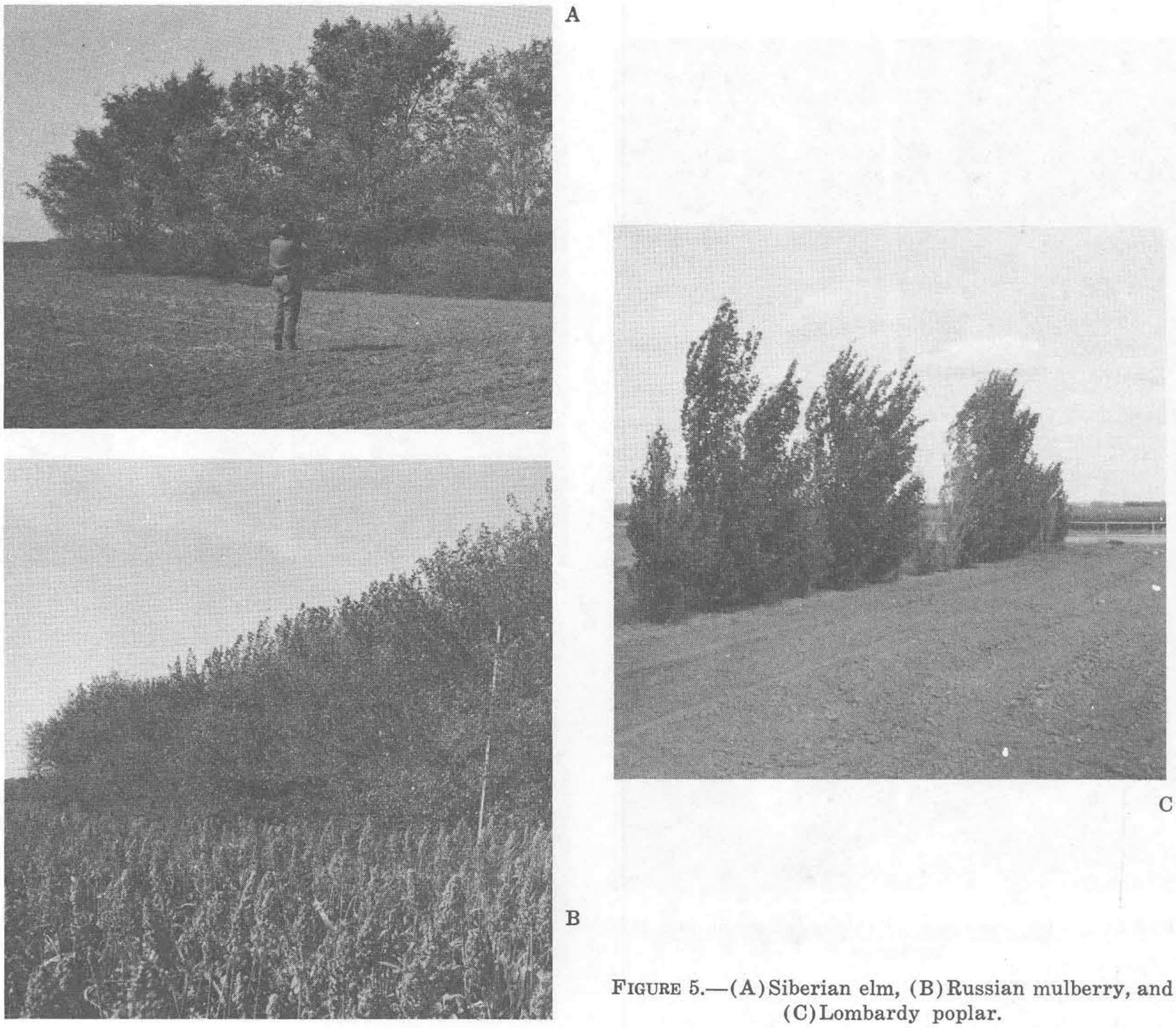


FIGURE 4.—Growth curves for indicated deciduous trees and shrubs.



A

B

C

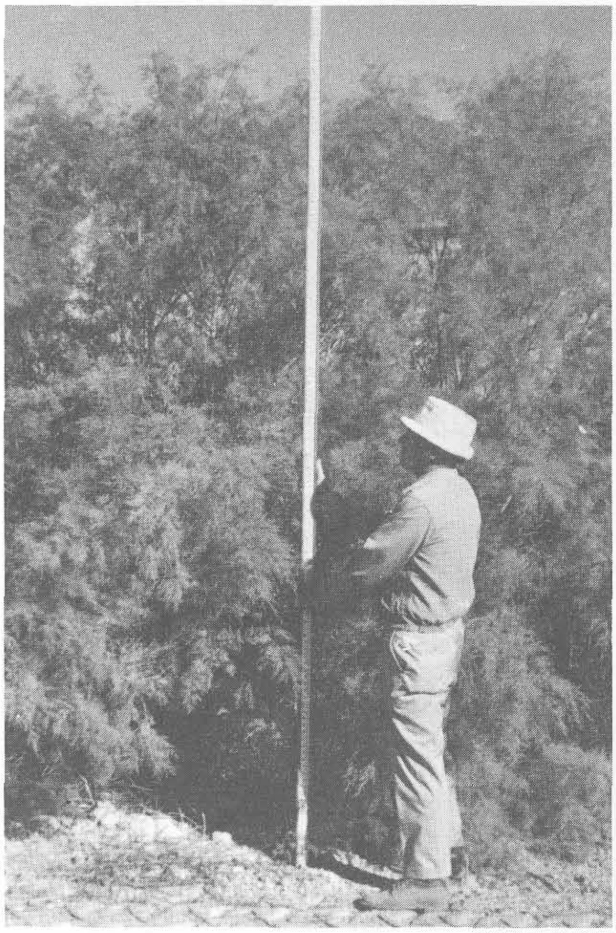
FIGURE 5.—(A) Siberian elm, (B) Russian mulberry, and (C) Lombardy poplar.

shown in figure 4 (upper). Tamarisk, American plum, caragana (figs. 6A, B, and C), honeysuckle, and fragrant sumac all grew and survived well at Colby. None of the shrubs did well at Garden City; tamarisk and fragrant sumac seem to be the best of those tested. Tamarisk, American plum, caragana, common lilac, and honeysuckle all grew and survived well at St. John.

Tree and shrub combinations. — Growth curves and survival percentages for the limited number of tree-shrub and tree-conifer combinations tested are shown in figure 7 (lower). Growth and survival of the honeylocust-caragana combination were reasonably good at Colby and Garden City (fig. 8A). The honeylocust-redcedar combination grew and survived well at Colby (fig. 8B) but redcedar survival was poor at Garden City. A valid comparison of the combinations cannot be made at St. John because the tests were terminated early there when consistent stands were not established. Results after 7 years indicate honeylocust-redcedar combinations are potentially effective barriers in the central test area. Poor survival of Lombardy poplar in the poplar-tamarisk combination, tried only at Colby, makes that an undesirable combination.

Coniferous trees.—Growth curves and survival percentages for all coniferous trees that survived through our evalution are shown in figure 7 (upper). In addition to the four species

A



B

C

FIGURE 6.—(A) Tamarisk, (B) American plum, and (C) caragana.

that survived at one or all locations, red and pitch pine failed 2 years at Colby, and red, white, Austrian, jack, and pitch pine all failed 2 years at St. John. Redcedar (fig. 9A) had the best survival record at all locations and grew tallest after 11 years at St. John. Tallest Virginia and ponderosa pines were at Colby (fig. 9B). In terms of growth and survival, all conifers tested could be recommended for planting at Colby; none could be recommended at Garden City; and redcedar and ponderosa pine appear to be best at St. John.

Ornamental grasses.—Pampasgrass (fig. 10A) was tested 12 years at Garden City and St. John and 11 years at Colby. Bamboograss (fig. 10B) was tested for 11 years at Garden City and St. John, but it winterkilled at Colby after 5 years. Average yearly height, excluding first year, for pampasgrass was 9.2 feet at Colby, 9.0 feet at Garden City, and 9.0 feet at St. John. Final survival was 82, 84, and 84 percent at Colby, Garden City, and St. John, respectively. Average yearly height, excluding first year, for bamboo was 9.2 feet at Garden City and 10.9 feet at St. John. Final survival was 87 percent at Garden City and 50 percent at St. John.

Soil water influences.—Water use in relation to growth of the trees and shrubs is summarized in figure 11. According to Kozlowski (*10*), most tree species initiate growth between April 15 and May 1 each year and complete 90 percent of their annual growth in 60 to 90 days. Therefore, water available for the trees' use, and assumed used by the trees, was determined by adding the inches of water in the soil profile

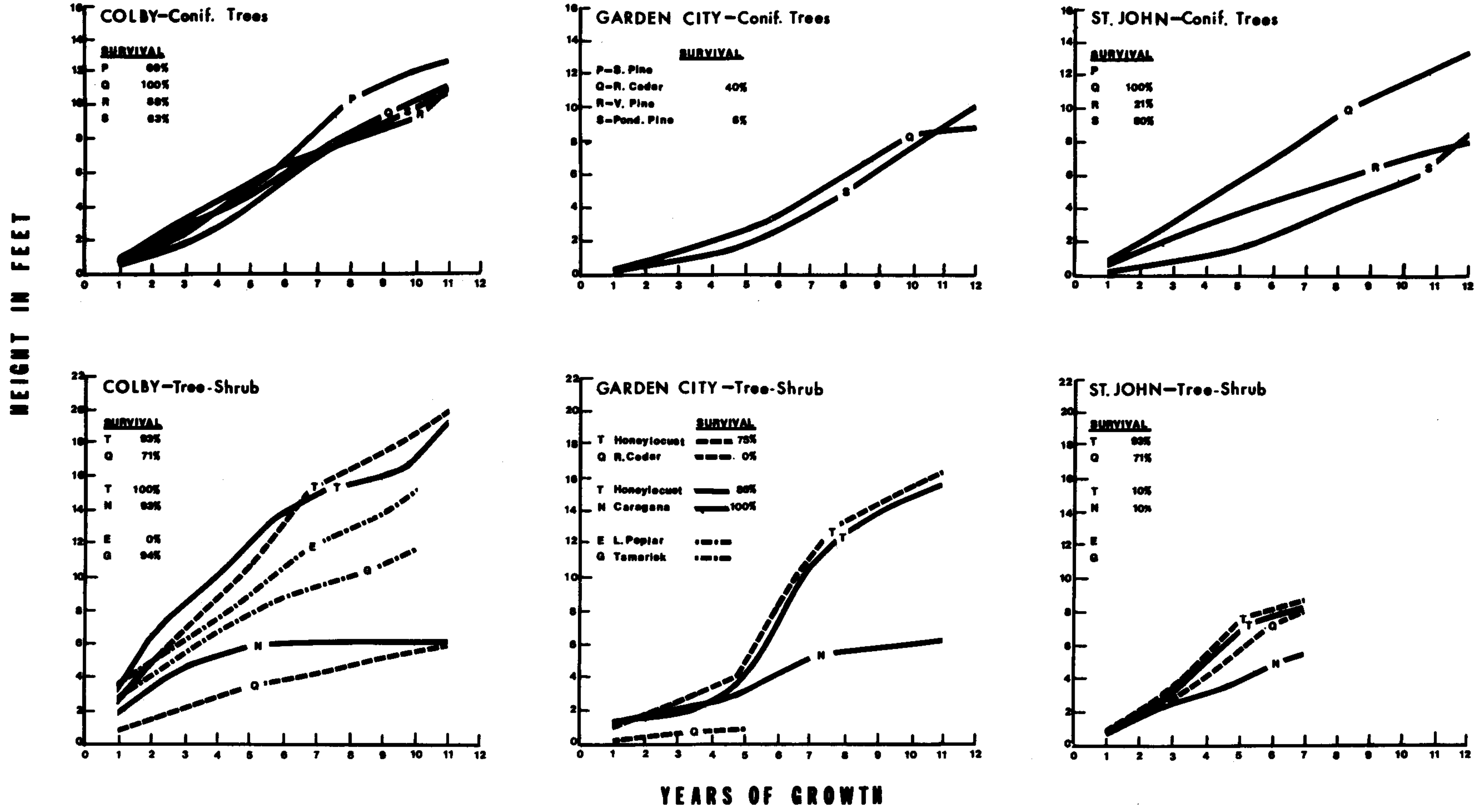


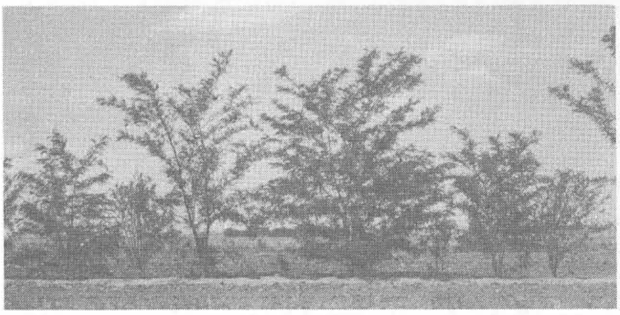
FIGURE 7.—Growth curves for indicated coniferous trees and tree-shrub combinations.

May 1 to the inches of precipitation received between May 1 and September 30 and subtracting the water in the soil profile September 30.

Inches of growth per inch of water used was calculated for the various trees and shrubs to provide a relative comparison of the different species at the three locations. Figure 11 shows that the most growth per unit of water was obtained by deciduous trees, followed by coniferous trees and shrubs. Differences in efficiencies are apparent within the broad categories, for example, Siberian elm averaged 2 inches of growth per inch of water used, while mulberry averaged only about 1 to 1; tamarisk 0.9 to 1; redcedar, 0.8 to 1; Virginia pine, about 0.6 to 1; spirea, poorest performer among the shrubs, 0.3 per inch of water used.

Although ornamental grasses do not provide so tall a barrier as trees, they compete well with shrubs in height and, as table 3 shows, water use efficiency is good.

Total climate influences.—Attempts to correlate annual growth of the trees and shrubs with the PDI generally failed. Apparently greater extremes in climate than encountered in the 12 years of this study are required for a significant relationship between tree growth and climate. Categorizing the climate according to



A

B

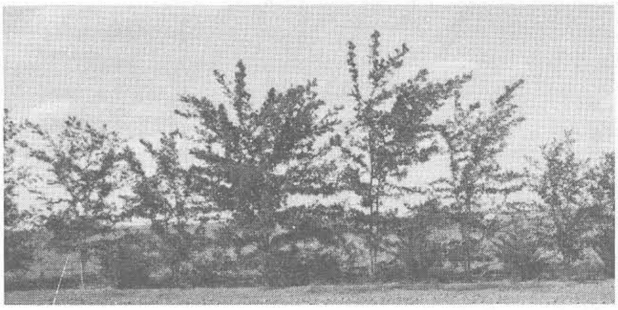
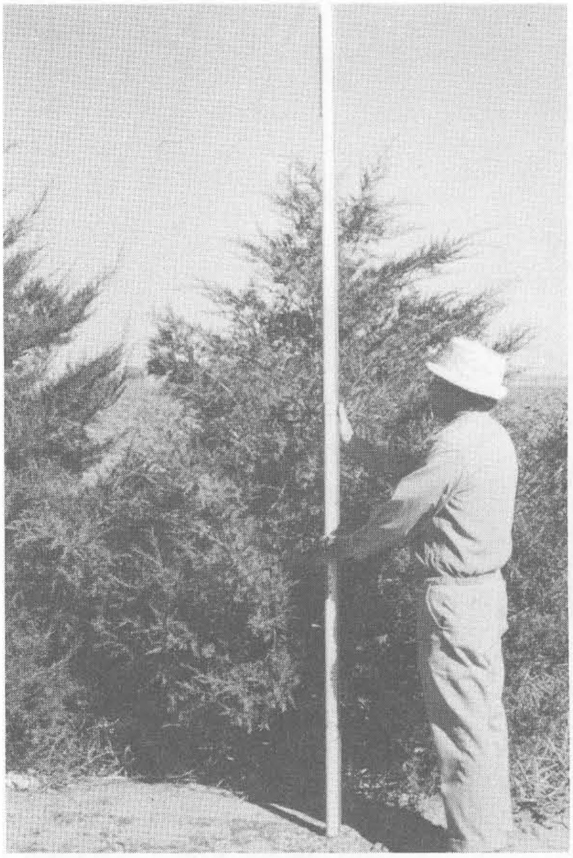


FIGURE 8.—(A) Honey locust-caragana and (B) honeylocust-redcedar.



A

B

FIGURE 9.—(A) Redcedar and (B) Virginia pine.

A

B

FIGURE 10.—(A) Pampasgrass and (B) bamboo.

table 2 shows that the St. John area experienced the severest climate with 9 years drier than normal: 3 years under extreme drought; 2 years under severe drought, 3 years under moderate drought, and 1 year under incipient drought conditions.

The Garden City area also had 9 years drier than normal but the climate was slightly less severe with 6 years' moderate drought, 2 years' severe drought, and 1 year of incipient drought.

The Colby area had the least severe conditions with 3 years of moderate drought, 5 years' mild drought, and 1 year of incipient drought. Figure 12 indicates some relative curves showing the annual growth of three species at the three locations and average annual PDI curves for the locations. Perhaps the closest cyclical correlation was at Garden City; in general, annual tree growth and annual PDI were not closely related.

Kozlowski (*10*) indicated that shoot formation of many trees is a 2-year process, with winter buds containing the primordia of the next season's growth. Therefore, a favorable environment during the year of formation is reflected in large shoot growth the next year, and height growth often is better related to the environment of the previous season. We examined data that way as well as in direct relation to current year growth and PDI, but the relationship was not improved.

Wind protection

Leeward wind velocity reduction patterns, effectiveness indices, and wind erosion-protected zones for seven of the barriers are summarized in figure 13. The effectiveness indices, which give relative comparisons of abilities of the barriers to reduce windspeed in the ground to 6-foot-height leeward zone ranged from 41.1 for tamarisk to 20.7 for the honeylocust-redcedar combination barrier. Siberian elm ranked third in effectiveness. It is susceptible to herbicide damage and to some extent to insect and disease attacks, but its relatively good performance in reducing wind leeward some distance and above ground level coupled with its rapid growth makes it one of the better barriers for use in the Central Great Plains to reduce wind to protect livestock and farmsteads.

The wind erosion protected zone (fig. 13), which indicates what happens at ground level, shows that tamarisk, honeysuckle, and plum would most effectively provide wind erosion control. Siberian elm provided reasonably good protection against winds up to 40 miles per

TABLE 3.—*Relative water use-growth efficiency of two ornamental grasses, pampas and bamboo*

Grass	Location		
	Colby	Garden City	St. John
	Inch/inch[1]	*Inch/inch*	*Inch/inch*
Pampas	6.6	6.9	6.7
Bamboo	([2])	6.2	7.2

[1]Inches of growth per inch of water used.
[2]Winter-killed.

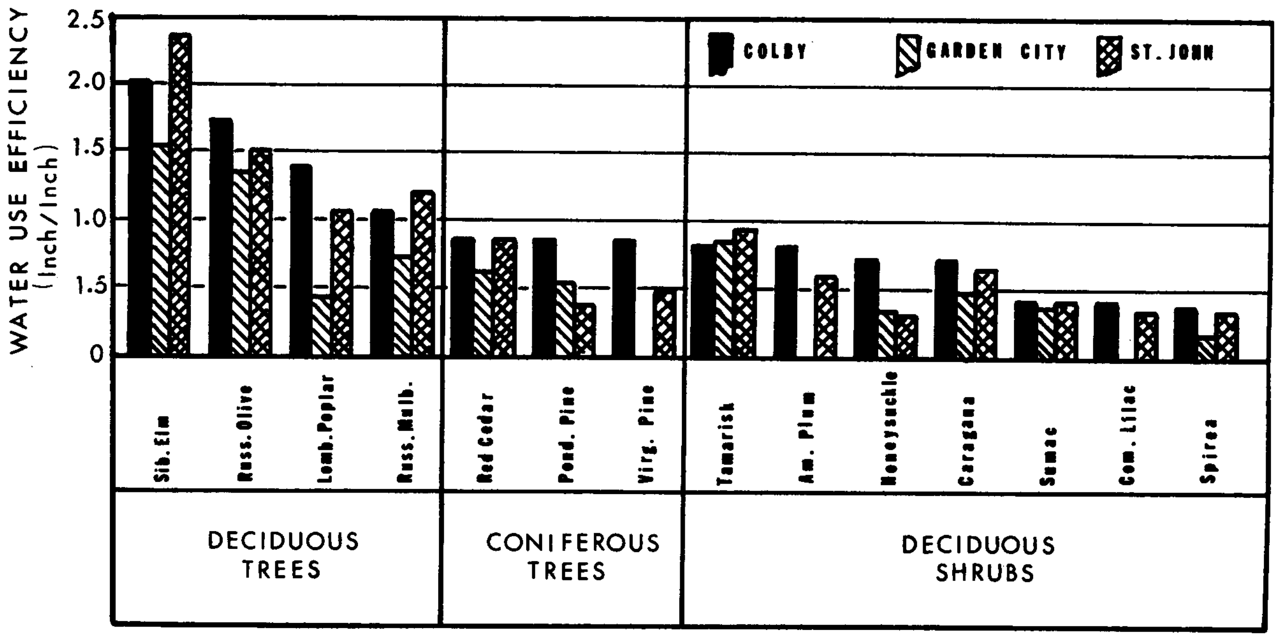


FIGURE 11.—Relative water use efficiencies for trees and shrubs.

hour at 50 feet but would not reduce the wind enough to protect soil from blowing when winds reach 50 miles per hour at 50 feet. The honey-locust-redcedar barrier is too open to offer any real protection even against 30-mile-per-hour winds at 50 feet.

Conclusions

Twelve years of testing several species of trees, shrubs, and grasses in southwestern, central, and northwestern Kansas, has shown that effective single-row vegetative barriers for wind erosion control in the Central Great Plains can be grown without special care or maintenance.

Some difficulty was experienced in establishing conifers, especially pines, but once started they grew and survived reasonably well at some locations. Redcedar and ponderosa, Virginia, and scotch pine have potential for use in windbreaks in the northwestern area. Only redcedar and ponderosa pine showed much potential for the central area and none of the conifers tested grew and survived well enough to be considered as single-row barriers in the southwestern area.

The deciduous trees (Siberian elm, Plains cottonwood, Russian-olive, and mulberry) grew and survived well in the northwest. Siberian elm, Russian-olive, mulberry, and Siouxland cottonwood grew and survived best in the central area. Siberian elm and mulberry were most promising by growth and survival for wind barriers in the southwest.

The deciduous shrubs (tamarisk, American plum, caragana, honeysuckle, and fragrant sumac, in that order) grew and survived best in the northwest. In the central area the best five shrubs in order of growth and survival were tamarisk, American plum, caragana, common lilac, and honeysuckle. Most of the shrubs failed in the drier southwestern area. Only tamarisk and fragrant sumac showed potential.

Growth and survival of combination honeylocust-caragana and honeylocust-redcedar barriers were reasonably good at the southwest and northwest test sites. Those combinations have potential for use as barriers in the south and northwest areas. A valid evaluation of tree-shrub or tree-conifer barriers cannot be made from our data for the central part because we terminated tests of combinations early because of failure to establish uniform stands. Seven years of results showed, however, that the honeylocust-redcedar combination had potential for barriers.

Pampasgrass produced an effective wind barrier every year at all three locations. However, bamboograss winter-killed at Colby after only

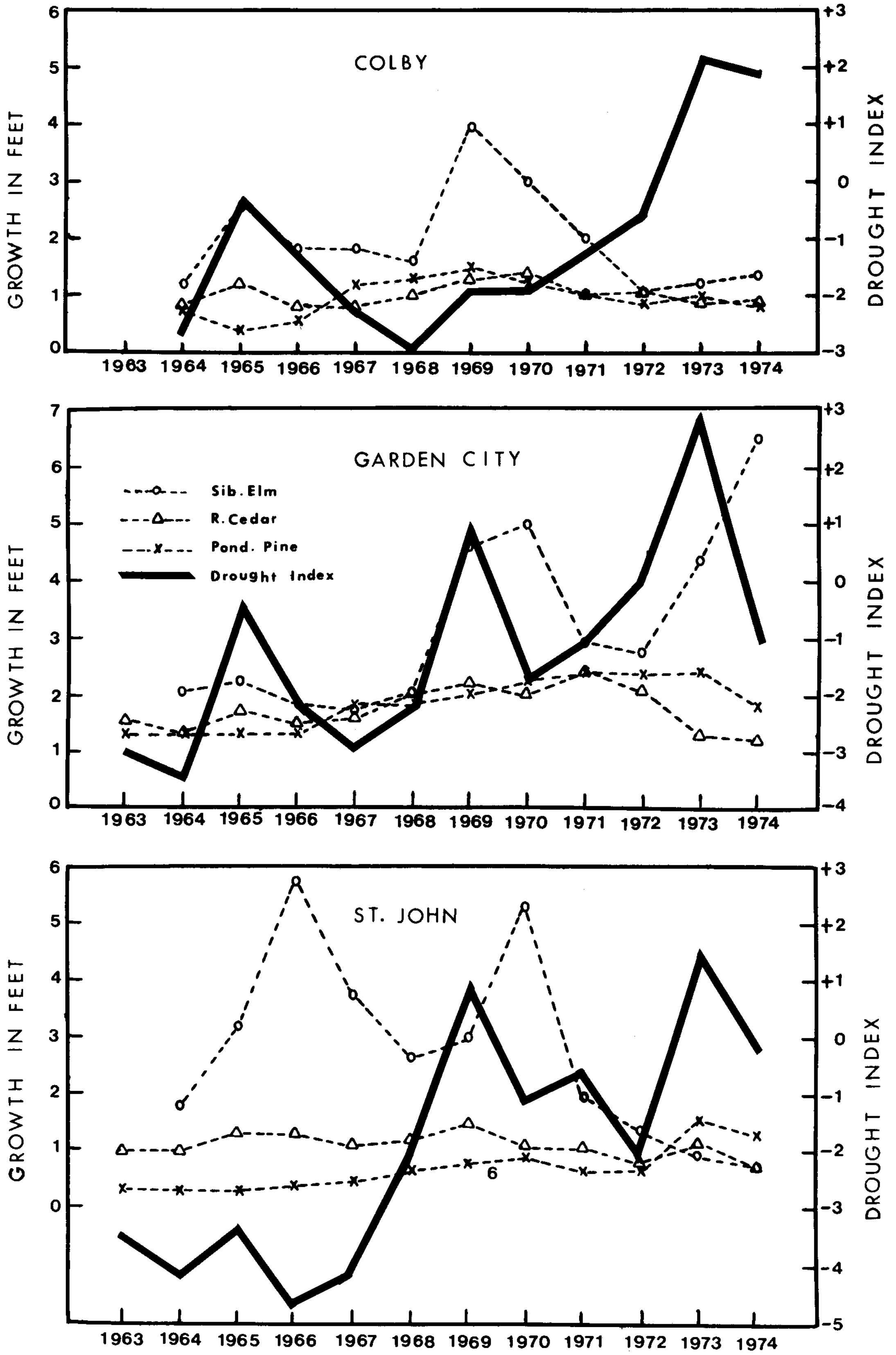
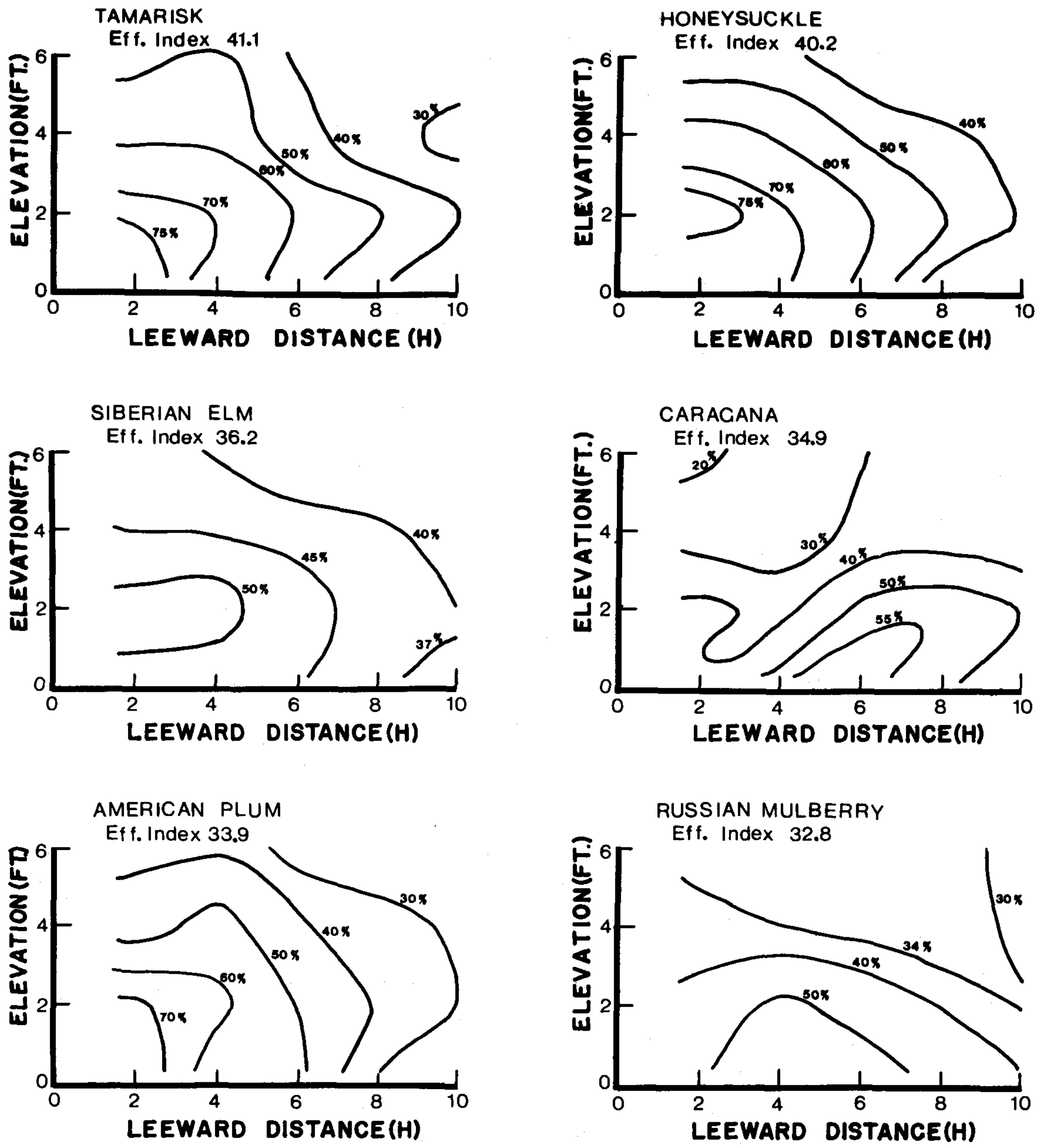
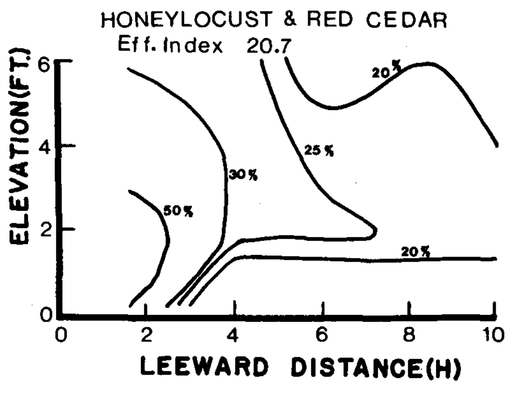


FIGURE 12.—Annual growth by three species in relation to the average annual Palmer Drought Index.





Wind-erosion-protected zones in terms of leeward H distance with windspeed reduced below 14 mph at 1 foot above ground when windspeed at 50-foot height ranges from 30 to 50 mph.

Barrier	Leeward distance protected from wind erosion when 1-foot elevation windspeed in mph is: 17 / 50-foot elevation windspeed in mph is: 30	23 / 40	29 / 50
Tamarisk	> 10	9.5	7.0
Honeysuckle	> 10	8.2	6.7
Siberian elm	> 10	8.7	0
Caragana	> 10	> 10	3.8
American plum	> 10	7.5	5.6
Russian mulberry	> 10	9.5	3.3
Honeylocust and redcedar	3.7	2.7	0

FIGURE 13.—Wind velocity reduction patterns and wind erosion protected zones for seven of the barriers.

5 years, and it is not recommended for planting in the northwest. These ornamental grasses are particularly effective as barriers because they stand well after frost and thus provide year-round protection. Their disadvantages are that considerable labor is involved in planting because they must be started from rootstock and bamboo tends to spread by widening its rows.

Evaluation of barrier growth in relation to water-use showed that ornamental grasses, deciduous trees, and shrubs, in that order, produced most height per inch of water used. Within those three broad categories, both ornamental grasses produced more than 6 inches of growth per inch of water used; deciduous trees ranged from 2 inches per inch of water by Siberian elm to about 1 inch per inch of water by mulberry; coniferous trees ranged from about 0.8 inch of growth per inch of water used to about 0.6 inch by Virginia pine; and deciduous shrubs ranged from about 0.9 inch of growth per inch of water by tamarisk to 0.3 inch per inch by spirea, the poorest performer among the shrubs.

Tree and shrub growth was not closely correlated with either concurrent year or prior-year PDI values. Apparently, variation in climate during the 12 years of this study was not great enough to discern differences in growth rates that might be directly related to immediate climatic condition.

Wind protection effectiveness indices (ground to 6-foot-height leeward) ranged from 41.1 for tamarisk to 20.7 for the honeylocust-redcedar combination barriers. Siberian elm with a value of 36.2 ranked third among the seven barriers evaluated. Best protection against wind erosion would be provided by tamarisk, honeysuckle, and American plum. Siberian elm would provide reasonably good protection against wind erosion for winds up to 40 miles per hour, but it is too porous to protect against winds of 50 miles per hour.

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