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Trees, Shrubs, and Annual Crops for Wind Barriers in Central and Western Kansas

AN INTERIM REPORT ON GROWTH, SURVIVAL AND SHELTER EFFECT

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in cooperation with

AGRICULTURAL EXPERIMENT STATION

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TREES, SHRUBS, AND ANNUAL CROPS FOR WIND BARRIERS IN CENTRAL AND WESTERN KANSAS
An Interim Report of Growth, Survival, Shelter Effect [1]

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PREFACE

Wind barriers absorb and deflect wind forces and thereby modify the energy budget and the microclimate in their leeward zones. The modification or shelter effect influences windspeed, air temperature, soil temperature, and atmospheric humidity, which in turn influence evaporation, plant transporation, wind erosion, snowdrifting, and crop yield.

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. For many years it was thought that the most desirable barrier characteristics could only be obtained with wide, multiple-row plantings. Generally, such barriers were slow growing and required considerable agricultural land.

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. A trend toward single-row barriers has developed recently. Single rows of privet are used in the vegetable-growing sections of New Jersey (1), many single-row deciduous and coniferous tree barriers have been planted in the northern Great Plains (2, 3), and single-row caragana hedges have been used in Canada for many years (4). Evidence here and abroad (5) indicates that field barriers need not be wide to effectively modify microclimate.

This is an interim report of growth, survival, and shelter effects of various trees, shrubs, and annual crops evaluated since 1963 as potential single-row wind barriers in central and western Kansas.

Species Tested

Seven species of deciduous trees, nine of coniferous trees, nine of deciduous shrubs, two of ornamental grasses, and three annual crops were tested during the 5 years at one or all of the four Kansas locations. Common and scientific names of all species tested are given in table 1.

TABLE 1.—Common and scientific names of species tested

Common	Scientific
Deciduous trees	
Mulberry, Russian	*Morus alba var. tatarica* Seringe.
Poplar, Lombardy	*Populus nigra* cv. lambardy
Elm, Siberian	*Ulmus pumila* L.
Cottonwood, Siouxland	*Populus deltoides*
Honeylocust	*Gleditsia triacanthos var. inermis*
Cottonwood, Plains	*Populus sargentii* Dode
Russian-olive	*Elaeagnus angustifolia* L.
Coniferous trees	
Pine, Austrian	*Pinus nigra* Arnold
Pine, Jack	*Pinus banksiana* Lamb.
Pine, Pitch	*Pinus rigida*
Pine, Ponderosa	*Pinus ponderosa* Laws.
Pine, Red	*Pinus resinosa*
Pine, Scotch	*Pinus sylvestris* L.
Pine, Virginia	*Pinus virginiana*
Pine, White	*Pinus strobus*
Redcedar, Eastern	*Juniperus virginiana* L.
Deciduous shrubs	
Honeysuckle	*Lonicera tatarica* L.
Lilac, Common	*Syringa vulgaris* L.
Sumac, Skunkbush	*Rhus trilobata* Nutt. ex T. & G.
Multiflora Rose	*Rosa multiflora* Thunb.
Spirea, Van Houtte	*Spiraea* X *vanhouttei* (Briot) Zab
Plum, American	*Prunus americana* Marsh.
Privet, Amur North	*Ligustrum amurense*
Tamarisk	*Tamarix*
Caragana, Siberian peatree	*Caragana arborescens* Lam.
Ornamental grasses	
Pampasgrass	*Cortaderia selloana*
Bamboo	*Bambusa arundinacea*
Annual crops	
Sunflower	*Helianthus annuus* L.
Kenaf	*Hibiscus cannabinus*
Hybrid forage sorghum "Cropguard"	*Sorghum vulgare*

LOCATION AND CLIMATE OF TEST SITES

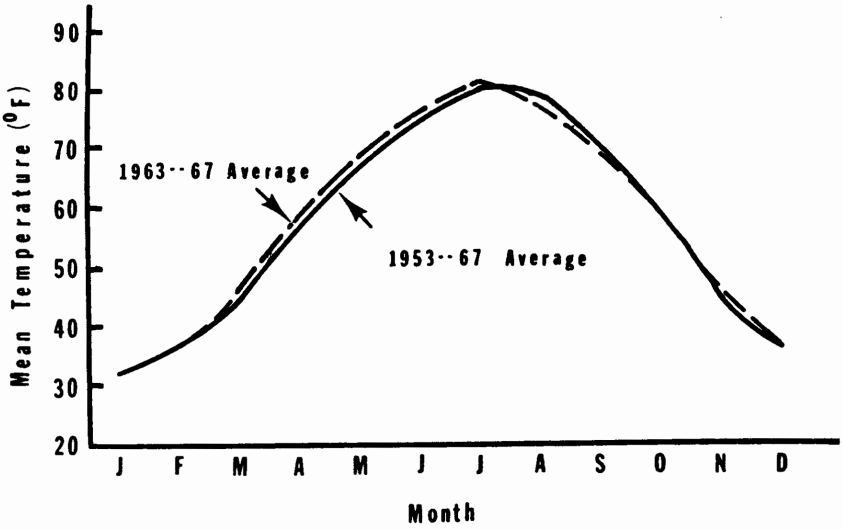
Main test sites were the Sandyland Experiment Field, St. John, Kansas; the Garden City Branch Experiment Station, Garden City, Kansas; and the Colby Branch Experiment Station, Colby, Kansas. Supplemental trials of the forage sorghum "Cropguard," sunflower, and several varieties of kenaf were conducted at Manhattan during 1964 and 1965. Average precipitation and temperature data for St. John, Garden City, and Colby are given in figures 1, 2, and 3. Mean temperatures for the principal growing season, April through September, for 1964 through 1967 were 71°, 68°, and 65° F., respectively, for St. John, Garden City, and Colby—all 1° less than longtime averages. Average seasonal precipitation for those 4 years was 2.84, 2.53, and 2.27 inches, respectively, for St. John, Garden City, and Colby. This was slightly above the 2.66- and 2.39-inch longtime averages for St. John and Garden City but slightly below the 2.50-inch longtime average for Colby.

HOW TESTS WERE CONDUCTED

Planting Procedure

Initial plantings consisted of 19 different kinds of plants at St. John and 12 at Garden City in 1963, and of 23 kinds at Colby the next year. More plants were added during the test at all locations and some species were dropped after performing poorly. Years tested are indicated in the table in the "Comparison of Barriers" section of this report.

Plants of a given species were planted in approximately 100-foot-long single rows at spacing intervals in the row 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. Three combination barriers, one of honeylocust and cedar, one of honeylocust and caragana, and one of poplar and tamarisk, also were planted at 4-foot intervals in the row. All plants were planted in one continuous end-to-end row along field fence lines at Colby and Garden City 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 in an effort to establish a continuous barrier.



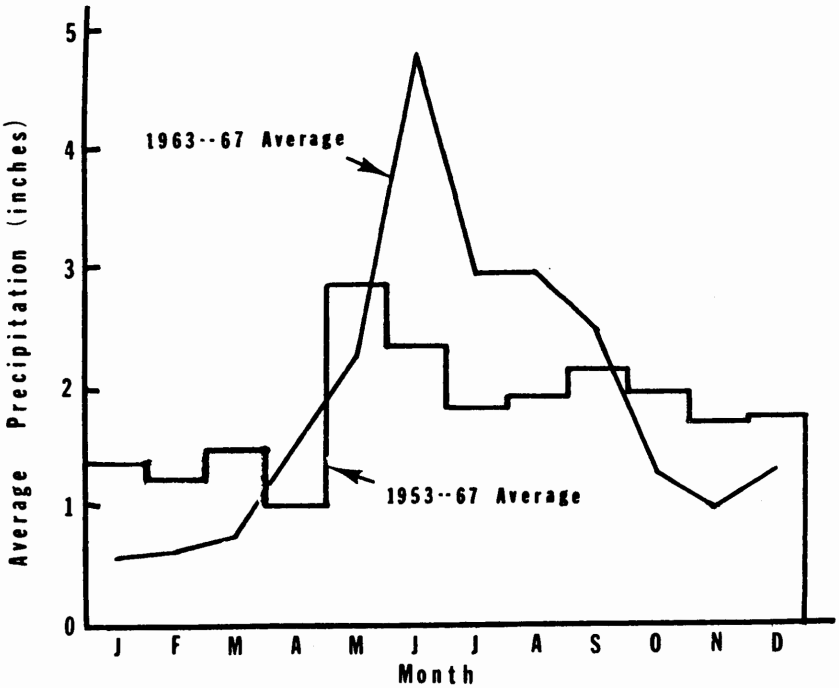


FIGURE 1.—Average temperatures and precipitation, Sandyland Experiment Field, St. John, Kansas, 1953-67 and 1963-67.

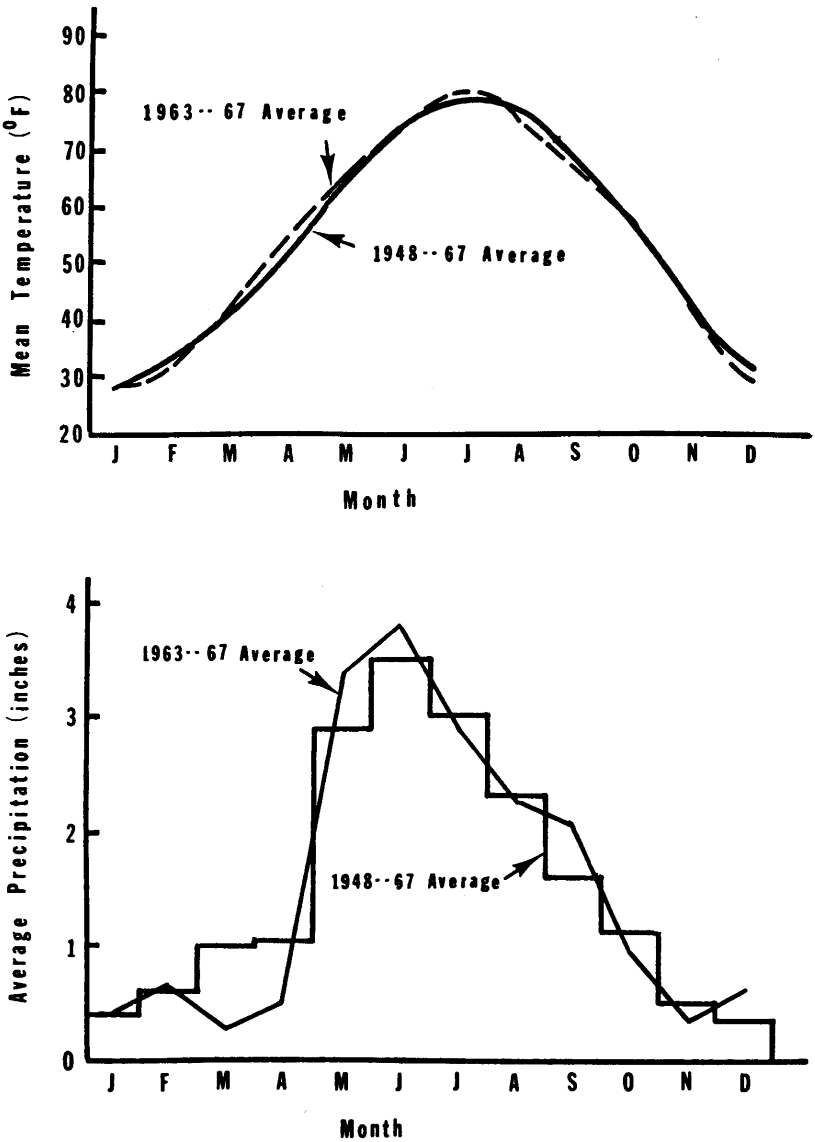


FIGURE 2.—Average temperatures and precipitation, Garden City (Kansas) Branch Experiment Station, 1948-67 and 1963-67.

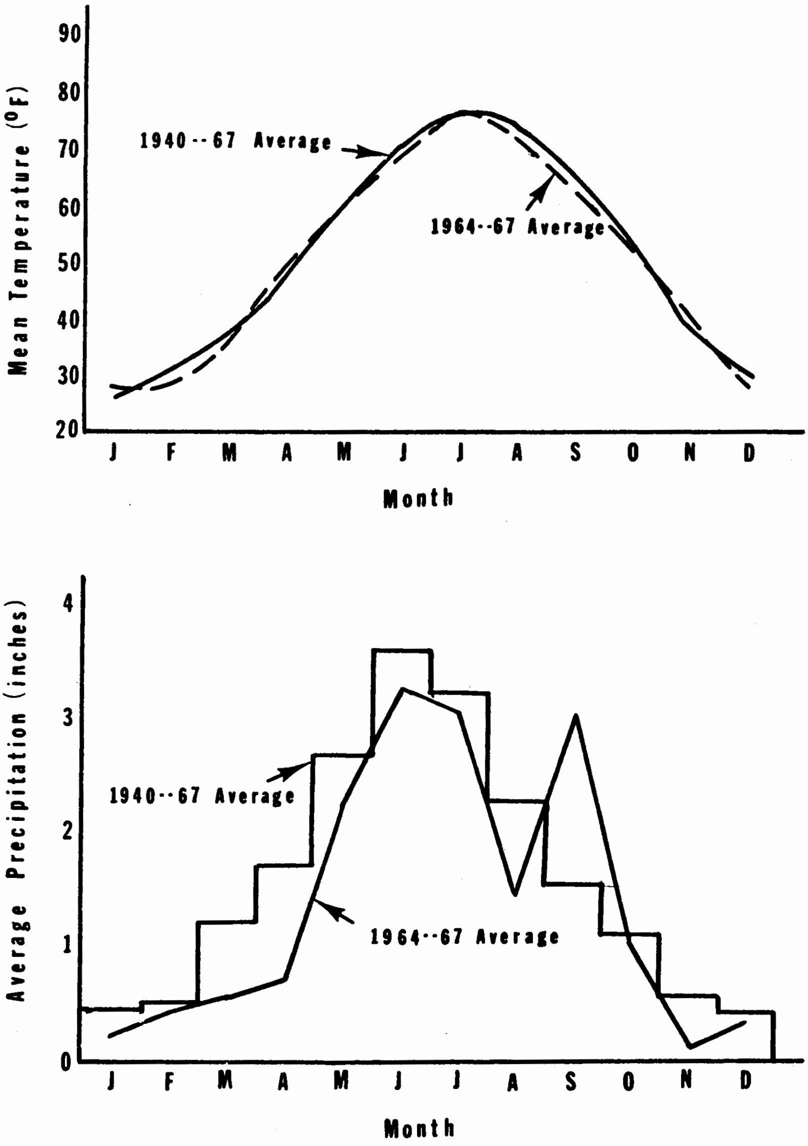


FIGURE 3.—Average temperatures and precipitation, Colby (Kansas) Branch Experiment Station, 1940-67 and 1964-67.

Care and Maintenance

Care and cultivation has been minimum, to evaluate performance under conditions on farms where little time or expense could be allotted to maintenance. Sweeps have been run along each side of the row when weeds became a problem, generally two or three times during the growing season, with some hand hoeing, usually twice each summer.

Rabbits have been a problem, especially during the winter, at Garden City and Colby, so the smaller trees and shrubs are sprayed each year with the repellent Tetramethylthiuramdisulfide used with a sticking and carrying agent (Trade name: Magic Circle Rabbit Repellent, Evans Orchard Supply Company, 305 Delaware Street, Kansas City, Mo.).[3] It has been effective when applied early in the winter before rabbits begin chewing on the trees and shrubs.

Measurements

Survival percentages and height and girth measurements have been made at the end of each growing season. Gravimetric soil moisture determinations have been made each month during the growing season from selected locations at each site since 1965. Soil samples were taken to 42 inches deep in increments of 0-6, 6-18, 18-30, and 30-42 inches.

Wind velocity profiles have been made on a few of the plantings with sufficient growth to produce a significant wind barrier. The data permitted velocity reduction patterns to be delineated, and resistance coefficients and turbulence intensities to be computed.

Precipitation and temperature data from Experiment Station records were also examined in relation to growth differences and used to compute the Thornthwaite (6) climatic index to determine if it might be related to growth rate of the plantings.

3 Trade and company names are included to be specific but they do not imply any endorsement or preferential treatment by the U. S. Department of Agriculture.

COMPARISON OF BARRIERS

Growth and Survival

Average height and survival data for each of the 100-foot-long plantings that showed potential as wind barriers at the end of the 1968 season are given in table 2 and 3. Some barriers like red pine, white pine, and Austrian pine, which were listed in table 1, are not included in tables 2 and 3 because they either failed completely or their survival percentages were too low.

Figures 4 and 5 show annual growth (height change) for some of the better tree and shrub barriers.

None of the plants have done so well at Garden City as at Colby or St. John (tables 2-3). Climatic conditions at Garden City have been more severe; both a tornado and a hailstorm struck Garden City in 1967. Those disasters resulted in negative growth by Lombardy popular and mulberry in 1967 (figure 4). Insects and rabbits have also caused the most damage at Garden City. Available soil water was slightly less at Garden City than at Colby or St. John in 2 of the 4 years (figure 6). However, differences in available soil water alone do not explain all the differences in growth rates for the different plant species. Growth rates of the tamarisk shrub and the mulberry tree are plotted against available soil moisture in figure 7. The general trend is toward increased growth with increased water in the soil, but the data are very erratic. Growth rate appears to be associated with age of tree. Light and temperature also affect growth, but it seems unlikely that substantial differences in light existed among the three locations. Temperature data were examined in two ways to see if they were related to growth rate: (*a*) Simple averages for the principal growth season, April through September, were plotted against growth rate, and (*b*) average monthly temperatures were combined with precipitation to compute the Thornthwaite climatic index (6), which was then plotted against growth rate. Neither method explained the differences in growth. Future analyses will consider maximum temperatures as a possible additional source of growth difference.

TABLE 2.—Average height and survival for fifth and sixth year growth of barriers at indicated locations.

Barrier	Location	Years of growth	Survival, percentage		Height, feet	
Deciduous trees and combinations:						
Elm, Siberian	Colby	5	100		8.2	
	St. John	5	90		16.4	
Mulberry, Russian	Colby	5	100		6.7	
	Garden City	6	100		4.0	
	St. John	6	100		12.6	
Poplar, Lombardy	Colby	5	75		12.9	
	Garden City	6	87		7.0	
	St. John	6	44		17.3	
			HL	CAR	HL	CAR
Honeylocust (HL) and Caragana (CAR)	Colby	5	100	100	12.0	6.1
	Garden City	5	100	100	3.5	2.8
	St. John	5	69	93	5.6	3.8
			HL	RC	HL	RC
Honeylocust (HL) and Redcedar (RC)	Colby	5	93	93	10.2	3.3
	Garden City	5	75	58	4.1	0.8
	St. John	5	93	71	7.6	3.9
Coniferous trees:						
Pine, Ponderosa	Colby	5	56		4.3	
	Garden City	6	17		2.6	
	St. John	6	78		2.4	
Pine, Scotch	Colby	5	63		4.6	
Pine, Virginia	Colby	5	82		5.0	
	St. John	6	17		4.6	
Redcedar, Eastern	Colby	5	100		4.2	
	Garden City	6	74		2.8	
	St. John	6	100		6.8	
Deciduous shrubs:						
Honeysuckle	Garden City	6	89		3.1	
	St. John	6	100		4.9	
Lilac, Common	St. John	6	100		4.3	
Sumac, Fragrant	Colby	5	100		3.8	
	Garden City	6	97		2.4	
	St. John	6	95		5.3	

TABLE 2.—*Continued*

Barrier	Location	Years of growth	Survival, percentage	Height, feet
Rose, Multiflora	St. John	6	100	4.6
Spirea, Van Houtte	Garden City	6	100	1.4
	St. John	6	74	2.9
Plum, American	Colby	5	100	5.6
	St. John	6	93	6.9
Privet, Amur North	Colby	5	100	3.8
	St. John	6	96	5.3
Tamarisk	Colby	5	100	7.3
	Garden City	6	74	6.1
	St. John	6	96	8.7
Caragana	Colby	5	100	6.7
	St. John	5	90	5.7
Ornamental grasses:				
Bamboo*	Colby	5	0	5.2
	Garden City	5	87	7.1
	St. John	5	75	10.5
Pampasgrass*	Colby	5	78	8.2
	Garden City	6	84	8.9
	St. John	6	86	10.0

* Grasses start growth from roots each year, so heights given are average for 1965, 1966, and 1967 season. Survival is given for 1968.

TABLE 3.—Average height and survival for second, third, and fourth year growth of barriers at indicated locations.

Barrier	Location	Years of growth	Survival, percentage	Height, feet
Deciduous trees and combinations:				
Russian-olive	Colby	3	100	4.9
	Garden City	3	56	3.9
	St. John	3	56	5.0
Cottonwood, Plains	Colby	3	100	6.5
	Garden City	2	19	3.6
	St. John	2	44	4.4
Cottonwood, Siouxland	Colby	2	88	2.7
	Garden City	2	12	2.1
	St. John	2	88	4.3
Elm, Siberian	Garden City	4	80	4.6
			P T	P T
Poplar, Lombardy (P) and Tamarisk (T)	Colby	4	77 88	7.5 7.2
Deciduous shrubs:				
Privet, Amur North	Garden City	4	52	1.9
Caragana	Garden City	4	90	2.3
Honeysuckle	Colby	4	97	3.6
Spirea, Van Houtte	Colby	4	100	1.6
Lilac, Common	Colby	4	91	1.9
Annual crops:				
Kenaf*	Colby	2	0	0
	Garden City	2	10	3.2
	St. John	2	50	4.9
	Manhattan	2	95	8.3
Sunflower*	Colby	2	7	5.0
	Garden City	2	3	3.0
	St. John	2	25	5.0
	Manhattan	2	30	6.0
Hybrid Forage Sorghum*	Colby	2	75	4.2
	Garden City	2	76	4.8
	St. John	3	80	5.0
	Manhattan	2	90	6.2

* "Years of growth" for annuals means number of years of trial. Survival percentages and heights are averages for years of trial.

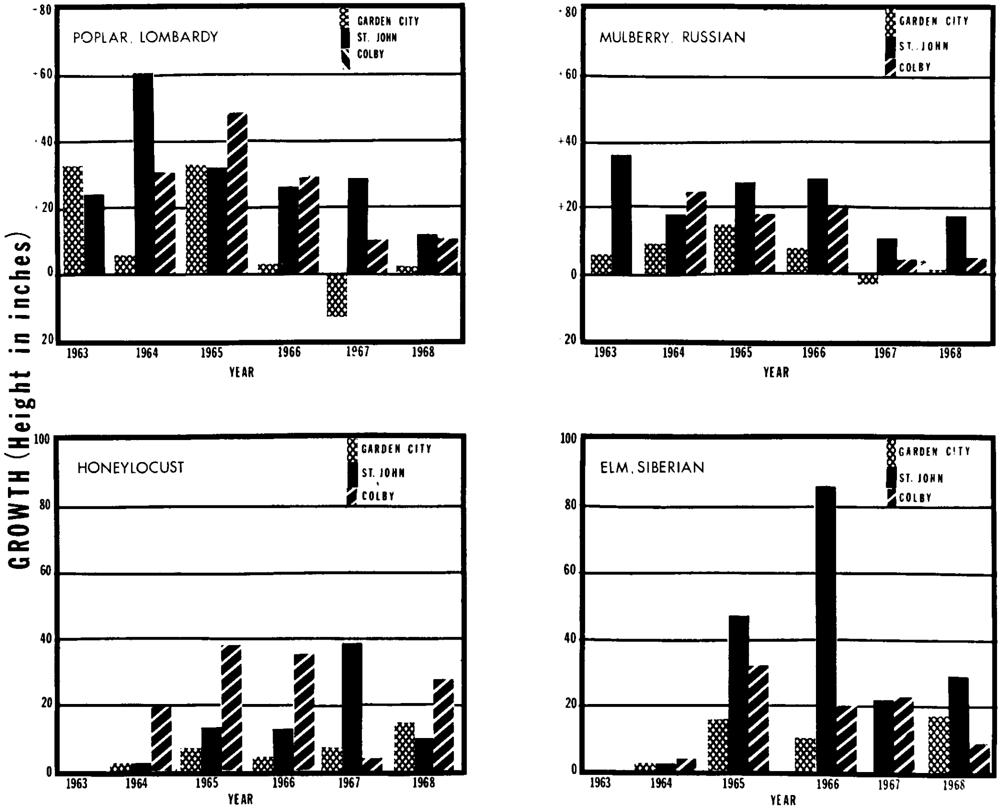


FIGURE 4.—Annual growth at Garden City, St. John, and Colby for indicated deciduous trees.

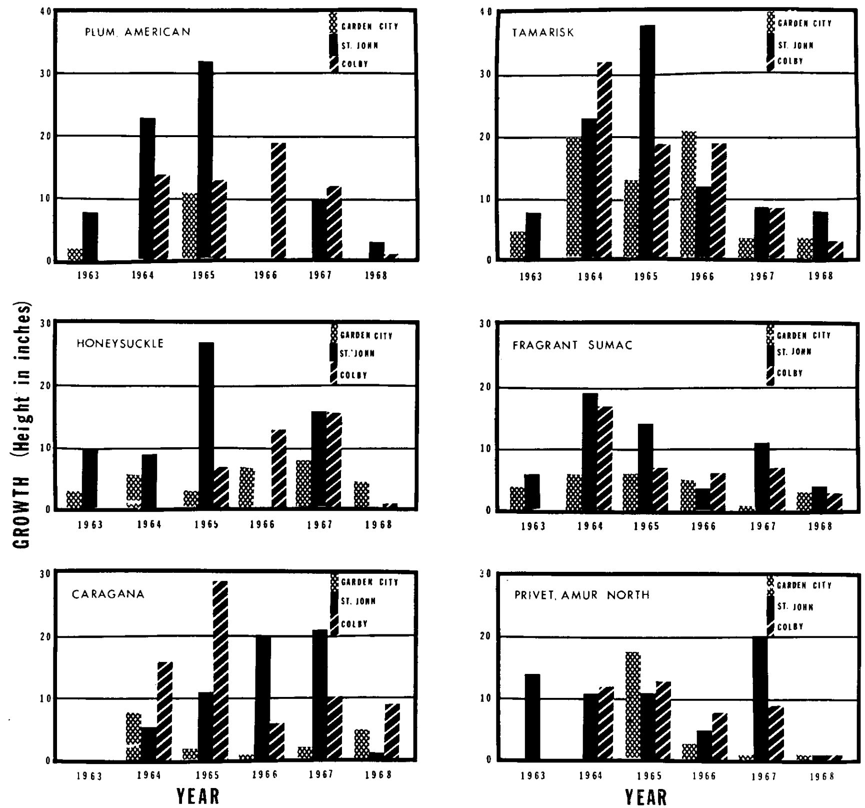


FIGURE 5.—Annual growth at Garden City, St. John, and Colby for six of the shrubs.

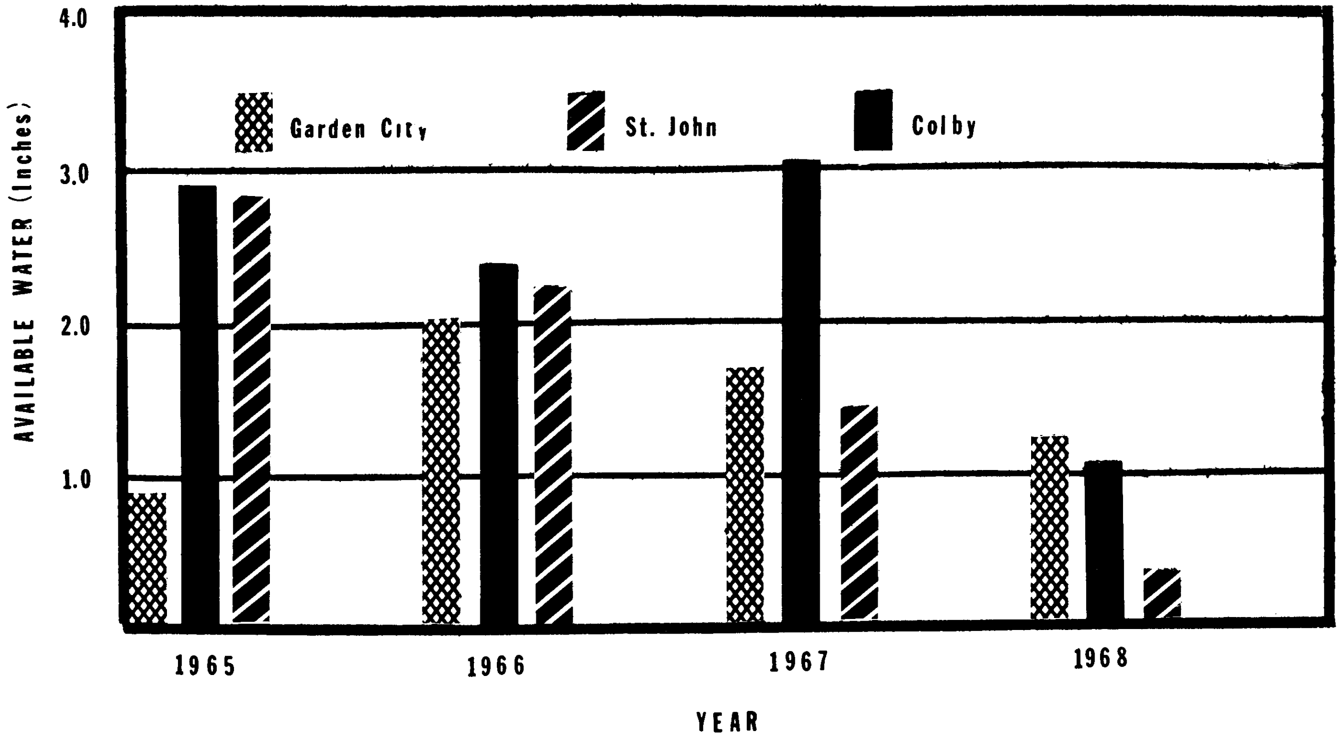


FIGURE 6.—Average soil water available monthly for 6 months, May 1 through November 1, Garden City, St. John, and Colby.

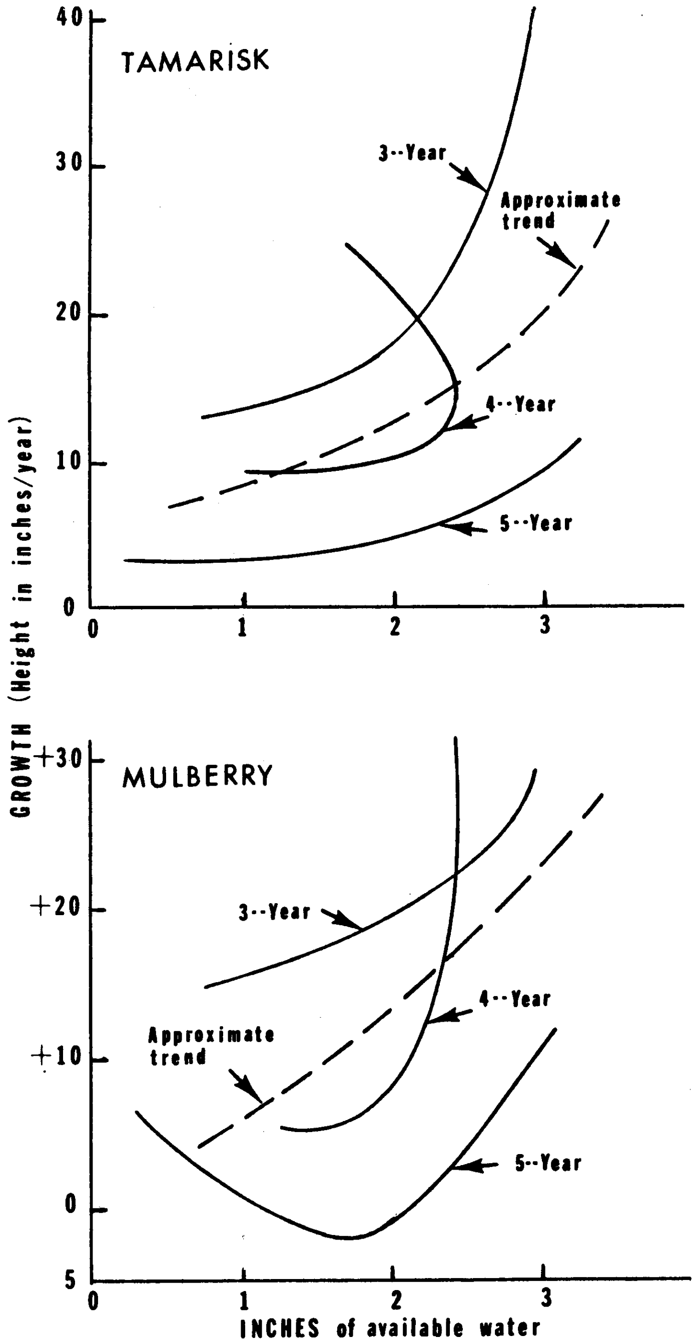


FIGURE 7.—Growth rates of tamarisk and mulberry in relation to available soil water.

The shrubs, tamarisk, plum, caragana, sumac, privet, and honeysuckle all have potential as wind barriers at St. John and Colby, but only tamarisk has made substantial growth at Garden City. Tamarisk appears to be the fastest growing shrub at all three locations (figure 8a). Caragana has grown exceptionally well at Colby and St. John and appears to have good potential as a porous barrier figure 8b). Privet has provided a fine, uniform, relatively dense barrier at St. John (figure 8c) and has survived well at Colby, but has grown less rapidly than is desirable.

Both Russian mulberry and Siberian elm have produced effective barriers at St. John and Colby (figure 9a and b). Mulberry has survived well at Garden City, but has not grown rapidly. Siberian elm was difficult to establish at Garden City; however, 80 percent of the trees were successfully established in 1964 and average 4.6 feet high (1969).

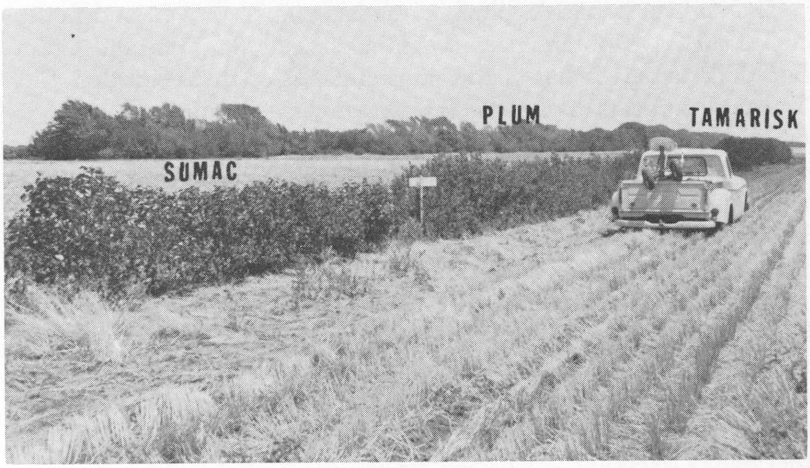
Lombardy poplar made rapid growth during the first 4 years and appeared to have excellent potential as a barrier; however, its high susceptibility to disease and insect attack caused it to begin dying out after 4 years (figures 10 and 11).

Honeylocust was not evaluated in a row alone. Used in combination with caragana and redcedar, it grew very rapidly, especially at Colby, and produced a substantial barrier with medium porosity in only 5 years (figure 12a and b).

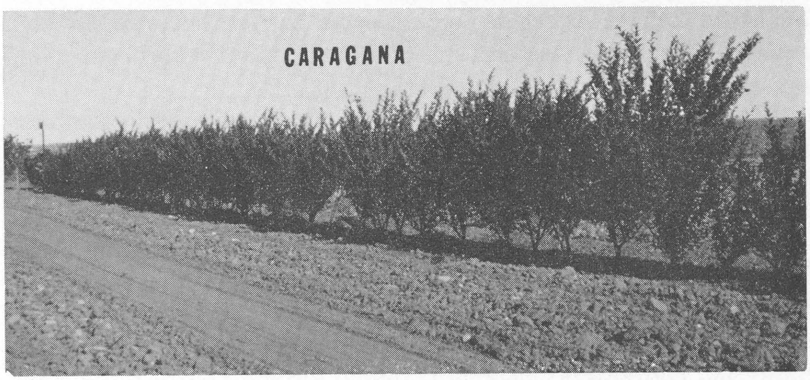
Russian-olive, Plains cottonwood, and Siouxland cottonwood have been evaluated 2 to 3 years. Russian-olive appears to have the best potential in northwestern Kansas. Plains cottonwood also has done well at Colby—6.5 feet high in 3 years and 100 percent survival. Siouxland cottonwood has real potential for wind barriers if a stand can be established. It was 4.3 feet high with 88 percent survival after 2 years at St. John.

Both Pampas and bamboograss have produced effective single-row barriers at all three locations (figure 13). However, bamboograss winterkilled twice during 5 years at Colby; it is not recommended for northwestern Kansas. The ornamental grasses are particularly effective as barriers because they stand well after frost and thus provide year-round protection. Their disadvantages are that they must be started from root stock and bamboo tends to spread by widening its rows.

Coniferous trees have not produced effective barriers in the 5 and 6 years of testing, mostly because of slow rates of growth and difficulties in establishing them. Redcedar has provided the best coniferous barrier; it reached 6.8 feet with 100 percent survival at St.



(*a*)



(*b*)

(*c*)

FIGURE 8.—Shrubs: (*a*) Six-year-old fragrant sumac (left), American plum (middle), and tamarisk (right) at St. John, Kansas, (*b*) 5-year-old caragana at Colby, Kansas, and (*c*) 6-year-old privet, Amur North, at St. John, Kansas.

FIGURE 9.—Deciduous trees: Top—6-year-old Russian mulberry at St. John, Kansas; bottom—5-year-old Siberian elm at St. John, Kansas.

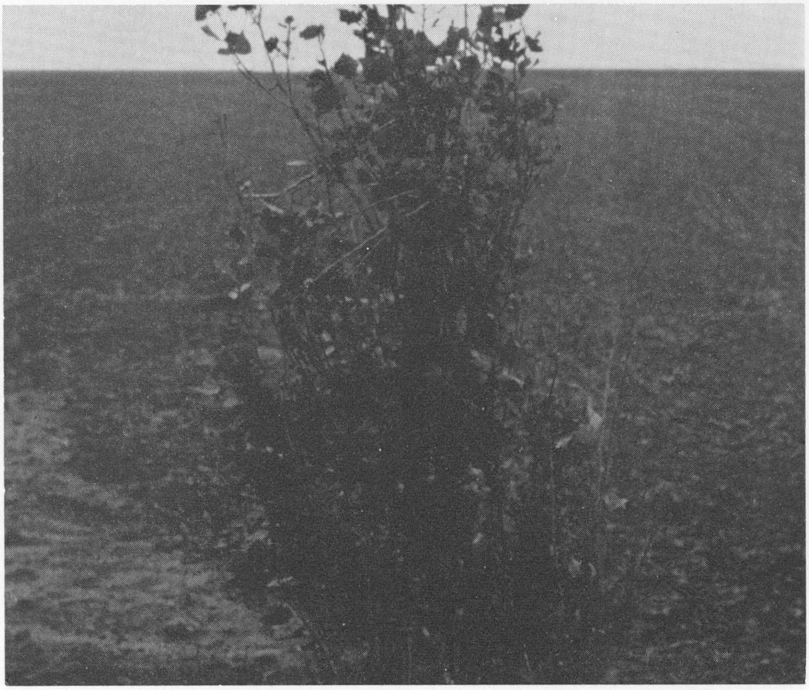


FIGURE 10.—Lombardy poplar showing insect and storm damage at Garden City, Kansas.

FIGURE 11.—Appearance of Lombardy poplar row (right) contrasted to Russian mulberry row (left) at St. John, Kansas, after 6 years' growth.

FIGURE 12.—Top—5-year-old honeylocust and caragana at Colby; bottom—5-year-old honeylocust and redcedar at Colby. Honeylocust is the taller one at both places.

FIGURE 13.—Ornamental grasses: top—pampas; bottom—bamboo, yearly growth.

John in 6 years and 4.2 feet with 100 percent survival at Colby in 5 years (figure 14). The pines seem to be best adapted to northwestern Kansas where Ponderosa, Virginia, and Scotch pines have survived reasonably well and have grown at moderate rates.

Only moderate success has been attained with the three annual crops evaluated. Hybrid forage sorghum "Cropguard" seems to have good potential as a wind barrier but it did not attain its full height potential in these studies. Sunflowers have not produced effective wind barriers despite attaining substantial heights at

FIGURE 14.—Six-year-old eastern redcedar at St. John, Kansas.

Manhattan, Colby, and St. John. They have too few leaves on their lower stems to provide a dense barrier. After frost, their heavy heads and the wind cause the plants to uproot and fall.

The fibrous plant, kenaf, has good potential as a wind barrier if moisture conditions are favorable and a uniform stand can be established. At Manhattan, under extremely favorable moisture conditions, several kenaf varieties reached an average height of 8.3 feet during 2 years of trial; however, at other locations survival was poor and heights averaged 5 feet or less. The plant stands well after frost and, if planted closely in the row, provides an effective barrier. Since kenaf does require high moisture, it likely has the most potential to protect sandy soils from wind erosion in areas with moderate to high rainfall.

Wind Protection

Wind velocity reductions for pampasgrass, foliated 3-year-old Lombardy poplar, and Russian mulberry at Colby are shown in figure 15. The wind reduction pattern for the poplars, which were 10.0 feet high, represents the protection provided by a young, moderately dense, closed-type barrier. Velocity reductions amount to 30 to 40 percent near the lee of the barrier and gradually decrease to zero at a leeward distance of about 15 times the barrier height. The mulberry, which was 6.0 feet high, formed a porous, open-type barrier because spacing between trees was not completely closed; velocity reduction ranged from zero near the immediate lee of the barrier to 30 percent near the ground 20 times height distant. Pampasgrass, which was 9.0 feet high, formed a good, rather uniform, moderately dense barrier. Its velocity reduction ranged from 40 percent near the immediate lee of the barrier to 20 percent at 20 times height distant.

Drag coefficients computed by the momentum transfer method (7) using wind profile data from one upwind and one leeward station for four of the 4-year-old wind barriers at Colby are shown in table 4. The coefficients, which indicate resistance to wind that the barriers provide, show that the tamarisk is a very dense barrier compared with the relatively porous pampasgrass, plum, and elm, whose coefficients are near 0.5.

TABLE 4.—Drag coefficients, 4-year-old barriers, at Colby, Kansas

Barrier	Height (feet)	Drag coefficient C_d
Tamarisk	7.1	0.89
Pampasgrass	7.8	0.56
American plum	5.5	0.52
Siberian elm	7.4	0.46

The effect of the dense tamarisk on leeward velocity reduction pattern is shown in figure 16. Velocity reduction of 70 percent near the barrier is considerably greater than the zero to 40 percent reductions shown for the pampasgrass, mulberry, and poplar barriers in figure 15.

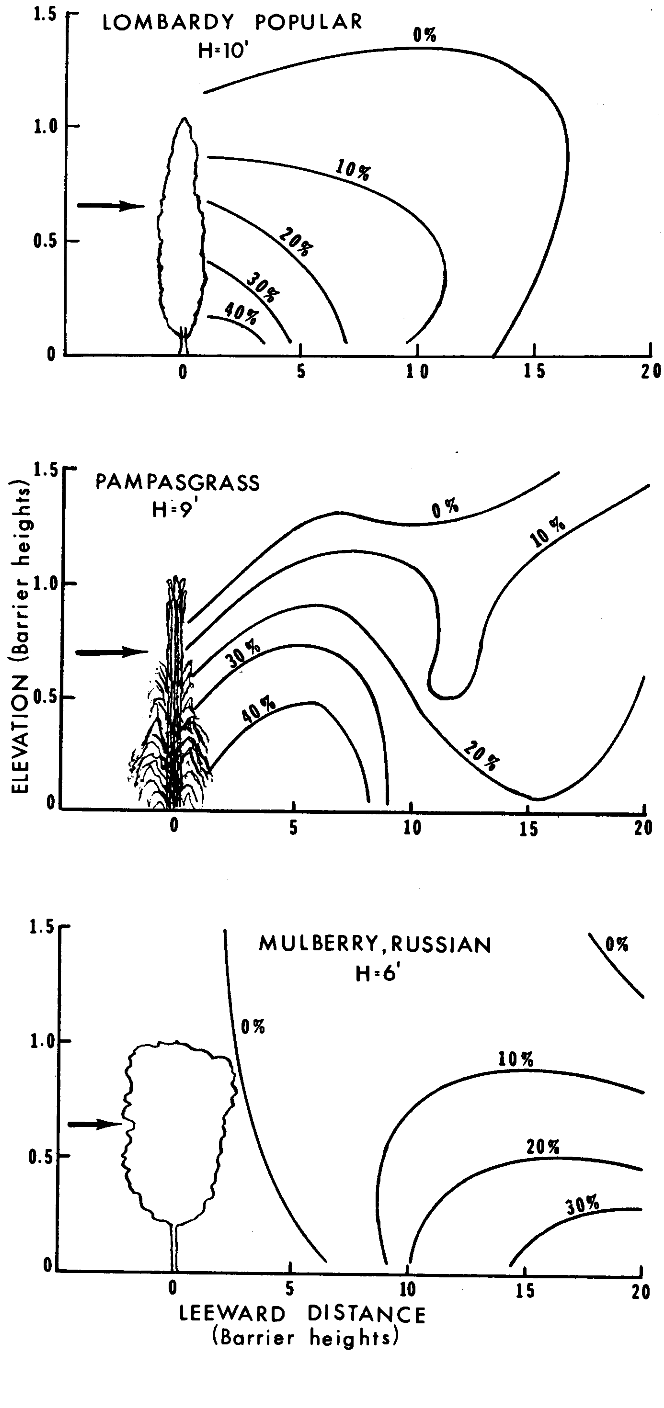


FIGURE 15.—Velocity reduction patterns for pampasgrass, foliated 3-year-old Lombardy poplar, and Russian mulberry barriers at Colby, Kansas.

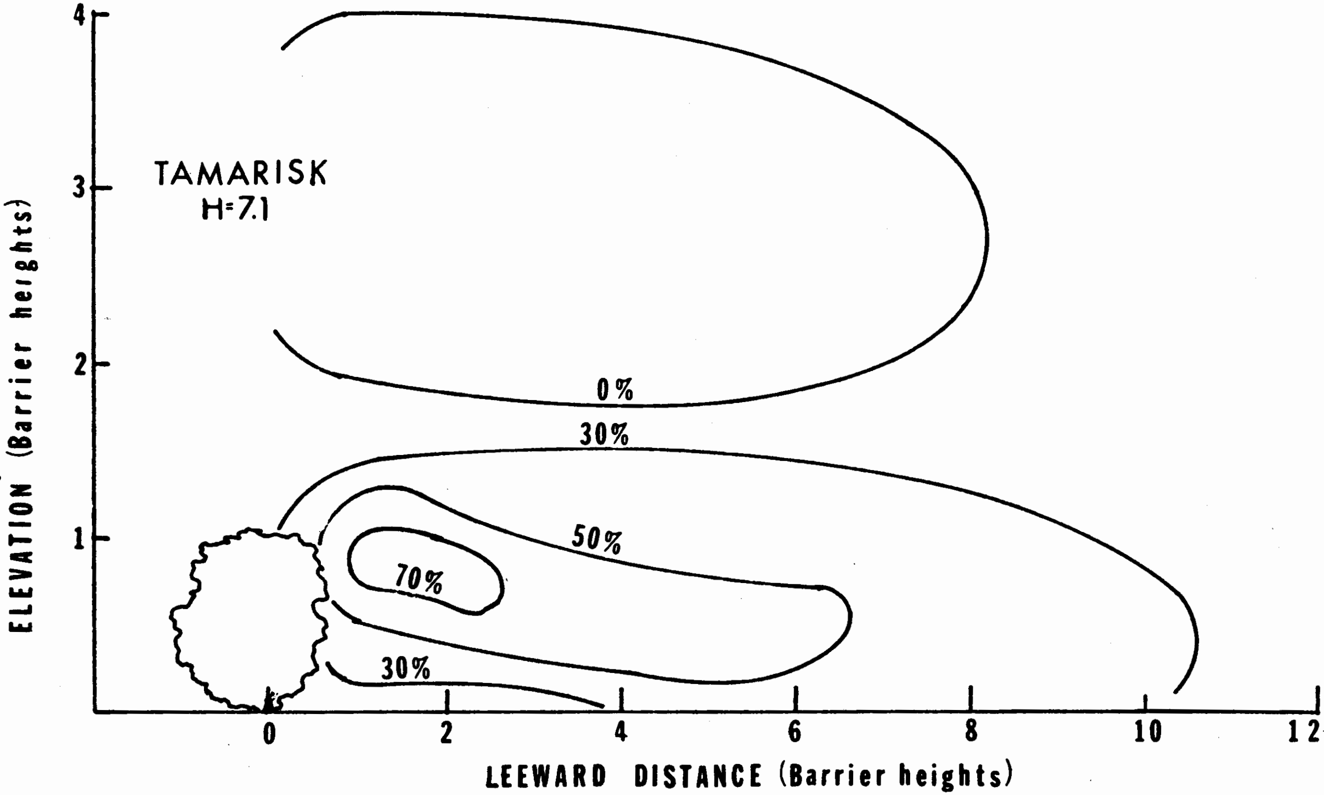


FIGURE 16.—Velocity reduction patterns for a 4-year-old tamarisk barrier at Colby, Kansas.

Figure 17 shows turbulence intensity windward and leeward of the less porous tamarisk. Turbulence intensity increased leeward of the barrier, reached a maximum close to the barrier in the region of minimum velocity, and moved closer to the ground with increasing leeward distance from the barrier.

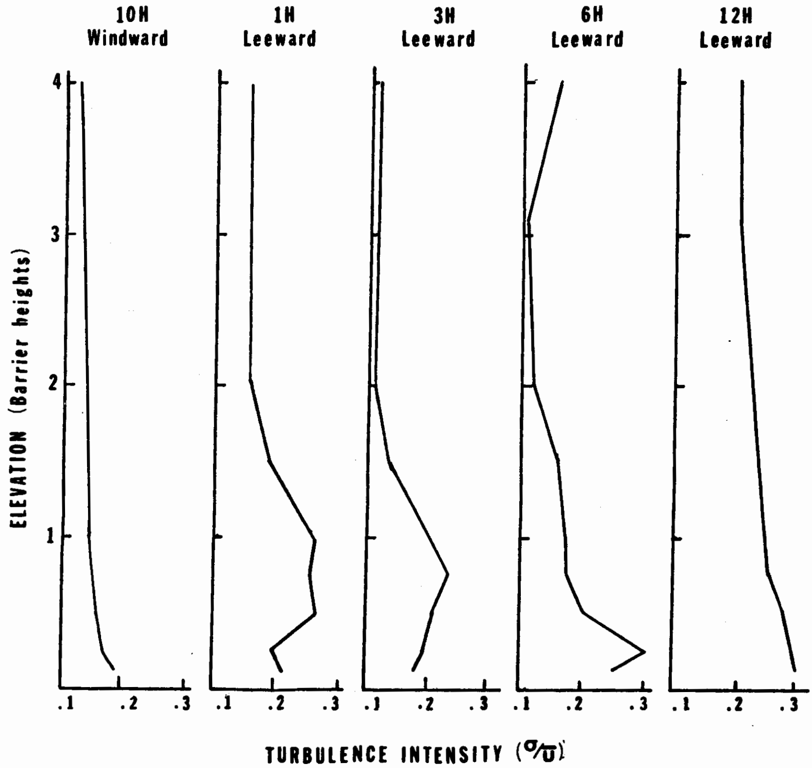


FIGURE 17.—Turbulence intensity windward and leeward of a 4-year-old, 6-foot-high tamarisk barrier at Colby, Kansas; 10H = 10 × height.

CONCLUSIONS AND RECOMMENDATIONS

Five years of testing several different kinds of trees, shrubs, grasses, and annual crops at Colby, Garden City, and St. John, Kansas, have shown that effective single-row vegetative barriers for wind erosion control can be grown in central and northwestern Kansas. However, in southwestern Kansas effective vegetative barriers have not been produced; this means of controlling wind erosion seems questionable there, unless supplemental water and care can be provided.

Shrubs in order of decreasing promise for producing effective barriers in central and northwestern Kansas are: tamarisk, caragana, plum, privet, honeysuckle, and sumac. If vegetative barriers are to be established with little care in southwestern Kansas, tamarisk is best.

Trees in order of promise in central and northwestern Kansas are: Siberian elm, Russian mulberry, honeylocust, redcedar, Russian-olive, Plains cottonwood, and possibly Siouxland cottonwood—if a uniform stand can be established. Based on results of our tests, none of these trees could be recommended for southwestern Kansas. Lombardy poplar made very rapid growth at Colby and St. John and fairly good growth at Garden City during the first 4 years but, because it is highly susceptible to insect and disease attacks after 4 years, it cannot be recommended as a wind barrier.

Combinations of trees and shrubs that showed good promise as effective barriers in a single row include honeylocust and caragana or honeylocust and redcedar. The honeylocust-caragana barrier is only moderately porous but both species grow rapidly and produce a tall barrier in a very few years. During the first years of growth, the honeylocust-redcedar combination produces a dense barrier near the ground with considerable openness in the upper portion, but honeylocust's rapid growth and redcedar's moderate growth produce a fairly dense barrier of effective height in 8 to 10 years.

Pampasgrass appears to be the best bet for an effective single-row, grass wind barrier. A perennial, it produces a barrier of good height and, because it stands well after frost, provides year-round protection. It has done quite well in all three areas of Kansas. Bamboograss has also produced an effective barrier most years at all locations but it has winterkilled 2 of 5 years at Colby and its row width spreads and encroaches on adjacent crops.

Based solely on results from this study, none of the annual crops tested can be strongly recommended for single-row wind barriers; however, hybrid forage sorghum and kenaf performed well enough for a moderate recommendation as wind erosion control barriers on sandy soils in areas with moderately high rainfall. Lack of foliage on their lower stem and blowing over made sunflowers ineffective wind barriers.

Leeward windspeed reduction, resistance coefficients, and turbulence intensity measurements on a few of the more promising barriers indicate that even very young vegetative barriers substantially influence wind patterns. Turbulence intensity is increased by the barrier and could increase evapotranspiration. The porous barriers, like pampasgrass and mulberry, reduce windspeeds from 20 to 30 percent near the ground at 20 heights distance from the barrier. Denser barriers, such as tamarisk, reduce windspeed as much as 70 percent immediately leeward of the barrier and about 20 percent at 20 heights distance leeward. Resistance coefficients indicate that tamarisk barriers have about 40 percent more resistance to wind than do Siberian elm, plum, or pampasgrass barriers.

This study shows the need for more investigations of the relationships of climate, soil, and plants. Present data do not fully explain variations in growth rate of plants between locations. Averages of temperature and other climatic data generally fail to explain such differences. Needed is an experimental design that will permit testing different plants under different controlled levels of soil water at each location. Also needed are management practices that provide better environmental conditions for the barriers. Soil profile modification should be tried, along with diversion terraces or channels, to provide supplemental water to barrier plants.

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