

Effects of Windbreak Plantings on Adjacent Crops

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Field windbreaks and farm shelterbelts are multipurpose assets to Great Plains agriculture. Though advantages outweigh the disadvantages, windbreak plantings in northeastern Colorado do depress growth and yield of adjacent annual crops. They apparently have little effect on native and introduced grasses. However, competitive effects on adjacent crops vary with age and species of the windbreak planting.

SOVIET INVESTIGATORS Bolyshev and Solov'yev (*2*) describe the value of shelter belts on virgin land as follows:

> "In arid steppe regions one of the most important conditions for producing steady crops is the presence of shelterbelts. This is shown by data accumulated over a period of many years by scientific research institutes and the abundant experience of state and collective farms both in Kazakhstan and in other regions having climate and soil conditions similar to those of Kazakhstan.
>
> "Shelterbelts improve the moisture relations of the air and the soil and protect the fields from hot, dry winds, from having the seedings blown away and from drifting of the land during the violent dust storms usual in Kazakhstan."

Chernikev (*3*) concluded that soil within shelterbelts in the Yergeni plateau had higher temperatures in winter and lower ones in the summer. Temperatures were reduced as much as 20°C. in the upper half meter of soil while soil parent material temperatures were decreased 1-4°C. within shelterbelt areas. Soil moisture relations, however, were only slightly improved.

Observations in the central Great Plains indicate that one disadvantage of windbreaks and shelterbelts is root extension into adjacent cropland. Working in the eastern portion of the Plains, Bates (*1*) found that some of the basic conditions which influence root spreading were: Species of tree, rainfall, texture and fertility of soil, and competition from other species within a planting.

Observations at a number of field stations in Wyoming, Kansas, Colorado, Oklahoma, Texas, and North Dakota show that windbreak competition with adjacent crops becomes more acute from east to west (sub-humid to arid), and from north to south (reduced snow contribution and higher temperatures) (*4, 5, 6*).

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Actual data for root extension effects in more arid regions is limited. At the Akron station it was shown that broadleaf trees 18-20 years old developed shallow root systems, 1-3 feet from the soil surface, that extended horizontally for considerable distances (*5*). Tap roots were lacking or turned at right angles. This indicated the roots were responding to soil moisture conditions. Established field crop variety testing had to be abandoned during the 1930's within 50 to 100 feet of the windbreak because of tree root extension.

In view of the advanced age (45-50 years) and possible future renovation of portions of the original plantings at Akron, it was decided in 1957 to obtain some measurements of effects on crop yields, soil moisture, extension of roots at selected sites, and soil fertility effects of windbreaks.

Experimental Procedure

The original tree planting experiments at the Akron station are well described and diagrammatically shown by Preston and Brandon (*5*). Positions of the 1957-1959 tree survival stands are shown on figure 1. The sketch is not to scale but demonstrates relative position of plantings and sampling. The species used for sampling measurements were healthy except for black locust in which the older trunks had died out and had been replaced by sucker growth.

Cropping

The fields adjacent to the east and north windbreaks were summer-fallowed in 1956 and planted to winter wheat that fall. Excellent growing conditions prevailed throughout the 1957 season. High yields of grain and straw were harvested (table 1).

The wheat stubble was subtilled early in the fall of 1957 and disk tilled twice in the spring of 1958 in preparation for grain sorghum planting. Sorghum (Reliance) was surface drilled June 6 and an excellent stand was obtained. It was cultivated twice with narrow sweep blades. High yield prospects were nullified by dry weather during August and early September. Conventional summer-fallow tillage was employed throughout the 1959 season with sweep and rod weeding operations as needed to control weeds. The cropping sequence for the land adjacent to the west windbreak included summer fallow in 1957, sudan grass in 1958, and summer fallow in 1959.

Harvesting

Hand sampling was used at predetermined distances of 30, 50, 70, 90, 110, and 130 feet at right angles from

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TABLE 1
Yield of Winter Wheat Adjacent to Windbreak, Central Great Plains Field Station, Akron, Colorado, 1957.

Distance from Windbreak	Ponderosa Pine			Siberian Pea and Chokecherry			Broadleaf[1]		
	Grain	Straw	Test Weight	Grain	Straw	Test Weight	Grain	Straw	Test Weight
feet	bu./ac.	t./ac.	lbs./bu.	bu./ac.	t./ac.	lbs./bu.	bu./ac.	t./ac.	lbs./bu.
30	3.0	.33	58	14.1	1.71	60	2.3	.31	57
50	4.7	.41	58	30.2	3.08	60	6.2	.86	58
70	23.5	2.56	61	30.3	3.35	60	6.6	1.01	60
90	32.4	3.57	60	27.6	3.51	60	14.6	1.67	60
110	33.8	3.66	61	33.9	3.95	60	22.3	2.47	61
130	32.4	3.67	60	24.6	3.17	60	25.6	3.15	62

[1] Broadleaf = black walnut and black locust.

Ponderosa pine roots 50 feet from tree into cultivated field.

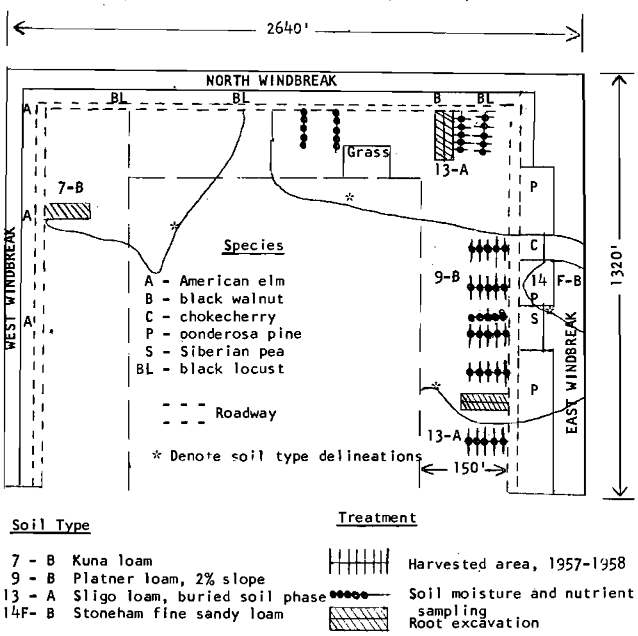
the plantings as shown in figure 1. At each sampling location, two rows 8 feet long were harvested to determine wheat yields in 1957. Similar techniques were employed for grain sorghum. The sorghum bundles were weighed immediately after cutting for total wet forage (stalk heads). The bundles were then air dried, the grain threshed and weight of grain and residue determined.

Soils

The soils are typical of the calcareous gently rolling "hardlands" of eastern Colorado. Sligo loam, buried soil phase, in the northeast corner of the plantings represents a depression topography while Stoneham fine sandy loam is on a crest. Stoneham soils are shallow and underlain with fine gravel. Platner loam covers broad level uplands of the region, somewhat deeper in profile than Stoneham but still underlain with fine gravel.

Gravimetric samplings for available soil moisture determinations were made July 2, 1958, on growing sorghum and again at the end of fallow in 1959 at locations shown on figure 1. Available soil moisture was calculated on the basis of 8 percent moisture as wilting point; this is near average for the soils involved.

Figure 1. Diagram showing positions and species of windbreak plantings, sampling areas for root extension, and soil type at the Central Great Plains Field Station, Akron, Colorado.



Composite soil samples (0-3 feet in depth) for nutrient determination were taken at the same interval distance and position as for soil moisture. The samples were analyzed for organic matter by wet combustion, for nitrates by phenoldisulphonic acid, and for available phosphorus by sodium bicarbonate extraction.

A 2.5 yard earth remover for shearing off top soil was used in October 1959 to examine root development of American elm, black walnut, ponderosa pine, and Siberian pea.

Climate

The 50-year average of rainfall at the Akron station is 17.1 inches and snowfall averages 32 inches. Snowfall is highly variable but it is an important factor in windbreak survival. Windbreaks and shelterbelts in the region are partially self-irrigating mechanisms from the snow trapped in and adjacent to the plantings. Climatic data for the 3-year testing period and the 50-year record is condensed in table 2.

During the three winter seasons of this investigation, two snow storms produced significant moisture contributions to crop land immediately adjacent to the windbreak. The storm of November 2, 1956, produced a 3-foot snow drift 60 feet in width immediately east of the east windbreak and immediately south of the north windbreak. A second storm, on March 24, 1959, deposited a 1.5 foot drift averaging 40-45 feet in width in the same places.

Significant runoff and temporary ponding on one occasion during the 3-year study was caused by a heavy rainstorm in July 1959 which flooded the land adjacent to the black walnut and black locust windbreak on the north and was reflected in higher total stored soil moisture during fallow (table 3). The last column of table 3 indicates the flooded area was 90 feet or more from the windbreak.

Crop Yield

Winter Wheat—1957

Growing conditions were favorable throughout the season, but grain yields were reduced 15-20 percent by hail. By May 1, extreme nitrogen deficiency and moisture shortage were in evidence on wheat adjacent to both the ponderosa pine and broadleaf species despite the extra moisture contribution from snow the previous fall. The primary effect was a very great difference in the color, height, and tillering of wheat in the area from the pine to a sharp line 55 feet away. A secondary spotty effect up to 85 feet from the windbreak was noted (table 1). The wheat near the Siberian pea and chokecherry bushes did not appear to be affected beyond 40 feet into the field. Affected wheat ripened 10 days later than that in the main field.

The effects of broadleaf species in the north field were gradually reduced with distance, the break was not so sharply defined as on wheat adjacent to the pine.

Yields of grain and straw confirmed the observation regarding the areas affected by the types of windbreak material. Normal production was regained at distances of 90, 50, and 130 feet respectively from the pine, bushes and broadleaf.

Grain Sorghum—1958

The same general areas that showed root sapping on wheat were also affected in grain sorghum (table 5). The effect on sorghum was progressively more pronounced after July 20 with the beginning of rapid elongation of plants. Dry weather conditions in late August and early September promoted moisture stress throughout the field. Bulk harvest of the main field exclusive of the affected area gave a 14.5 bushel per acre yield.

Early in May, an application of 25 pounds of nitrogen per acre (ammonium nitrate—33.5 percent N) was made in an 8-foot strip 40-50 feet in the sorghum field and parallel to the windbreak. The fertilizer produced an early vegetative response on the sorghum but continued root sapping reduced the yield and the vegetative response to fertilizer disappeared. This indicated that nitrogen deficiency as well as moisture stress may be caused by competitive root sapping.

Yields of total wet forage, grain, and dry residue of sorghum were affected much as wheat yields had been the previous season (table 5).

TABLE 2
Climatic Summary of 1957-1959 Period and 50-Year Average, Central Great Plains Field Station, Akron, Colorado.

Crop Season	*Total Rainfall*	*Rainfall Mar.-Sept.*	*Seasonal Temperature*	*Total Snow Fall*[1] *Oct.-Apr.*
	inches	*inches*	*°F.*	*inches*
1957	18.07	12.60	61	67
1958	14.38	10.09	64	28
1959	13.77	9.97	65	19
1909-1959	17.10	11.51	63	32

[1] Period beginning fall of previous year.

TABLE 3
Available Soil Moisture, End of Fallow, September 10, 1959, Central Great Plains Field Station, Akron, Colorado.

Distance from Windbreak	*Ponderosa Pine*	*Siberian Pea & Chokecherry*	*Black Walnut Black Locust*
feet	*inches*	*inches*	*inches*
30	.4	2.5	.2
50	.8	2.9	2.0
70	2.1	3.3	3.9
90	3.1	2.9	4.9
110	3.1	3.3	5.6

TABLE 4
Available Soil Moisture Under Sorghum, July 2, 1958. Central Great Plains Field Station, Akron, Colorado.

Distance from Windbreak	*Ponderosa Pine*	*Siberian Pea & Chokecherry*	*Black Walnut Black Locust*
feet	*inches*	*inches*	*inches*
30	1.0	1.8	0.9
70	1.9	2.1	0.9
110	2.2	2.5	1.8

[1] Means of four samples at each location.

Soil Moisture

As the distance from given windbreak materials increased, the amount of available soil moisture decreased during the sorghum growing season (table 4). Total moisture was low at the time of sampling.

Soil moisture extraction by roots during fallow correlated with yield reductions observed for wheat and sorghum (tables 1, 3, and 5). Of the four broadleaf species only the black walnut showed serious moisture sapping at a distance of 90 feet.

American elm root 92 feet from tree. It is 0.25 inch in diameter at this point.

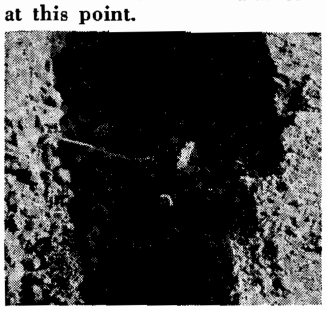


TABLE 5
Yield of Sorghum Adjacent to Windbreak, Central Great Plains Field Station, Akron, Colorado, 1958.

Distance from Windbreak	*Ponderosa Pine*			*Siberian Pea and Chokecherry*			*Broadleaf*[1]		
	Wet Forage	*Dry Residue*	*Grain*	*Wet Forage*	*Dry Residue*	*Grain*	*Wet Forage*	*Dry Residue*	*Grain*
feet	*t./ac.*	*t./ac.*	*bu./ac.*	*t./ac.*	*t./ac.*	*bu./ac.*	*t./ac.*	*t./ac.*	*bu./ac.*
30	.92	.41	3.6	2.34	.96	15.1	.79	.33	1.2
50	1.23	.53	6.8	2.60	.94	12.7	1.23	.55	9.2
70	1.91	.75	11.1	2.49	.89	12.9	1.04	.42	6.0
90	2.51	.98	13.6	2.68	1.02	12.9	1.58	.63	9.6
110	2.57	.95	13.5	2.95	1.20	12.9	3.08	1.17	16.0
130	—	—	—	—	—	—	3.20	1.28	20.4

[1] Broadleaf = black walnut and black locust.

TABLE 6
Root Extension into Test Field, Selected Sites, Central Great Plains Field Station, Akron, Colorado, October 1959.

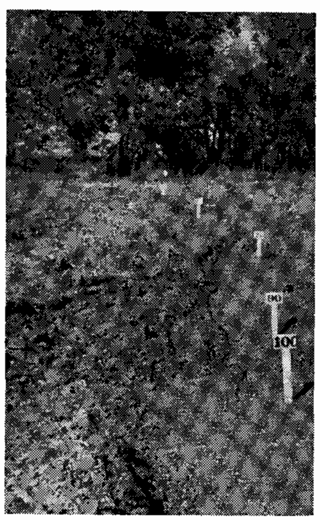
	Age	*Height*	*Diameter*[1] *Trunk*	*Ave. Depth Main Roots*	*Root Diameter at Indicated Distance from Trunk* 30 Feet	50 Feet	70 Feet	90 Feet	110 Feet	*Maximum Distance—Roots from Trunk*	*Root-Height Ratio*
	years	*feet*	*inches*	*inches*	*inches*	*inches*	*inches*	*inches*	*inches*	*feet*	
American elm	49	26	16.0	12-14	1¼	1	¾	¼	fibers	112	4.3:1
Black walnut	49	29	11.5	14-16	3	1½	1¼	½	fibers	112	3.9:1
Ponderosa pine	47	31	15.0	9-12	¾	½	⅛	—	—	84	2.7:1
Siberian pea	23	9	—	9-12	fibers	—	—	—	—	36	4.0:1

[1] Measured two feet above base level.

Observations on Excavated Roots

When exposed by excavation, the roots of the American elm, black walnut, ponderosa pine, and Siberian pea were found to be shallow, indicating lateral extension for nutrient and water requirements (table 6). Rootlets radiated upward and downward from the main roots. The quantity of rootlets on both the American elm and black walnut specimens decreased rapidly as the distance from the trunk increased. Up to 50 feet from the tree the rooting system of the ponderosa pine was a mixture of numerous small diameter roots and fibers. Beyond 50 feet, the rooting system was predominantly smaller fibers and these ended 80 feet from the trunk. Siberian pea and chokecherry were planted more recently than the black walnut and black locust; therefore, their root development is proportionately smaller. Roots of these species did not extend beyond 36 feet from their trunks.

(Below) Black Walnut root 35 feet from tree. Stake is 1.75 inches wide. (Right) The same root extends 112 feet into cultivated field.



The general pattern of root distribution found by excavation correlated well with the observations of decreased growth and yield of wheat and sorghum (tables 1 and 5), with soil moisture extraction (table 3), and with nitrate nitrogen levels (table 7).

Soil Analysis

The analyses of root extension effect on organic matter and available phosphorus were not conclusive. The levels of these soil characteristics were more a function of soil type than any other factor. Platner loam adjacent to the Siberian pea and pine was low in organic matter and phosphorus. The level of organic matter and phosphorus was considerably higher adjacent to the black walnut, black locust and chokecherry. Sampling at 0-3 foot depths tended to dilute the average percentage of organic matter. There was some speculation that organic matter content of soil would increase closer to the trees as the result of root decay, but there was no evidence that this was the case in the cultivated field area. No analysis was made of the soil directly under the tree canopy. There was a slight trend toward higher phosphorus levels closer to the windbreak but a more detailed analysis would have to be made to see if the trend was real.

Nitrate-nitrogen levels after summer fallow appeared to be a function of both initial organic matter levels and root sapping. There was a fairly sharp increase in nitrate nitrogen levels between the 70 and 90 foot sampling points for pine and between the 50 and 70 foot sampling points for bushes and broadleaf species (table 7). In each of the broadleaf check areas, there was a higher nitrate accumulation 70 feet from the tree than at the 50 and 90 foot sampling points. Whether this indicated zone of inactive feeding at the time the samples were taken is not known. Soil moisture samples taken at the same time did not show this particular phenomena.

Summary

Root extensions by windbreak materials is an accepted hazard in semi-arid regions. The total area of

TABLE 7
Level of Organic Matter, Nitrate Nitrogen and Available Phosphorus, as a Function of Distance from Windbreak, Central Great Plains Field Station, Akron, Colorado.

Distance from Windbreak	*Ponderosa Pine* O.M.	NO_3—N	P_2O_5	*Siberian Pea and Chokecherry* O.M.	NO_3—N	P_2O_5	*Broadleaf*[1] O.M.	NO_3—N	P_2O_5
feet	*percent*	*lbs./ac.*	*lbs./ac.*	*percent*	*lbs./ac.*	*lbs./ac.*	*percent*	*lbs./ac.*	*lbs./ac.*
30	.59	41	68	1.01	56	74	1.02	54	153
50	.71	33	51	1.12	72	75	1.03	74	147
70	.67	38	43	1.04	93	67	1.05	153	142
90	.69	60	49	.96	92	61	1.03	120	128
110	.73	65	60	—	—	—	.99	124	123

[1] Broadleaf = black walnut and black locust.

farmland occupied by windbreaks is very small. Observations in northeastern Colorado indicate that sapping has little effect on native and introduced grass plantings but does depress growth and yields of adjacent annual crops. It appears that broadleaf trees are more competitive in this respect than are conifers. Conifer plantings at Akron have shown little sapping effect until 10-15 years after establishment from seedlings. Broadleaf plantings in the area show serious sapping into crop land up to a distance of 50 feet within 5-8 years. Bush type species apparently have a very minor effect on adjacent crops.

The data obtained from the Akron plantings showed a direct yield reduction in wheat and sorghum attributed to extraction of water and some nitrate nitrogen as far as windbreak planting roots extended into the field. The deleterious effects of windbreak root extension were gradually reduced as distance from the windbreak increased. Excavated roots were very shallow and indicated possible growth extension for water. The ratio of root length to tree height was more than 2.5:1 in the cases tested.

The ability to trap snow within and around a planting is helpful for the survival of shelterbelts and windbreaks in low rainfall areas.

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