Windbreak Effects on Soil Water and Wheat Yield

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ABSTRACT

WINDBREAKS, although beneficial for wind erosion control, compete with crops for space and soil water. Soil profile water content, measured along perpendicular transects adjacent to single-row windbreaks of tamarisk, Siberian elm, Russian-olive, honeysuckle, and Siberian peashrub near Colby, Kansas (1978-1982), was significantly different with distance in 6 of 15 sampling dates. Soil water data from several sampling dates suggested that tamarisk is the highest water user and Siberian peashrub the lowest among species (honeysuckle omitted). Half the windbreak lengths were root pruned in April 1980, and winter wheat yields in the 1/2 to 2H (H = windbreak height) root-pruned zone were 1.6 times those in the same unpruned zone (1982). Assuming 13 cents/kg for wheat, that difference would equal about $205 more per km of pruned windbreak length.

INTRODUCTION

Windbreaks have long been recognized for protecting soils, crops, and livestock. They influence evaporation, transpiration, wind erosion, snowdrifting, and crop yields (Stoeckeler, 1962; Tinus, 1976). Although generally benefical, windbreaks also compete with crops for space, soil water, and nutrients. Because of tree/shrub root competition, crop yields are usually reduced in the 1/2 to 1 1/2H (H = windbreak height) zone adjacent to field windbreaks and, in some cases, up to 3H (Stoeckeler, 1962; Greb and Black, 1961).

Root pruning (cutting) has been used and/or suggested for reducing the adverse effect of root competition on adjacent crops (Stoeckeler, 1962; Frank et al., 1976; Naughton and Capel, 1982). Limited quantitative data are available to evaluate this practice. We initiated this study to determine root competition effects on soil water content and winter wheat yields adjacent to single-row windbreaks in northwest Kansas. We also wanted to study the effects of root pruning on those same variables. We emphasize that this study does not attempt to evaluate the entire zone of windbreak influence—20 to 30H on the leeward side—but only the root influence zone (0 to 3H) on adjacent soil water and wheat yields.

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EXPERIMENTAL METHODS

The study was conducted at the Agricultural Experiment Station, Colby, Kansas, (39°23′ N; 101°04′ W) under nonirrigated field conditions. Five east-west oriented single-row windbreaks established in 1964 by Woodruff et al. (1976) were studied (Table 1). Trees/shrubs leaf out about May 1 and drop their leaves about October 1 in the area. Soil adjacent to the tamarisk, Siberian elm, and Russina-olive was a Keith silt loam, buried phase (Aridic Argiustolls; fine-silty, mixed, mesic) and that adjacent to the honeysuckle and Siberian peashrub was a Richfield silty clay loam (Aridic Argiustolls; fine, montmorillonitic, mesic).

Gravimetric soil water content was determined three times each season (about May 1, July 21, and September 20, 1976-1982) to depths of 1.52 m along perpendicular transects (south side) at 0H, 1/2H, 1 1/2H, 2H, and 3H distance from the windbreaks (except honeysuckle; 0H, H, 2H, 3H). The top three soil-depth sampling increments were 0.3 m each and the fourth was 0.6 m. The perpendicular transects originated at the center of both pruned and unpruned lengths.

Roots were pruned on both sides of the windbreaks along one-half their lengths (15.29 m) at distances of H, 1/2H, 1/2H, H, and 3/4H for tamarisk, Siberian elm, Russian-olive, honeysuckle, and Siberian peashrub, respectively, using a heavy-duty trencher operating at > 1 m depth in April 1980. All distances were measured from the centerline of the tree/shrub row. Black polyethylene (0.15 mm thick) was placed vertically in the trench before backfilling in an attempt to delay new roots from growing back into the area occupied before pruning. Holes at the pruning line were opened in early May 1983 adjacent to the Siberian elm and Russian-olive to examine the condition of the polyethylene and root growth since initial pruning.

TABLE 1. SPECIES AND PHYSICAL DATA ON SINGLE-ROW WINDBREAKS REPORTED IN THIS STUDY, COLBY, KS 1978-1982.

Windbreak species	Avg. height, m	Length, m	Age (1980), yr
Tamarisk (*Tamarix gallica* L.)	3.0	30.5	16
Siberian elm (*Ulmus pumila* L.)	9.1	30.5	16
Russian-olive (*Elaeagnus angustifolia* L.)	6.7	30.5	16
Honeysuckle (*Lonicera tatarica* L.)	1.8	30.5	16
Siberian peashrub (*Caragana arborescens* Lam.)	3.0	30.5	16

TABLE 2. MONTHLY PRECIPITATION AND PREVAILING WIND DIRECTION AT COLBY, KANSAS, 1978-1982.

	Precipitation, cm												
Year	J	F	M	A	M	J	J	A	S	O	N	D	Annual
1978	0.61	2.06	0.28	3.66	11.05	9.32	3.89	2.95	0.28	1.93	2.34	1.12	39.47
1979	1.96	0.08	6.55	1.37	11.61	9.60	19.46	6.78	0.13	2.92	2.21	2.29	64.95
1980	2.11	1.73	6.15	3.45	6.27	3.71	6.15	5.11	3.00	1.83	0.15	0.10	39.75
1981	1.75	0.76	8.59	8.89	22.66	0.38	8.00	3.66	1.83	1.65	5.16	0.03	63.35
1982	0.51	1.07	2.77	2.62	13.49	14.43	7.90	8.41	4.52	6.76	0.66	3.48	66.09
Normal	1.12	1.22	2.95	4.14	6.93	9.45	8.25	5.97	3.66	3.25	1.40	1.04	49.38
	Prevailing wind direction (Goodland, Kansas, 74 km West of Colby, 5-yr avg)												
	NNW	NNW	NNW	NNW	S	S	S	S	S	SSE	NNW	NNW	

TABLE 3. SAMPLING DATES WHERE MEAN SOIL WATER CONTENT OF THE TOP 1.52 M WAS SIGNIFICANTLY DIFFERENT ALONG PERPENDICULAR TRANSECTS FROM UNPRUNED, SINGLE-ROW WINDBREAKS AT COLBY, KS.

Sampling date, month-year	Mean soil water content, cm/1.52 m — Distance from windbreak along transect in windbreak heights						Crop sequence
	OH	½H	H	1½H	2H	3H	
May 1979	48.21a*	37.92c	38.91bc	39.78bc	44.15ab	40.69bc	Fallow
Sept. 1979	25.04c	28.35c	30.12c	32.59bc	37.82ab	43.15a	Fallow
July 1981	27.64c	28.50c	33.05bc	38.48ab	42.11a	44.12a	Fallow
Sept. 1981	26.26c	26.19c	30.35c	35.97b	38.28b	44.65a	Fallow
July 1982	30.63ab	25.81b	25.53b	30.61ab	31.90ab	41.00a	Wheat
Sept. 1982	30.51b	26.80b	29.01b	32.77b	34.32b	43.59a	Wheat

* Means in same row followed by same letter(s) are not significantly different at the 95 or 99% level using Duncan's multiple range test.

Winter wheat (*Triticum aestivum*, var. Larned) yields were determined from hand-harvested perpendicular zones 0.61 m wide and 1/2H to H, H to 1 1/2H, 1 1/2H to 2H, and 2H to 3H long in both pruned and unpruned areas adjacent to the windbreaks on the south side in 1980 and 1982 (a wheat-fallow rotation was used by Station personnel). The south side was chosen because: the adjacent field was farmed as a single block; a farm road was located along the north side; and data reported by Stoeckeler (1962) indicated that small grain responded favorably to shelter on that side of east-west windbreaks in Kansas. At the study site, winter wheat is seeded about September 15, goes dormant about December 7, breaks dormancy about March 15, heads about June 1, and is harvested about July 4.

Precipitation data were available from a rain gauge located near the Experiment Station Headquarters (Table 2).

RESULTS AND DISCUSSION

Soil Water—Unpruned

Among 15 sampling dates, six indicated a significant difference in mean soil water content with distance from unpruned windbreaks (Table 3). Four of the six dates were during the fallow "year" of the wheat-fallow sequence. As expected, the midsummer and fall dates showed lower soil water content near the windbreaks. Except for May 1979, there were no significant differences in soil water with distance at the first sampling near the beginning of the tree/shrub-growing season. The soil profile had recharged during the 7-month nongrowing period (October-April). The high soil water content at 0H in May 1979 was due to snow deposition in the tree/shrub row.

During the wheat "years" (1978, 1980, 1982), when the crop also was using soil water, no differences were noted with distance from the windbreak except in July and September 1982. Between wheat maturity and the July 1982 soil water measurements, rainfall of 16.71 cm was sufficient to recharge the zone beyond the influence of windbreak roots (3H), creating the difference in soil water content with distance. That same pattern was still evident in September 1982.

Among 15 sampling dates, six indicated a significant difference among windbreak species (honeysuckle omitted) in mean soil water content of a 1.52-m deep by 3H-long perpendicular transect adjacent to them (Table 4). Five of the six dates were during the fallow year where windbreak soil water use was not confounded with wheat water use. Of those six dates, "highest" soil water was found four times for Siberian peashrub, twice for Russian-olive, and once each for Siberian elm and tamarisk. Conversely, "lowest" soil water was found five times for tamarisk, twice each for Russian-olive and Siberian elm, and once for Siberian peashrub. These data suggest that tamarisk is the highest water user and Siberian peashrub the lowest among the four species. Perhaps that is logical because Siberian peashrub is a short-growing-season shrub—dropping its leaves before the other species—and tamarisk is a water-loving shrub.

TABLE 4. SAMPLING DATES WHERE MEAN SOIL WATER CONTENT OF A 1.52-M DEEP BY 3H-LONG PERPENDICULAR TRANSECT FROM UNPRUNED, SINGLE-ROW WINDBREAKS WAS SIGNIFICANTLY DIFFERENT AMONG WINDBREAK SPECIES LOCATED AT COLBY, KS.

Sampling date, month-year	Mean soil water content, cm/1.52 m — Windbreak species				Crop sequence
	Tamarisk	Siberian elm	Russian-olive	Siberian peashrub	
May 1979	36.17c*	39.07bc	44.02ab	47.19a	Fallow
June 1979	32.51b	34.11b	42.11a	44.53a	Fallow
Sept. 1979	28.04b	31.24b	32.84b	39.29a	Fallow
May 1981	43.89a	39.57ab	44.73a	36.42b	Fallow
Sept. 1981	32.44b	36.14a	31.60b	34.26ab	Fallow
April 1982	31.27b	36.86ab	35.56ab	39.93a	Wheat

* Means in same row followed by same letter(s) are not significantly different at the 95 or 99% level.

TABLE 5. SAMPLING DATES WHERE SOIL WATER IN TOP 1.52 M WAS SIGNIFICANTLY HIGHER IN ROOT-PRUNED ZONES COMPARED WITH UNPRUNED ZONES ADJACENT TO SINGLE-ROW WINDBREAKS AT COLBY, KS.

	Soil water, cm/1.52 m				
	Windbreak species				
Treatment	Tamarisk	Siberian elm	Russian-olive	Siberian peashrub	Mean
	September 1980 (wheat)				
Unpruned	23.52	24.94	23.27	23.67	23.85β*
Pruned	32.00	27.56	26.29	26.29	28.03α
Mean	27.76α*	26.25α	24.78α	24.98α	
	July 1981 (fallow)				
Unpruned	35.26	36.88	36.04	38.61	36.70b†
Pruned	37.67	39.62	43.15	43.31	40.94a
Mean	36.46a†	38.25a	39.59a	40.96a	
	July 1982 (wheat)				
Unpruned	26.14	26.24	26.95	34.98	28.58b†
Pruned	27.18	30.94	33.65	42.90	33.67a
Mean	26.66b†	28.59b	30.30b	38.94a	
	September 1982 (wheat)				
Unpruned	27.89	31.45	28.98	34.80	30.78β*
Pruned	31.85	38.18	29.57	37.36	34.24α
Mean	29.87β*	34.81αβ	29.27β	36.08α	

* Means followed by same Greek letter are not different at the 90 percent level.
† Means followed by same letter are not different at the 95 percent

However, possible variations in soil water holding capacity and possible differences in snow deposition patterns (not measured) weakens conclusions concerning water use differences among species. Also, 9 of the 15 dates showed no difference in adjacent soil water content among species.

Soil Water—Pruned vs. Unpruned

Among eight sampling dates following pruning, two showed significant differences in soil water content between pruned and unpruned treatments (Table 5). Although two other dates showed significant soil water differences only at the 90% level, they are included in Table 5 for trend information. Both significant cases were on the midsummer sampling date. During the fallow year (1981), by midsummer a difference due to pruning would be expected because no crop was competing with the windbreaks for water. In the wheat year (1982), as indicated earlier, sufficient rainfall had occurred between crop maturity and the July sampling date to exhibit a difference in soil water between the pruned and unpruned zones. No differences in soil water between pruned and unpruned treatments were found at the beginning of the growing season because of recharge during the prior 7 months (October-April). In all cases the zone of soil water measurement for comparison was that from the pruning point to 1 1/2H from the windbreaks.

In July 1982 only Siberian peashrub showed a significant difference in soil water content among species.

Wheat Yields—Unpruned

Fig. 1 indicates how winter wheat yields were reduced closer to the windbreaks. These 2-year results (1980, 1982) pooled for all species, show a yield reduction of 25,

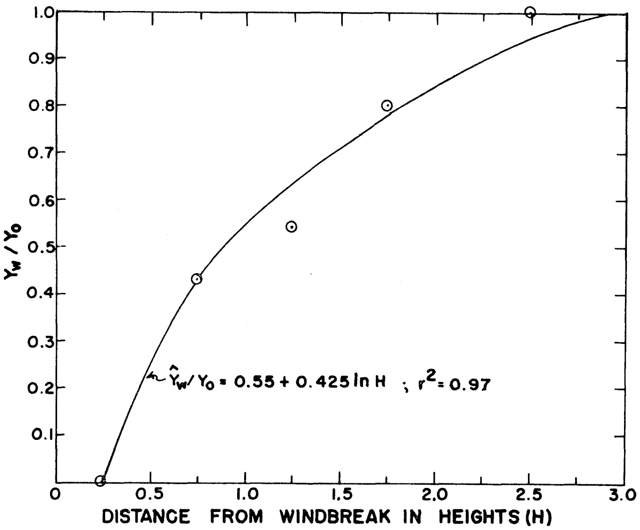

Fig. 1—Ratio of winter wheat yields at various points in the 0 to 3H zone (Y_w) to that at 3H (Y_o) adjacent to unpruned single-row windbreaks, Colby, Kansas.

50, and 75% at distances of 1.6, 0.9, and 0.5H, respectively (compared to those at 3H). Because of tree/shrub canopy width, usually no crops are planted within 1/2H of windbreaks. Consequently, yields are zero in the 0 to 1/2H zone adjacent to them. Visual effects of root competition on adjacent winter wheat were observed. The most obvious effects were delayed emergence and limited growth in the fall following wheat seeding in the zones containing tree/shrub roots. Crop maturity was delayed about 10 days the following summer in the root-affected zones and weed encroachment was more severe than in unaffected zones.

Wheat Yields—Pruned vs. Unpruned

Fig. 2 shows that root pruning eliminated adverse effects on winter wheat yields in the 1/2 to 2H zone adjacent to single-row windbreaks. These are 1982 results only, because root pruning in the spring of 1980 was too late to influence yields. There were no significant

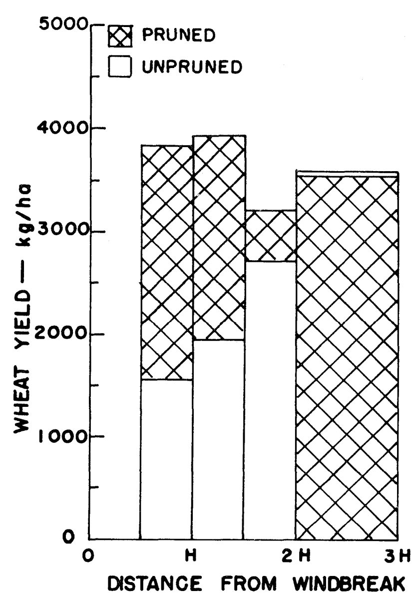

Fig. 2—Effect of root pruning on winter wheat yield adjacent to single-row windbreaks, Colby, Kansas, 1982.

TABLE 6. EFFECT ON WINTER WHEAT YIELDS OF ROOT PRUNING SINGLE-ROW WINDBREAKS AT COLBY, KS (YIELDS MEASURED FROM A ½ TO 2H-LONG PERPENDICULAR TRANSECT).

	1982 Winter Wheat Yield, Kg/ha					
	Windbreak species					
Treatment	Tamarisk	Siberian elm	Russian-olive	Honeysuckle	Siberian peashrub	Mean
Unpruned	2172	2051	2179	2502	2112	2203b*
Pruned	2872	2986	4284	3679	3780	3520a
Mean	2522a*	2518a	3231a	3090a	2946a	

* Means followed by same letter are not significantly different at the 99% level.

differences in wheat yield due to species as a result of root pruning (Table 6). Mean yields in the 1/2 to 2H root-pruned zone were 1.6 times those in the same unpruned zone.

Assuming an 8 m windbreak height, the 1/2 to 2H zone would be 12 m wide. Using the mean difference in yield between pruned and unpruned windbreaks in that zone and a wheat price of 13 cents/kg, pruning would provide 20.5 cents/m per crop year more than unpruned under our study conditions. That would equal $205 more per km of windbreak length.

Naughton and Capel (1982) reported costs of about 3.1 cents/m to root prune windbreaks (both sides) using a modified subsoiler and a farm tractor (1981-1982 costs). The use of a trencher and polyethylene was for research purposes only. Their cost of $1.15 per m for trenching (1980 cost) and 26.5 cents/m for 6 mil polyethylene (1983 cost) are too expensive for practical field use.

Other Considerations

Two questions remain partially unanswered at this time. First, how often should root pruning be repeated? Stoeckeler (1962), from a root-pruning demonstration near Mangum, Oklahoma, reported that pruning appeared to be effective for at least a 3-year period. Naughton and Capel (1982) found that root pruning single-row osageorange (*Maclura pomifera*) windbreaks lasted at least 5 years in Marion County, Kansas. The holes opened adjacent to the Siberian elm and Russian-olive in May 1983 showed the polyethylene to be in good condition except for tears in the upper edges due to chisel tillage in the spring of 1981. No roots were found that had penetrated the plastic. However, some Siberian elm roots had grown over the top of the plastic at depths of 15 to 20 cm. The calloused ends of several roots for both species had resprouted, with most new root diameters $\leqslant$ 0.6 cm. For the conditions of our study, it appears that pruning should be repeated about every 3 years.

The second question concerns possible adverse effects of root pruning on the windbreak. We have not seen any visible effects on the five species studies. Except for 1980 (when the root pruning was performed), rainfall has been above normal at the study site (Table 2). Consequently, we do not know if extended drought might affect root-pruned windbreaks. However, in areas with significant snowfall, deposition over winter in the tree/shrub row should help recharge soil water inside root-pruned zones.

References

1. Frank, A. B., D. G. Harris, and W. O. Willis. 1976. Influence of windbreaks on crop performance and snow management in North Dakota. In: Sym. Proc., Shelterbelts on the Great Plains. Great Plains Agr. Council Pub. No. 78, pp. 41-48.
2. Greb, B. W., and A. L. Black. 1961. Effects of windbreak plantings on adjacent crops. J. Soil and Water Conserv. 16(5):223-227.
3. Naughton, G. G., and S. W. Capel. 1982. Root-pruning osageorange windbreaks. In: Proc. of 34th Ann. Meeting of Great Plains Council Forestry Com., Great Plains Agr. Council Pub. No. 106, pp. 233-242.
4. Stoeckeler, J. H. 1962. Shelterbelt influence on Great Plains field environment and crops. USDA, FS, Prod. Res. Rpt. No. 62, 26 pp.
5. Tinus, Richard W. (ed.). 1976. Shelterbelts on the Great Plains. Sym. Proc., Great Plains Agr. Council Pub. No. 78, 218 pp.
6. Woodruff, N. P., J. D. Dickerson, E. E. Banbury, A. B. Erhart, and M. C. Lundquist. 1976. Selected trees and shrubs evaluated for single-row windbreaks in the Central Great Plains. USDA, ARS-NC-37, 15 pp.

Pump Selection for Center Pivots

(continued from page 68)

pumps. For the conditions examined, CP systems with oversize pumps can be used with fixed nozzle impact sprinklers to achieve adequacies of irrigation in excess of 80% on all of the terrains considered except the upward 5% slope. Pump size had little affect on the uniformity of application. When constant discharge nozzle sprinklers (or sprinklers with pressure regulators) are used, pump size had little effect on the adequacy or irrigation.

The performance of CP systems with conventional fixed nozzle impact sprinklers was most affected by terrain. Water application and the adequacy of irrigation varied widely between upward and downward sloping terrains. These effects were not as pronounced on CP systems with constant discharge nozzle sprinklers. Uniformity of application varied a small and probably insignificant amount with terrain. Energy use was independent of terrain for the conditions examined.

References

1. Edling, R. J. 1979. Variation of center pivot operation with field slope. TRANSACTIONS of the ASAE 22(5):1039-1043.
2. Heermann, D. F. and P. R. Hein. 1968. Performance characteristics of self-propelled center pivot sprinkler irrigation systems. TRANSACTIONS of the ASAE 11(1):11-15.
3. James, L. G. 1982. Modeling the performance of center pivot irrigation systems operating on variable topography. TRANSACTIONS of the ASAE 25(1):143-149.
4. Kincaid, D. C. and D. F. Heermann. 1970. Pressure distribution on a center pivot sprinkler irrigation system. TRANSACTIONS of the ASAE 13(5):556-558.
5. Solomon, K. and J. C. Bezdek. 1980. Characterizing sprinkler distribution patterns with a clustering algorithm. TRANSACTIONS of the ASAE 23(4):899-902, 906.