Field Windbreak Management and Its Effect on Adjacent Crop Yield

A Preliminary Investigation

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The devastating effects of high wind on North Dakota topsoil was witnessed throughout the state during the winter of 1989-90. Fields unprotected by crop stubble or windbreak plantings were vulnerable to extensive wind erosion. Widespread planting of single-row field windbreaks has been done in the past and continues today to help reduce such erosion. Field windbreaks do play an important role in preventing the loss of valuable topsoil. One criticism of field windbreaks, however, is that these plantings can reduce crop yields immediately adjacent to the windbreak (Greb and Black, 1961; Frank **et al**., 1974; Zohar and Brandle, 1978). Trees may compete directly with crops for moisture and nutrients, resulting in decreased plant height and reduced yield.

Windbreak management may provide a way to minimize competition between trees and crops (Frank, 1979; Umland, 1979). The following study was initiated in the spring of 1989 with the objectives of 1) implementing prescribed management practices on selected single-row field windbreaks and 2) monitoring crop yields at prescribed distances away from the windbreak.

MATERIALS AND METHODS

Two mature, healthy, single-row field windbreaks were selected for this investigation. The first, located near Absaraka on Gardena sandy loam soil, was a 27-year-old, 36 feet high green ash (*Fraxinus pennsylvanica* Marsh.) windbreak, interplanted with American plum (*Prunus americana* Marsh.). The second was a 20-year-old, 30 feet high Siberian elm (*Ulmus pumila* L.) windbreak located at the Red River Valley Potato Research Farm south of Grand Forks on Bearden clay loam soil. A 2,400 feet length of trees in each windbreak was divided into four 600 feet sections, one for each of the four corresponding cultural treatments: thinning, fertilizing, root pruning and control. The width of these four treatment blocks, located on the windward side of the windbreak, was determined by calculating the average height of each windbreak and multiplying that value by 10.5. This provided the necessary width in each treatment block to allow the collection of yield data at four prescribed distances away from the windbreak (1H, 2H, 5H and 10H). These distances corresponded to 1X, 2X, 5X and 10X the average height of each windbreak.

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Thinning

Manual thinning was done at the Absaraka site between May 1-4. Green ash with multiple stems originating from ground level were cut back to a single stem. Final spacing for the green ash in the thinned section was approximately 9 feet between stems. On each of the remaining stems, all lower limbs were removed to a 6-foot height above ground. All of the American plum (*Plunus americana* Marsh.) understory plants in the thinning treatment were removed at ground level using a brush cutter. The cut stumps were sprayed with 2,4-D to prevent regrowth. A small percentage of plum did resprout. These were again removed. The Siberian elm windbreak at Grand Forks was thinned between May 8-10, using the same thinning criteria as described for the green ash windbreak. Thinning the Siberian elm windbreak to 9 feet between stems was difficult since the distance between trees was more variable, ranging from 2 feet between trees in some sections and up to 12 feet in other sections where trees had died out. The Siberian elm windbreak did not have an understory species. Final spacing between trees was approximately 9 feet.

Fertilizer

Soil was sampled in the 600 foot x 380 foot fertilizer treatment block at depths of 0 to 6 inches, 6 to 24 inches, and 24 to 48 inches at the Absaraka site which was to be planted to corn, and 0 to 6 inches and 6 to 24 inches at the Grand Forks site which was to be planted to potatoes. Composite samples from the various depths were analyzed at the NDSU Soil Testing Lab for macro- and micronutrients, pH and organic matter content. Analysis results were used to determine levels of nutrients to apply for each crop involved. At the Absaraka site a 37-13-0 N-P-K granular fertilizer was uniformly applied to the fertilizer treatment block with a Tandy drop spreader fertilizer attachment. At the Grand Forks site a 30-75-60 N-P-K granual fertilizer was commercially applied to the fertilizer treatment block with a Terragator drop spreader fertilizer implement.

Root Pruning

A 24 inch long, single-blade, three-point mounted implement was used to prune tree roots in the root pruning treatment. A double pass was made at a distance equivalent to three-fourths the average height of each tree row (.75H) on the windward side of each windbreak. The first pass was made at a 12 inch depth, and the second pass was made in the same trench in the reverse direction at the final depth of 24 inches.

Control

A single control block was used for comparisons to the applied treatments. The control plots received none of the above treatments. Standard farm practices were implemented at each location for each crop.

Yield Measurements

'Garst 8939' hybrid field corn was planted on May 15 at the Absaraka site and the potato cultivar 'Monona' was planted on May 17 at the Grand Forks site. Routine cultivation was done at both sites across all treatments to control weed populations. There were 16 plots per treatment (4 distances X 4 replicates). Four distances from the windbreak were chosen as target strips to monitor crop yield: 1H, 2H, 5H and 10H. The corn was hand-harvested on October 19. Ears from a 20 foot length of row from each of two adjacent rows in each plot were harvested, weighed and dried down to 4 percent moisture content. Data included: plants per acre, number of ears per plant, total wet weight, total dry weight, test weight, hundred kernel weight, average ear length, average ear diameter, kernel depth, kernel rows per ear, kernels per row, percent stem lodging, percent root lodging and percent ear drop. Yield per plot in bushels per acre was calculated at 15.5 percent field moisture. Potato samples were harvested on September 15. A mechanical harvester was used to harvest the tubers from a hundred foot length of row from each plot. Tubers were weighed and total weight per plot was recorded. Yield per acre was calculated.

RESULTS

Corn Yield

Composite yields were combined across the four distances for each treatment. Significant differences were found in yields between the thinning treatment (91 bushels per acre) and the control (67 bushels per acre). Yields for the thinning treatment were not significantly greater than yields from the fertilizer or root pruning treatments (Table 1). Hundred kernel weights and test weights for all three treatments were significantly greater than the control, with the fertilizer treatment producing the highest hundred kernel weight and the thinning treatment producing the highest test weight. Average ear length for the thinning treatment (6.8 inches) was significantly greater than the control (6.4 inches). No significant differences among treatments were detected for plants per acre, number of ears per plant, average ear diameter, kernel depth, kernel rows per ear, percent stem lodging, percent root lodging, or percent ear drop.

Composite yields were combined across the four treatments for each distance. Test weights compared in relation to the distance from the windbreak indicated significantly greater test weights for the plots immediately adjacent to the windbreak compared to weights taken 10 times farther from the windbreak, suggesting a beneficial effect from the trees (Table 2). Average ear length from plots harvested at the 10H distance was signficantly greater than the 1H distance (Table 2). Distance 5H produced the greatest number of kernels per ear followed by 10H and 2H. No significant differences among distances were detected for plants per acre, number of ears per plant, yield per plot, hundred kernel weight, average ear diameter, kernel depth, kernel rows per ear, kernels per row, percent stem lodging, percent root lodging, or percent ear drop. There were no significant treatment by distance interactions for any of the measured variables.

Table 1. The effects of thinning, fertilizing and root pruning in a 27-year-old, single-row green ash field windbreak on the yields of the corn cultivar 'Garst 8939' at a single site near Absaraka, N.D.[1]

Treatment	Yield/Plot (bu/acre)[2]	Test Weight (#/bu)	Hundred Kernel Weight (gm)	Average Ear Length (in)
Thinning	91.1 a[3]	56.9 a	18.9 a	6.8 a
Fertilizing	86.7 ab	56.3 a	19.3 a	6.5 ab
Root Pruning	80.8 ab	56.1 a	18.7 a	6.5 ab
Control	67.4 b	54.3 b	16.3 b	6.4 b

[1] Non-significant differences among treatments were found for plants per acre, number of ears per plant, average ear diameter, kernel depth, kernel rows per ear, kernels per row, percent stem lodging, percent root lodging or percent ear drop.

[2] Individual values in each column represent combined data across the four distances for each treatment.

[3] Column means followed by different letters are significantly different at $P \leq 0.05$ based on Student-Newman-Kuels test.

Table 2. The effects of distance from a 27-year-old, single-row green ash field windbreak on the yields of the corn cultivar 'Garst 8939' at a single site near Absaraka, N.D.[1]

Distance	Yield/Plot (bu/acre)[2]	Test Weight (#/bu)	Average Ear Length (in)	Kernels/ Ear
1H	68.4 a[3]	56.7 a	6.2 b	497 b
2H	83.2 a	56.3 ab	6.5 ab	542 b
5H	90.4 a	55.5 ab	6.8 a	608 a
10 H	84.0 a	55.1 b	6.8 a	598 ab

[1] Non-significant differences among treatments were found for plants per acre, number of ears per plant, average ear diameter, kernel depth, kernel rows per ear, kernels per row, percent stem lodging, percent root lodging or percent ear drop.

[2] Individual values in each column represent combined data across the four distances for each treatment.

[3] Column means followed by different letters are significantly different at $P \leq 0.05$ based on Student-Newman-Kuels test.

Potato Yield

Potato yields ranged from 74 hundredweight per acre for the root pruning treatment to 57 hundredweight per acre for the thinning treatment (Table 3). There were no significant differences in yield among the three treatments and the control. Extreme soil variability coupled with erratic alkalinity levels throughout the site confounded the treatments, resulting in very irregular treatment effects. There was a significant difference in yields among the four distances. Plots at 1H had the lowest yield (45 hundredweight per acre), significantly lower than the other three distances (66, 70 and 85 hundredweight per acre for distances 2H, 5H and 10H, respectively) (Table 4). Regression analysis identified a significant relationship between plot yield and distance from the windbreak, accounting for approximately 50 percent of the variability in yield. There were no significant treatment by distance interactions for yields per plot.

Table 3. The effects of thinning, fertilizing and root pruning in a 20-year-old, single-row Siberian elm field windbreak on the yields of the potato cultivar 'Monona' at a single site near Grand Forks, N.D.

	Treatment			
	Thinning	Fertilizing	Root Pruning	Control
Yield/plot[1] (hundredweight per acre)	57 a[2]	66a	74 a	69 a

[1]Yield/plot represents combined data across the four distances for each treatment.

[2]Means followed by the same letter are not significantly different at $P \leq 0.05$ based on Student-Newman-Kuels test.

Table 4. The effects of distance from a 20-year-old, single-row Siberian elm field windbreak on the yields of a potato cultivar 'Monona' at a single site near Grand Forks, N.D.

	Distance			
	1H	2H	5H	10H
Yield/Plot[1] (hundredweight per acre)	45 c[2]	66 b	70 b	85 a

[1]Yield/plot represents combined data across the four treatments at each distance.

[2]Means followed by different letters are significantly different at $P \leq 0.05$ based on Student-Newman-Kuels test.

DISCUSSION

Field windbreaks had a large effect on yield expressed as plot differences at the various sampling distances away from the windbreak. The effect could not be generalized. For most variables measured in the corn study, the windbreak had no effect on yield. Some variables, however, displayed reduced yields adjacent to the windbreak while other variables displayed enhanced yields adjacent to the windbreak. Favorable changes in microclimate associated with the proximity of the windbreak may account for the enhanced yields (Bouchet **et al**, 1963; Brown and Rosenberg, 1971; Kort, 1988). With other variables the greatest yields occurred near mid-field. This may be a response to better snow and moisture distribution across the field caused by the windbreak (Scholten, 1988). The benefits of improved microclimate and better snow distribution are unique to field windbreaks as a conservation tool and were apparently unaffected by the applied management practices in 1989, the year practices were implemented.

The test windbreak management practices also influenced crop yields, particularly for those variables affected by windbreak proximity. Generally, the management treatments produced greater yields than did the controls. In the green ash windbreak, thinning produced the greatest yields. Thinning not only reduces tree to crop competition, it also improves snow and moisture distrubtion in subsequent years (Frank, 1979; Umland, 1979; Scholten, 1988), factors not present in the year of implementation. Of the three treatments applied to the green ash windbreak, root pruning typically produced the lowest yields. In the Siberian elm windbreak however, the root pruning treatment produced the highest yield, though not significantly different than the control. The extreme soil variability and irregular alkalinity levels associated with the Grand Forks site tended to confound treatments, resulting in plot to plot variability within replications within treatments. Under improved circumstances the root pruning treatment may prove to be the most beneficial treatment at the Grand Forks site, because Siberian elm has one of the most aggressive root systems of any windbreak species (Umland, 1979).

In 1990, additional yield data will be collected from the field on the leeward side of the same two windbreaks. Sampling techniques to reduce soil variability will be used to improve the correlation between yield and management treatment or sampling distances from the windbreak. Monitoring crop yields on the leeward side of the windbreak should produce a greater yield difference between the thinned treatment and the other treatments, especially in years with normal snowfall, when thinning and branch elevation should allow more uniform distribution of snow loads across the field.

Single-row field windbreaks are perennial tree plantings which provide an aspect of soil protection unavailable from other conservation methods. Field windbreaks generally produce an overall increased yield (Kort, 1988), yet they can compete with adjacent crops to reduce yields. Preliminary results from this study examining two field windbreaks indicate that windbreak management practices such as thinning and root pruning may minimize these competitive effects without jeopardizing the unique conservation aspects of field windbreaks.

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