COMPETITION FOR WATER BY WINDBREAK TREES: DISTANCE OF IMPACT ON WHEAT YIELD

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Abstract

Windbreaks are important for conservation of energy and resources on many farms. Trees and shrubs in windbreaks also compete with adjacent crops for water, nutrients, and light. Roots and leaves of some species also release compounds that retard or prevent growth of other plant species. An experiment at the Columbia Basin Agricultural Research Center, at Pendleton, provided an opportunity to quantify the distance to which the yield of winter wheat was reduced by competition along a tree line. Wheat yield was reduced by 28% in a zone 100 ft from a row of mature, 56-ft high, Austrian pine trees. The zone of visual effect on wheat growth extended at least 120 ft from the tree trunks, and 100 ft past the tips of the longest branches. Wheat growth was also visually affected up to 35 ft from a row of shorter (14-ft high) blue spruce trees. The importance of these measurements is discussed with respect to yield on farm fields, the potential for improving yield by pruning tree roots, and the experimental design for research experiments in fields adjacent to windbreaks.

Key words

water stress, wheat, yield, windbreak trees, Austrian pine, blue spruce, allelopathy

Introduction

One or more lines of narrowly spaced trees are used to slow the velocity of wind moving through many farmsteads. Windbreak tree planting became popular as a way to reduce wind erosion following the dust-bowl era. Windbreaks have also been advocated as methods for reducing heat loss around buildings, protecting livestock, providing wildlife habitat, reducing sound transmission from roads to nearby buildings, and trapping wind-blown snow. Windbreaks were widely planted along driveways, fence lines and around rural farmsteads during the 1950's, 1960's and 1970's.

It is also clear, however, that windbreak trees compete for resources such as water, light and nutrients, and that the zones of resource competition extend into nearby crops, pastures and landscape plantings. But there is less understanding about the distance to which the competition occurs, and the magnitude of impact that the trees have on productivity of adjacent crops. This information could become useful when accurate estimates of crop yield are required for fields that include significant areas bordering windbreak plantings.

There are reports that the competition between windbreak trees and adjacent crops may occur as far as three times the height of the tree (Kort, 1988; Sudmeyer and Scott, 2002; Sudmeyer et al., 2002a, b). The competition is, of course, strongly influenced by prevailing soil and climatic factors in the region. In dryland regions of Australia it is widely recommended that farmers prune the roots of windbreak trees to reduce the impact on crops within the 3-times-height zone adjacent to the tree line. The pruning apparently does not reduce tree performance or health, and improves crop yields in fields bordering the windbreaks. We are not aware of measurements that document the tree-crop interaction in the Columbia Plateau.

During 2003 we had an opportunity to observe and measure the magnitude of competition in a wheat crop near a windbreak at the Columbia Basin Agricultural Research Center (CBARC), at Pendleton. This paper reports findings from a seed treatment experiment that provided information relating to the extent of yield reduction in winter wheat adjacent to a windbreak.

Methods

Eleven seed treatment variables were evaluated on Stephens soft white winter wheat at CBARC-Pendleton, where mean annual rainfall (20-yr mean) is 17.9 in. The soil is a Walla Walla silt loam. The trial was planted into an area maintained as a winter cereal/summer fallow rotation.

Wheat was planted at 25 seeds/ft^2 into 5 x 40 ft plots with a Hege plot drill equipped with a cone seeder and five disk-openers spaced at 12 in. Wheat was planted on October 23, 2002 at 1.5-in. depth into moist soil.

The experimental design was a randomized complete block with seed treatments replicated six times. Replicates of 40-ft long plots were aligned east-to-west, and perpendicular to a north-to-south orientation of a windbreak consisting of Austrian pine trees (*Pinus nigra*). The trees were planted at 14-ft intervals in 1967 and, in 2003, had an average height of 56 ft, with a range of heights from 52 to 63 ft. The border of the experiment nearest the tree line was placed 70 ft from the tree trunks.

Data included grain yield and test weight for the wheat crop. Additional measurements were reported by Smiley et al. (2004). Data were analyzed by analysis of variance. An aerial photo of the Station was taken on June 12, 2003 (Fig. 1). The tree-wheat interaction was clearly visible on the aerial photograph but was not detected at ground level. The extent of visual damage to the wheat crop could be measured from the aerial photograph and compared with the average yield for treatments in each replicate of the seed treatment experiment.

Results

Growth and yield were limited by drought conditions at CBARC-Pendleton during both 2002 and 2003. “Growing-season” precipitation (Sep-Aug) deviated from the 20-yr mean by –27% during 2002 and by –10% during 2003. Spring-season precipitation (Mar-May) during 2002 deviated from the 20-yr mean by –32% during 2002 and by –58% during 2003.

The 2002-2003 early winter remained dry but late-winter and spring rainfall was plentiful until April, after which no rain fell. Rainfall amounts (in inches) for each month from September 2002 through July 2003 were as follows; 0.2, 0.6, 1.1, 3.1, 3.3, 2.2, 2.2, 1.8, 1.0, 0 and 0. Grain filling occurred under very dry and hot conditions.

Winter wheat stands (plants/ft of row) two months after planting did not differ ($p<0.05$) among seed treatment variables or replicates. Diseases were not considered to be of limiting severity or incidence. Grain yields and test weights were acceptable for the region and year (Fig. 1). Yields and test weights differed significantly among replicates but not among treatments within each replicate. There was a distinct reduction in yield and test weight in replicate number one, compared to the other five replicates. Replicate one covered the zone from 70 to 110 ft from the trunks of the Austrian pine trees.

The visible effect of drought stress in the wheat, as seen on the aerial photograph, extended to a distance of about 120 ft from the tree line, or approximately 10 ft into replicate two. This distance represented a competitive effect of the trees that extended a horizontal distance of 2.1 times the average height of the trees. Branches of the tallest tree had a radius of 23 ft. The zone of visible crop competition therefore extended about 100 ft beyond the tips of the longest tree branches.

The aerial photo also showed competition from Colorado blue spruce trees (*Picea pungens*) in a more recently planted windbreak across the road from the seed treatment experiment discussed here. Trees in the blue spruce windbreak were planted at 15-ft intervals during 1991 and were thinned to 30-ft spacing during 2001. The blue spruce trees are currently 14-ft high (range of 10 to 17 ft), and had a visible influence extending 35 ft (2.5 times the average tree height) into the wheat crop.

Discussion

Without the aerial photograph, we would not have noticed the effects the windbreak trees were having on the adjacent crops. These effects were not apparent at ground level. The reduction in yield of crops in replication one clearly demonstrate the effect of windbreak trees on adjacent crops. In our situation, the effect of Austrian pine extended an average horizontal distance of 2.1 times the height of trees. Other scientists (Kort, 1988; Sudmeyer and Scott, 2002; Sudmeyer et al., 2002a, b) reported tree influences extending from 1.5 to 3 times the height of trees. Variations in the zones of influence could be attributed to tree species, and to prevailing soil and climatic factors of the region.

Water availability is the major limiting factor influencing crop yields in eastern Oregon. We strongly suspect that windbreak trees reduced yield of adjacent crops largely through reducing the soil water available to the crops. With an obviously bigger and more extensive root system, the pine trees have an enormous competitive advantage over the shallow and less extensive crop roots. Neutron attenuation methods will be used to test this assumption in the spring of 2004. Sudmeyer et al. (2002b) attributed the reduction in yield of crops adjacent to windbreak trees to water stress.

Other factors including shading, nutrition and allelopathy may also affect crops growing adjacent to windbreak trees. Shading was assumed to have minimal effects. The trees at the station shaded part of the crop during the morning but the crop was in full sunlight during the afternoon.

Allelopathy is the production of biochemicals that benefit or adversely affect other plants. Allelopathy, if present, could adversely influenced the crop adjacent to windbreak trees. The lack of understory growth around the Austrian pine and Colorado blue spruce could be an indication of adverse allelopathic effects. Red pine (*Pinus densiflora*) and black pine (*Pinus thumbergii*) have been found to have strong adverse allelopathic effects on other surrounding plants (Rizvi et al., 1993). More work is needed to determine the influence of allelopathy on adjacent crops. Shading and weed control (as needed) may also reduce understory growth but may not influence crop growth beyond the tree line. Allelopathic effects may extend beyond the tree line in areas colonized by tree roots.

Based on these results, it is likely that yields of adjacent crops will be reduced whenever they are closer than 120 ft from the tree trunks, or about 100 ft from the closest branches of mature trees. It is especially important that the wider-than-anticipated zone of competitive interaction be considered when research and demonstration experiments are established near windbreaks. Experiments should either be separated from a mature windbreak by approximately 150 ft, or the experimental design should be established, as in our research, to ensure that the variability due to competition will be minimized by replicates oriented perpendicular to the tree line.

Additionally, the wider-than-anticipated zone of competition near windbreak trees could be put to positive use for investigations of drought tolerance, disease intensity, or other factors. The concept for the experimental design would be opposite that used for line-source irrigation studies, in which experimental variables are replicated perpendicular to an irrigation line, for the purpose of monitoring plant growth, disease, or other factors under progressively lower levels of available water. This would, however, require a better understanding of the phenomenon observed in the research reported here. Specifically, it will be important to be more certain that the variability was indeed mostly or entirely related to availability of water rather than to interactions including nutrition, morning shading, or allelopathy.

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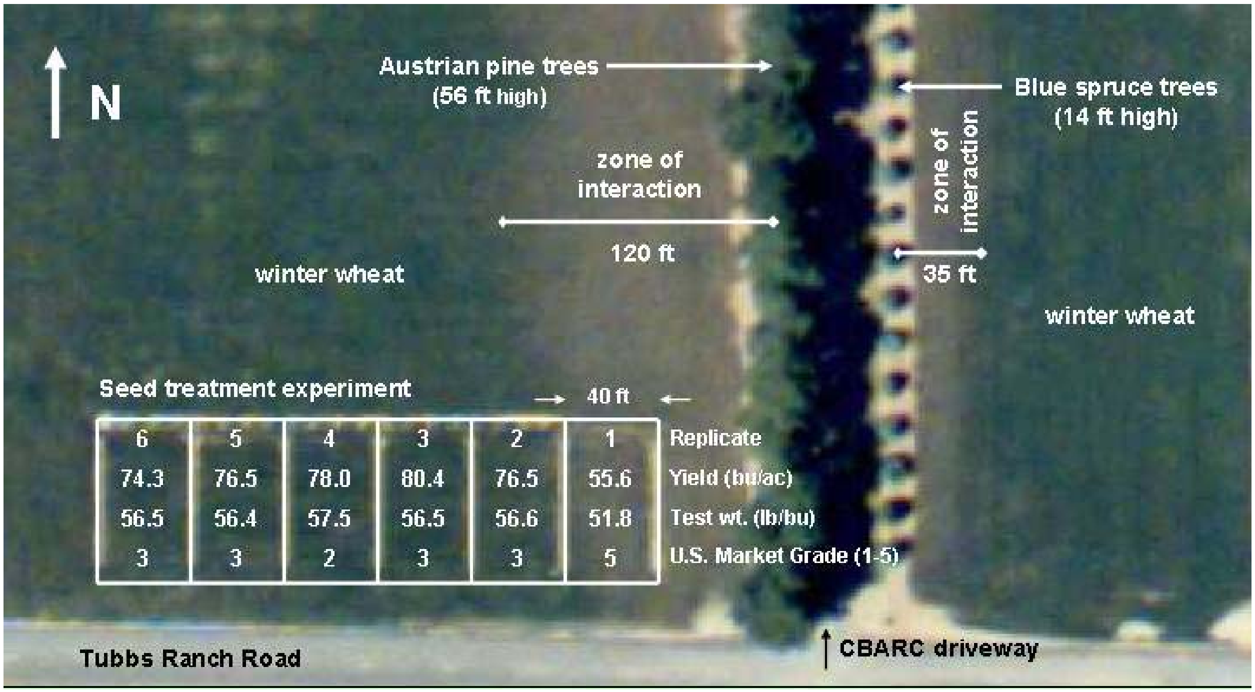

Figure 1. Aerial photograph of the visually apparent tree-crop interaction for winter wheat crops growing adjacent to two rows of trees (each row with a different height) at the Columbia Basin Agricultural Research Center (CBARC) near Pendleton on June 12, 2003. The boxed diagram highlights an experimental area (55 x 240 ft.) composed of six replicates of 11 seed treatment variables growing in 5 x 40-ft. plots oriented in the east-west direction.