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Windbreaks and Crop Production

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WINDBREAKS AND CROP PRODUCTION[1]

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ABSTRACT.—The 21st century is nearly here, and with it the problems associated with an ever increasing population, decreasing natural resources and degradation of the environment. Efficient food production will become imperative. Windbreaks provide one means of increasing production efficiency without jeapordizing the environment. Crop yields for grain and forage crops, speciality and vegetable crops, and orchard and vineyard crops are increased substantially when grown in the protected zone of a windbreak. Crop quality is enhanced and flexibility in marketing is increased by the use of shelter. Overall economic return from sheltered crops is optimized.

INTRODUCTION

The value of windbreaks in agricultural systems has been recognized for many years. As early as the 18th century Scottish agriculturalists were using windbreaks as a means of developing marginal lands. In the early 1800's Albrecht suggested that the forest regions of the Westerwald plateau of Germany, an area devastated by extensive harvesting for charcoal, could be reclaimed by the planting of a system of windbreaks (Caborn, 1957). Following the dust bowl of the 1930's, The Prairie States Forestry Project planted millions of trees throughout the North American Great Plains in an attempt to moderate the climate and reclaim the damaged lands (USFS 1935). These windbreak planting efforts continue today and are one of several tree planting practices recognized by the Conservation Reserve Program (CRP).

Comprehensive reviews on the benefits of windbreaks are available in Bates (1911), Caborn (1957), Stoeckeler (1962), Read (1964), van Eimern et al. (1967), Waister (1972), Grace (1977), and Sturrock (1984). In 1986 an International Symposium on Windbreak Technology was held in Lincoln, Nebraska providing a comprehensive review of windbreak technology (Brandle et al. 1988) and an extensive bibliography of windbreak literature (Brandle and Hintz, 1986).

The effects of windbreaks on field and forage crops, speciality crops, and orchards and vineyards were reviewed by Kort (1988), Baldwin (1988), and Norton (1988) respectively. This paper summarizes the general effects of wind protection on crop production using examples from our current research.

GENERAL WINDBREAKS INFLUENCES

The primary effect of a windbreak is a reduction in windspeed resulting in microclimate changes in the protected zone. This change in microclimate influences the crop grown in the protected zone. The relationship between shelter and crop response is a dynamic system, subject to continual change as a result of changes in macroclimate, windbreak efficiency, and in the protected crop (Sturrock 1984). Final crop yield is the culmination of a series of interacting factors present during the growth and development of the crop (fig. 1). As a result, crop yield data from around the world vary, reflecting the many different site conditions. However, in general, crop yields are depressed immediately adjacent to the windbreak, are increased above that of the unprotected field in the protected zone, and are equal to that of the unprotected field outside of the protected zone (fig. 2). The net windbreak effect is given by the increase in yield in the protected zone minus losses due to sapping and to the area planted to trees.

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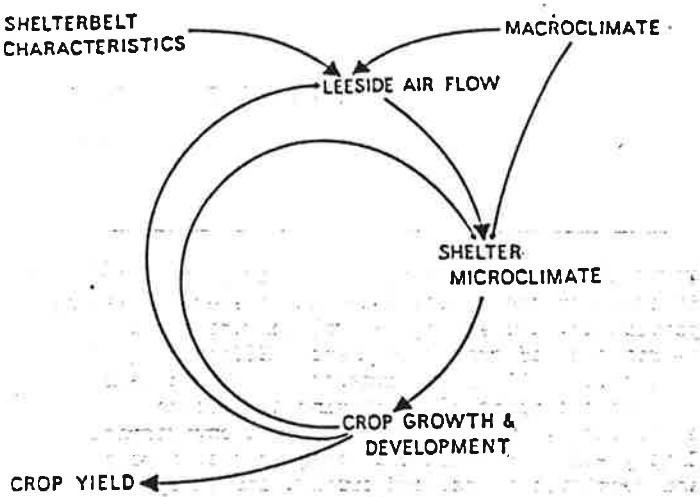

FIGURE 1.--Diagram of the interrelationships of a dynamic shelter system and crop response. (From Sturrock 1984).

Table 1.--Relative responsiveness of various crops to shelter (Kort 1988).

Crop	No. of field/years	Weighted mean yield increase %
Spring wheat	190	8
Winter wheat	131	23
Barley	30	25
Oats	48	6
Rye	39	19
Millet	18	44
Corn	209	12
Alfalfa	3	99
Hay (mixed grasses & legumes)	14	20

FIELD AND FORAGE CROPS

Kort (1988) summarized the relative responsiveness of various field and forage crops to shelter (Table 1) and indicated that these increases had been attributed to improved microclimate, reduced wind erosion, improved snow management, and reduced wind damage to plant material. Improved water use efficiency may also be a significant factor in improved yield (Sturrock 1984; Davis and Norman 1988).

In studies in eastern Nebraska on winter wheat Brandle et al. (1984) reported an average yield increase of 15% over a 6 year period and indicated that protection during the winter was a primary reason for the yield increase. Figure 3 illustrates the damaged areas in a 40-acre (16.1 ha) windbreak system. This pattern of damage was present in all years with severe winters and resulted in significant yield reductions in the exposed areas.

The use of perennial herbaceous barriers as windbreaks was reviewed by Black and Aase (1988). Used primarily in semi-arid areas where proper snow management provides critical soil moisture for crop production, the use of tall wheatgrass (Agropyron elongatum L.) barriers has increased cropping success. During the 18-year study, annual cropping was successful 10 out of 18 years (55%) without wind barriers. However, with wind barriers the success rate increased to 14 of 18 years or 78% (Black and Aase 1988).

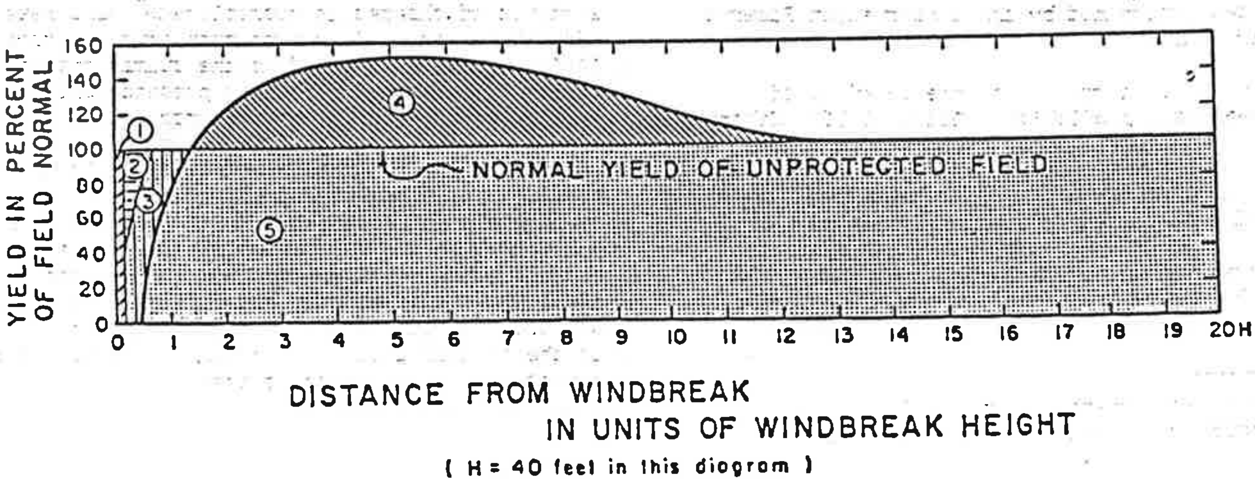

FIGURE 2.--Crop yield to the lee of a windbreak expressed as percent of field normal. (1) Unplanted field borders, (2) Normal crop loss at field borders, (3) Crop loss in the strip adjacent to the windbreak, (4) Crop gain in the protected zone, and (5) Normal crop yield of the unprotected field. (From Read 1964).

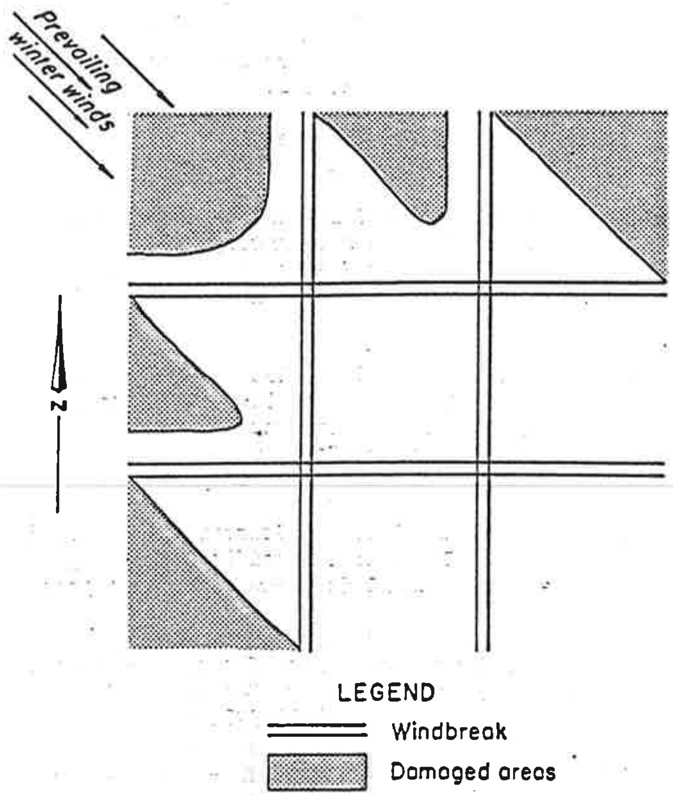

FIGURE 3. Damage to winter wheat in a 40-acre tick-tac-toe pattern windbreak system in eastern Nebraska. Shaded areas indicate damage due to winter kill and reduced yield. Windbreaks consist of two rows of either green ash (Fraxinus pennsylvanica L.) Austrian pine (Pinus nigra Arnold) and eastern red cedar (Juniperus virginiana L.) or eastern cottonwood (Populus deltoides Bartr), scots pine (Pinus sylvestris L.) and eastern red cedar) (Brandle et al. 1984).

Baldwin (1988) discussed the effects of shelter on soybean production. In his research, soybean yields in fields protected by a 5m white spruce [Picea glauca (Moench) Voss] windbreak were increased 12% in the leeward protected zone (Baldwin & Johnson 1984). Radke and Burrows (1970) reported soybean yield increases of 12.5% over a 4 year period at 11 different sites in Minnesota. In their study, protection was provided by temporary corn windbreaks.

Ogbuehi and Brandle (1981a; 1981b; 1982) reported an average yield increase of 23% in a two year study in eastern Nebraska. They attributed the yield increase in shelter to a change in canopy structure which allowed light to penetrate to lower levels of the canopy. As a result, there was greater photosynthesis and greater bean yield in the lower levels of the soybean canopy.

SPECIALITY CROPS

The influence of shelter on speciality crop production has been reviewed extensively by Naegeli (1941), and van Eimern (1964). More recently Sturrock (1984) and Baldwin (1988) have provided additional information on the impact of wind protection on the production of high-value speciality crops.

Vegetable and speciality crops are extremely sensitive to damage by wind and wind blown soil (Finch 1988). While yield increases have been reported for a number of crops the increase in crop quality is considerably more important. In tobacco, (Nicotiana sp.) leaves of sheltered plants were of higher grade and quality resulting in a 15% quality bonus when sold (Kreutz 1952a; 1952b). In sugar beet (Beta vulgaris L.) sugar content was increased from 8 to 20% (Bender 1955; Hanke and Kaiser 1957). Tip-burn of lettuce (Lactuca sp.) was decreased (Cardwell 1936) and yields increased (Grace 1977). Early ripening has been reported for tomatoes (Lycopersicon sp.) (Bagley and Gowen 1960; Bagley 1964), potatoes (Solanum sp.) (van der Linde 1958), and red peppers (Capsicum sp.) Kreutz 1952b).

Modern studies on the effects of windbreaks on speciality crop production are not as abundant as those on field and forage crops. However, there is little doubt that vegetable and speciality crops benefit from shelter (Baldwin, 1988). In general, maximum yield increases are found within 3H to 6H (H=height of the windbreak). In addition to yield and quality benefits, the earlier maturity of shelter grown crops can be a significant marketing advantage.

ORCHARD & VINEYARD CROPS

The influence of windbreaks on orchard and vineyard crops has been reviewed by Caborn (1957), van Eimern et al. (1964), Waister (1972), Sturrock (1984), and Norton (1988). Without exception, these reviews indicate that orchards and vineyards benefit from the improved microclimate found in the sheltered zone. Reductions in windspeed resulted in less mechanical damage caused by the whipping of leaves, branches, buds, flowers, and fruit. By moderating the microclimate within the orchard, conditions for bee activity and pollination are enhanced, fruit set is improved, and final yield is increased.

As in the case of speciality crops, improved crop quality is of considerable importance and is reflected in a higher rate of return. Quality increases have been reported for plum (Prunus sp.) (Preez 1986), pear (Pyrus sp.) (Proctor 1982), kiwifruit (Actinidia chinensis Planch) (McAneney et al. 1984) citrus (Rodriquez et al. 1986; Pohlan et al. 1986; Nikolaishvili and Kiguradze 1986), and banana (Musa sp.) (Holder and Gumbs 1983).

In addition to improved crop yield and quality benefits, windbreaks increase flexibility in orchard and vineyard management. Decrease in windspeed may allow for more timely application of pesticides, enhanced water use efficiency and irrigation management, and improved frost management (Norton 1988).

SUMMARY

The potential impact of windbreak systems on agricultural production must be recognized. Soil and water provide the basis for all agricultural production and must be protected. Windbreaks provide one means of optimizing production while providing adequate protection for soil and water (Brandle and Hintz 1988).

By providing adequate wind protection, crop production per unit of land can be enhanced 10 to 50% or more. In non-irrigated agricultural systems, windbreaks can increase water use efficiency of the crop. Used in conjunction with irrigation, windbreaks reduce evaporation and enhance the distribution of irrigation water, providing increased water management efficiency. In areas where snow provides a significant proportion of the annual precipitation, windbreaks provide for efficient snow management, resulting in increased soil moisture. In this case, improved water management results in improved crop yield.

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