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Windbreaks

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Windbreaks

Robert Rouse and Laurie Hodges

Windbreaks are an important and often overlooked component of a plasticulture system. They provide benefits regardless of where you farm or what crops you are raising. When wind protection is included in a plasticulture production system, crops benefit from less wind stress and an improved microclimate for growth and development. There is less crop injury due to soil abrasion or wind-whipping of plants, less extreme soil temperature fluctuations, and improved soil warming. Wind protection often results in earlier yields of higher-quality crops.

Vegetables in general have a very low tolerance to wind stress (table 6-1). Wind is not only a concern in horticultural production along the coasts; it is a problem wherever crops are grown—in mountainous areas, along river valleys, and in the middle west and central plains. The preferred soils for horticultural crop production are light, sandy, well-drained soils. Crops on these soils are very likely to respond positively to intensive plasticulture production systems. However, these soils are also most subject to soil erosion by wind. Consequently, crops grown on these sites will be subject to the adverse effects of wind for at least part of the growing season.

There are two factors to consider regarding wind stress. One is direct physical injury or abrasion caused by windblown soil or abrasion from leaves or other plant parts rubbing against each other. Fine soil particles, both organic and mineral, are easily moved by wind. Often these particles contain 10 to 20 times as much humus and phosphate as the heavier particles that stay on the field. Many growers have seen sandy soils blowing across rows covered with plastic mulch.

When young, tender plants are either transplanted or direct-seeded and emerge early in the season on plastic mulched beds, and there is potential for problems if winds are not controlled. When plants are more mature, winds may cause them to lodge, break, or lose fruit. Plants can be uprooted from the planting hole by a combination of wind and soil erosion in a plasticulture system. Wind-stressed fields may experience more disease.

The second factor is that of the indirect effects of wind on plant physiology and on the environment immediately around the plant (the microclimate). Reports indicate that the potential for reduced yields of vegetable crops occurs when wind velocity exceeds approximately 9 miles per hour. You may not notice differences in pollination or fertilization, the rate of growth, or crop quality unless you have a comparable field or growing area that is protected from the wind. Also, the effect of wind stress on young plants may become evident only after several weeks of exposure.

<table>
<thead>
<tr>
<th>Crop</th>
<th>Physiological injury</th>
<th>Mechanical injury</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cotton</td>
<td>≥13</td>
<td>≥13.4</td>
</tr>
<tr>
<td>Corn</td>
<td>9-13</td>
<td>13.4</td>
</tr>
<tr>
<td>Milo</td>
<td>≥9</td>
<td>≥13.4</td>
</tr>
<tr>
<td>Cucumber</td>
<td>≥9</td>
<td>&gt;11.0</td>
</tr>
<tr>
<td>Pepper</td>
<td>≥9</td>
<td>&gt;11.0</td>
</tr>
<tr>
<td>Cabbage</td>
<td>≥9</td>
<td>&gt;11.0</td>
</tr>
<tr>
<td>Wheat</td>
<td>≥7</td>
<td>≥13.4</td>
</tr>
</tbody>
</table>

For example, young tomato transplants had significantly more catfacing when they were exposed to as little as 7.5 minutes of 30-mile-per-hour wind (Greig et al. 1974). At the physiological level, you may not notice any crop injury. However, wind increases transpiration and changes plant water status. Typically, plants exposed to winds are shorter and have thicker leaves than those protected from wind stresses. Leafy greens raised with wind protection may be of higher quality—sweeter and more tender—than those with full exposure to winds.

Younger plants are more susceptible to wind injury than older, more established plants. Unfortunately, the seasons with the highest and most frequent winds often coincide with the use of young transplants in plasticulture systems. One secret for successful production of high yields of high-quality marketable fruit is to reduce wind stress through the use of natural or artificial windbreaks or shelterbelts.

Some of the problems associated with wind are obvious, some are not so obvious. Several are discussed below.

**Abrasion Injury**

When mechanical wind injury is considered, growers are usually concerned about soil erosion and plant abrasion by the soil particles. The “sandblasting” of newly transplanted vegetable crops can lead to injury, disease, or death, depending on the severity and duration of the damage.

As mentioned earlier, sandy soils are prime candidates for plasticulture production systems. They also have a more limited water-holding capacity and will dry out quickly. Dry, sandy soils are very subject to wind erosion. Smaller particles such as silts and clays can be blown at lower wind speeds. Muck soils, which are high in organic matter, can also have severe wind erosion problems as they dry. Soil erosion is more likely in large open fields than small protected ones. Soil does not ordinarily blow until wind velocity approaches 12–13 miles per hour 1 foot above the soil surface. This is known as the threshold erosion velocity, and the ability for the wind to carry soil is proportional to the cube of the wind’s velocity. Therefore, if there is a small reduction in the wind speed, there is a greater proportionate reduction in the rate of soil loss.

Sand abrasion injury can cause total death of the plant if the injury is severe enough. Growth may be slowed or altered if meristem tissue is injured, resulting in more branching and delayed maturity. Wounds on leaf surfaces caused by windblown soil or leaf-to-leaf abrasion can provide entry points for plant pathogens, especially bacterial pathogens carried on windblown rain, irrigation water, or soil.

Windblown soil not only damages crops and reduces soil fertility but also fills up ditches, both drainage and irrigation. It can also pile up along fences or rows and on roadways. Blowing soil can and does limit visibility and leads to hazardous highway driving conditions.

Remember, as wind speeds increase, direct damage by wind becomes more of a problem. In the United States, wind speeds of 20–45 miles per hour, with higher-velocity gusts of wind, can occur during the growing season due to passing storms or weather fronts.

**Wind-Whipping**

Wind-whipping can be a severe problem in vine crops, sometimes leading to plant death. It can be more of a problem for vine crops grown on raised plastic-mulched beds. The situation becomes more acute as young plants start to vine or run. Wind blowing in one direction will blow and twist the vines. Many times, the wind direction changes abruptly, turning and twisting the vines. This can place extreme pressure on the stem near the soil line. The stem may crack and break. Entire plants have been twisted or broken off at the soil line by wind action. In other cases, young melon plants have been pulled from the soil by the force of the wind.

**Lodging**

Lodging is the flattening of a crop by strong winds. This phenomenon often occurs when winds accompany or follow a heavy rain. It is a problem in corn or heavily fruited crops. Strong winds can cause an entire length of staked tomato plants loaded with fruit to fall like dominos.

When crops are trellised or staked, damage from moderate winds can be overcome with adequate end bracing and breaks in the staked system. Using larger-
diameter stakes at the end rows provides greater stability to the staked system. Some growers use reinforcement bars (rebar) to increase stability of trellising systems. Breaking up the rows with picker crossovers every 100 feet will help.

Lodged plants are harder to harvest, may fall over the raised beds into the alleys, and may produce more cull fruit. Including windbreaks at regular intervals perpendicular to the prevailing winds across a field can reduce lodging and increase harvest labor efficiency and marketable yields.

**Plant Damage and Disease Potential**

Plants damaged or wounded by the mechanical effects of wind have more entry points for pathogens, especially bacteria. Shelter from wind, windblown rain, and windblown soil particles can reduce the incidence of disease.

One example of this involves strawberries. Strong spring winds can have a desiccating effect on uncovered strawberry plasticulture plants. The leaves can be scorched brown, causing them to die. The dead leaves, if not removed, can be a haven for gray mold *Botrytis cinerea*, which, if conditions are right, can devastate a strawberry crop. In a research trial at the University of Nebraska, bell peppers in wind-exposed plots had ten times more bacterial leaf spot than peppers planted with wind protection.

In cropping systems, some air movement is desirable to dry plant foliage quickly after rain, dew, or irrigation to minimize disease potential. But too much air movement can injure plants or their fruit.

**Wind Stress**

Although reducing wind erosion and associated plant abrasion is often the primary reason for using windbreaks, simple wind stress cannot be ignored. In general, the threshold wind speed resulting in decreased vegetable yields is about 9 miles per hour. Many studies have shown growth effects at wind velocities less than this. Table 6-2 shows the effect that different wind speeds can have on plants.

Grains and grasses are more tolerant to wind stress and abrasion than vegetables—thus their suitability for use in annual windbreak systems. Some field reports indicate that solanaceous crops such as peppers, tomatoes, and eggplants are more sensitive to wind stress than other vegetables, with reported thresholds for yield reduction at wind velocities as low as 4.5 miles per hour. Other reports indicate that crops grown for vegetative parts, such as leafy greens or asparagus, may be more sensitive than those grown for reproductive

<table>
<thead>
<tr>
<th>TABLE 6-2</th>
<th>Wind speed and the effect upon plants</th>
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<tbody>
<tr>
<td>WIND SPEED</td>
<td>Wind speed and the effect upon plants</td>
</tr>
<tr>
<td>kilometers/hour</td>
<td>meters/second</td>
</tr>
<tr>
<td>Calm</td>
<td>0-2</td>
</tr>
<tr>
<td>Light air</td>
<td>2-6</td>
</tr>
<tr>
<td>Light breeze</td>
<td>7-12</td>
</tr>
<tr>
<td>Gentle breeze</td>
<td>13-19</td>
</tr>
<tr>
<td>Moderate breeze</td>
<td>20-29</td>
</tr>
<tr>
<td>Fresh breeze</td>
<td>30-39</td>
</tr>
<tr>
<td>Strong breeze</td>
<td>40-50</td>
</tr>
<tr>
<td>Gales</td>
<td>51-100</td>
</tr>
<tr>
<td>Storm</td>
<td>101-120</td>
</tr>
<tr>
<td>Hurricane, typhoon</td>
<td>&gt; 120</td>
</tr>
</tbody>
</table>
structures, such as tomatoes, peppers, and beans. Still other reports indicate that cucumbers and squashes may tolerate more wind damage than muskmelons and watermelons.

To date, these observations have not been substantiated by research. But considering the low wind velocities that result in significant yield reduction or crop injury, growers should include wind protection regardless of the crop being grown.

Wind can increase transpiration, or plant moisture loss that occurs through the leaves and other plant parts. Abrasion or wounding of the plant stem and leaf cuticle increases water loss from the plant. This additional moisture loss can have a very negative impact, especially on a new vegetable transplant or seedling that has a reduced root area and limited ability to take up soil moisture. More mature plants will need more irrigation to compensate for the loss.

Excess water loss through the plant leaves can lead to desiccation and leaf scorch or dieback, nature’s way of equalizing water uptake with water loss. With plug transplants, it is critical to have good soil coverage over the plug root ball. Exposed peat pots or plug plant mix can act like a wick, drying the root ball and causing plant desiccation and death. The reduced root area and uptake function of new transplants coupled with cool or cold, wet soils can result in very little new root growth and development. Microclimate modification is critical to overcome these negatives, and wind protection and windbreaks can help greatly in this regard.

Whatever heat may be retained by soil, soil moisture, and plants on a sunny day can be removed rapidly by wind. One reason growers use plastic mulch is that it absorbs heat during the day and retains much of that heat in the soil during the night. The effect of warming the soil promotes plant growth and earlier crop maturity. By reducing air movement and heat transfer from the soil to the air at night, windbreaks also promote earlier crop maturity. Typically, air above a sheltered crop is 2°–3°F warmer than above a comparable, unsheltered area. The reduction of wind velocity by wind barriers has many ramifications on the microclimate of the protected zone, especially air temperature, soil temperature, and relative humidity in the crop canopy.

Dry air can reduce the effectiveness of pollination and result in lower yields of marketable fruit. Reducing wind and air movement within the crop canopy leads to higher relative humidity surrounding the floral parts than for wind-exposed plants, resulting in better fertilization and improvements in marketable yields. With a plasticulture system in place, crop transpiration will contribute to the relative humidity in the crop canopy, but less water will be lost by evaporation directly from the soil. The benefits of wind protection on crops grown under arid and semi-arid conditions can be significant.

Summing up all the effects of wind stress and abrasion, it comes back to a matter of dollars lost. Wind stress slows crop development and time to market and increases water use. Under windy conditions, fruit size, color, and flavor may be adversely affected. Delayed time to market usually has an adverse effect on profit. Abrasion or scarring on the saleable part of any commodity will result in lower grades and more culls. To achieve the maximum potential from crops grown in a plasticulture system, it is imperative to include windbreaks to minimize these deleterious effects of wind stress and wind erosion. The rest of this chapter is devoted to solutions to the problems associated with wind in plasticulture production systems.

Windbreaks, either temporary or permanent, are needed to limit the impact of wind on a crop. Specific guidelines exist for each type of windbreak regarding its appropriateness for different situations. For further assistance, contact your local soil conservation program or Cooperative Extension office. Some general principles are discussed in the following sections.

A windbreak is an obstruction that is placed in the path of a wind flow and causes an alteration in the wind velocity. Windbreaks are most effective when they are perpendicular to the wind flow. As wind strikes a windbreak, it must move over, through, or around the obstruction. This alternation in wind di-
rection creates a small area on the windward side of the windbreak and a larger area on its leeward side that is protected from the full force of the wind. The extent of the leeward protection is related to the height of the windbreak.

As wind passes over a windbreak, turbulent currents that are of a lower velocity than the main wind stream are created when the air that is forced over the windbreak descends to meet the air that was forced through the windbreak. At the ends of the windbreak, eddy currents form as air moves through the openings between rows or windbreak systems. The wind velocity in these eddy zones may be higher than the unobstructed wind.

Windbreaks that are impenetrable to air also create a strong vacuum on their protected leeward side that tends to pull or suck the obstructed wind stream into the protected zone. This reduces the level of leeward protection afforded by the windbreak. Windbreaks that allow some wind penetration reduce the vacuum and consequently improve the windbreak's effectiveness.

The objectives in designing a windbreak for crop protection are: (1) to achieve enough height to create protection for the desired distance on the leeward side of the windbreak; and (2) to achieve enough penetrability to reduce the effects of eddy currents and the leeward vacuum, yet still afford the desired amount of wind protection and wind speed reduction.

Wind erosion is a function of the length of the unobstructed area along the direction of the prevailing wind (that is, parallel to the wind). Sometimes this is assumed to be the “width” of the field. As this distance increases, the amount of wind erosion increases. Windbreaks break up the field into smaller fields (or wind runs) and thereby reduce the length factor in the wind erosion equation. When rye strips are included in a plasticulture system, each strip reduces the wind run and lessens the wind velocity.

**General Design Criteria for Successful Windbreaks**

- The optimal cross-sectional shape of a windbreak has vertical rather than sloping sides.
- The optimal density for a windbreak is 40–60%.
- A windbreak should extend to the ground.
- The width of windbreaks has a negligible effect on protection, except as it affects penetrability. Generally, a 40–60% density is preferred as a good compromise between distance protected leeward and land used by the windbreak. A single row of rye may provide this or a single row of snow fencing. More individual rows may be required depending on the plant species and in-row spacing. For perennial (tree or shrub) windbreaks, multiple rows are planted with the plants staggered in the rows (offset from one row to the next) to achieve the desired density and level of protection as quickly as possible. For most plants, two to three rows are sufficient. The species height within a windbreak’s width should be varied to create rough windbreak edges.

- The zone of protection created by a windbreak possessing the above characteristics extends leeward for a distance equal to 30 times the windbreak’s height. Maximum protection is provided at a leeward distance of five to seven times the windbreak’s height.

- Windbreaks work most efficiently when their length is 11.5 times greater than their mature height.

These general design rules, from *Landscape Design for Wind Control* by Pitt, Kissida, and Gould, are very appropriate for shelterbelt design and permanent windbreak plantings. The information is also good to know when planning and planting temporary or annual windbreaks.

Most research literature agrees that windbreaks can provide leeward protection for roughly ten times their height (10H) and windward protection for a smaller distance (1H–3H). The maximum wind reduction occurs in a zone 3H–6H leeward. The extent of the protection depends on the height and density of the windbreak. The density depends on the width of the barrier and the type of plant material used in the windbreak. For example, a tree windbreak composed of conifer species will be more dense than one composed of deciduous species.

**Annual Windbreaks**

Many different small-grain crops can be used for annual windbreaks in plasticulture production systems. The two main methods currently used are (1) plant-
ing strips of small grain between the rows after laying the plastic mulch or (2) planting the small grain and then later establishing the planting beds within the field of grain.

Strips of small grain, most often annual rye, are perhaps the most common method to provide wind protection for high-value crops such as melons, tomatoes, peppers, squash, and so forth, grown with or without plasticulture techniques (photo 6-1). The following example shows how to integrate small-grain windbreaks with plasticulture of melons.

A general recommendation for windbreaks in a plasticulture system is to plant strips of annual rye every 30–40 feet across the field. The grain strips are usually 6–8 feet wide or at least the width of the tractor and equipment. Where climate allows, they should be established in the fall and planted at a time that allows successful germination and adequate fall and winter growth to ensure rapid growth in the spring. This will ensure that the grain gains the height needed for adequate wind protection when the crop emerges or is transplanted. If planting cool-season crops such as broccoli, you may want to plant the rye strips closer together to ensure adequate wind protection when the rye is shorter early in the season. Remember, the best wind protection is in the area within ten times the height of the windbreak.

Prepare the soil as for planting any small-grain crop. The seeding rate for the small grain should be comparable to that used when establishing a good cover crop, yet not so heavy as to cause lodging. For example, on the DelMarVa Peninsula, rye can be seeded at 80–110 pounds per acre in mid- to late September.

One advantage of rye is that it can be planted later in the fall than most other cover crops. Rye can establish in very cool weather and will germinate at temperatures as low as 34°F. Vegetative growth requires temperatures in the 40°F range.

Small-grain windbreak strips of cereal rye can eventually grow 5 feet tall. The strips can be mowed, chopped, rolled, or sprayed after the windiest part of the season has passed or left standing until harvest (photo 6-2). To prevent heading yet still provide some wind protection, some growers cut the rye back to about a 3-foot height of stems. Other growers even harvest the strips. Growers should do whatever works best for their individual operations.

Small-grain windbreaks also can help reduce erosion, suppress weeds, and act as a nutrient catch crop. One disadvantage is that temporary windbreak strips occupy 6–8 feet of field for every 20–40 feet across the field. If a grower has a wind-erosion problem, however, this disadvantage is negligible. Windbreaks reduce sandblasting that damages young plants and also reduce whipping and damaging of vines. Melons grow faster, because the temperature around the plant is higher due to shelter from the wind.

This small-grain windbreak system often produces melons one to two weeks earlier than melon production on bare ground without wind protection. Often total marketable yields of vine crops increase due to improved bee pollination of the protected crop.
bining improved yields and earlier production, the pricing advantages gained help offset the land used for windbreaks. In addition, windbreak strips are often used as drive and spray roads later in the season, which reduces plant damage since equipment is not driven over the vines.

An alternative to using rye windbreaks every 30–40 feet across a field is to use rye or another small grain as in-row protective strips. In this technique, a cover crop is fall-drilled over the entire field or small strips are seeded on 5- to 6-foot centers. Instead of plowing the field in the spring, an agricultural rototiller is used to till strips through the cover crop. One or two plastic-covered raised beds are formed in this tilled swath. A strip of grain approximately 20 inches wide is left between the beds or between the group of two beds. The rye or small-grain mini-strip is allowed to grow. Once this mini-strip reaches the desired height, it is killed with a selective grass herbicide or, using a shielded sprayer, a nonresidual herbicide for general vegetation control, such as glyphosate or paraquat. The mini-strip vegetation is eventually tilled into the soil middles, mowed, or left to protect the exposed soil surface. Tillage or mowing must be accomplished before the crop extends beyond the plastic mulch.

Strawberry production in a plasticulture system provides an example of one way to incorporate an annual small-grain windbreak with a transplanted crop. The site selected should have a wooded area or windbreak to protect the strawberry planting from prevailing winds. However, air movement through the site must be sufficient to dry plants quickly after dew or rainfall to minimize the potential for fungus disease. To further protect this high-value, tender crop from wind and water erosion, the row middles can be overseeded with annual rye grass. This is done after the raised plastic beds are made but before the holes are punched in the plastic to plant the strawberries. An overhead irrigation system can be used to wash seeds off the plastic and to help get the rye established. In the late winter, the rye grass can be controlled with a labeled contact grass herbicide, or the middles can be sprayed with a shielded sprayer applying a nonselective herbicide such as paraquat or glyphosate. Spraying must be done carefully, following all label precautions.

The benefits in reduced wind and soil abrasion to the strawberry crop, especially early in the season, are significant. However, one precaution is necessary. A number of growers and specialists have observed that, when living mulches are used in row middles between the raised plastic mulch in plasticulture strawberry production, there can be a loss of a degree or two in frost protection versus a bare-soil row middle. There are two reasons for this: one, if the mulch is killed and covered by a heavy residue, the soil will not warm as quickly and two, if the living mulch is not killed soon enough, it can deplete soil moisture. In each case, as the temperature drops, there is less latent heat held in the soil moisture to radiate back to the surrounding plants.

**Perennial or Permanent Windbreaks**

Hardwood and pine woodlands provide wind protection if they are perpendicular to the direction of the wind. Permanent windbreaks can also be established with a wide range of perennial plants, including native or horticultural trees, shrubs, and tall perennial grasses (photo 6-3). The major advantage of establishing a perennial windbreak is that they are higher and last longer. With protection on both the leeward and windward sides of a windbreak, the sheltered zone between two parallel windbreaks can extend for 300 to 500 feet or more. While it may take 10 to 20 years for a tree windbreak to reach its mature height, most tree windbreaks have a life span of more than 50 years. The real plus is that once they are established, they
can provide protection throughout the year for a number of years.

A wide range of species are appropriate for use in perennial windbreaks. In their Maryland Cooperative Extension leaflet, “Plants for Windbreaks” (now out of print), Kissida, Pitt, and Gould discuss the materials and advice below.

Evergreen trees are the foundation of windbreaks. Their year-round, dense foliage and branches extend to the ground and provide a greater amount of protection during the winter than deciduous trees. Therefore, evergreen trees should be included in all windbreaks wherever possible.

Shrubs are commonly planted along the windward edge of a windbreak to increase its density. They also provide ideal low windbreaks and frequently serve as living snow fences. In many areas, shrub rows provide newly planted evergreens with protection while the trees are getting established.

In selecting plants for use in windbreaks, it is important to consider wind tolerance along with other factors. Each species will have advantages and disadvantages in any given situation. For example, in Maryland, eastern red cedar, Canada hemlock, loblolly pine, and arborvitae are not recommended. Although these plants would appear to be suitable at first glance, they are not included for the following reasons:

Eastern red cedar is the alternate host for cedar-apple rust, a serious disease of apples and crabapples.

Canada hemlock is easily desiccated by continued exposure to cold winter winds.

Loblolly pine, used extensively on the eastern shore, loses its lower branches early in its growth cycle, making it a poor choice.

Arborvitae has dense foliage, but its wood is weak and stems break under heavy snow or ice.

Some of the trees suggested for use in windbreaks (and their limitations) are listed below:

**Leland cypress (Cupressocyparis leylandii).** Mature height is 80–100 feet. This fast-growing, extremely vigorous tree is narrowly pyramidal (almost columnar) with very compact, flattened branchlets. It will grow in a variety of soils. Its columnar habit makes it hard to blend into the landscape. It is very tolerant of seashore locations and free of disease and insect pests. Ice storms can cause damage.

**Norway spruce (Picea abies).** Mature height is up to 90 feet. This medium-fast-growing, dark green, dense, pyramidal tree has graceful, pendulous branches. It likes moist, fertile soil. It is susceptible to spruce gall, aphid damage, and spider mites.

**White spruce (Picea glauca).** Mature height is up to 90 feet. This medium-fast-growing native tree has a pyramidal habit with light bluish green needles. It can endure heat and drought better than most spruces and is very hardy. Several other spruces are more ornamental. It is susceptible to spruce gall, aphid damage, and spider mites.

**White pine (Pinus strobus).** Height is up to 150 feet. This very fast-growing, dense, rounded to pyramidal tree has soft, flexible, and delicate green needles. Drooping needles give it a graceful appearance; it is picturesque when old. White pine is susceptible to white pine weevil and white pine blister rust but is otherwise free of insect pests and diseases.

**Scots pine (Pinus sylvestris).** Mature height is up to 75 feet. This medium-fast-growing, open, round-topped tree has an irregular habit of growth. It is valued for its bluish green foliage and picturesque, open habit at maturity. It has coarse, reddish brown bark and large branches. It is susceptible to Nantucket pine tip moth when young and girdling by mice but is otherwise free of pests and diseases.

**Douglas fir (Pseudotsuga menziesii).** Mature height is 80–150 feet (300 feet or more on the West Coast). This medium-fast-growing tree has a densely pyramidal shape with bluish green needlelike foliage. It is readily distinguished from all other evergreens by its unique pendulous cones and very soft needles. It is considered one of the best native evergreen ornamentals. It is susceptible to bagworm and white mealy bug injury, which can be easily controlled. This tree does not do well where temperatures remain high for long periods.
**Eastern red cedar** (*Juniperus virginiana*). Mature height is 25–30 feet for use as screen or hedge. A native evergreen, it is naturally upright and requires very little trimming. Plant trees about 4–6 feet apart in a row. It is a problem host for cedar apple rust and bag worms and is slow-growing.

Single and double rows of windbreaks are the normal recommendation. A double row usually consists of a row of trees with shrubs or slow-growing conifers on the windward side of the break. To ensure a good stand and offer early protection, plant trees at a closer spacing, but thin or remove them to the recommended spacing once they begin to close in. It may seem like permanent windbreaks take up a lot of land, but if a 1,000-foot-long windbreak occupies 10 feet between rows or even a width of 20 feet when mature, it occupies less than one-half acre and provides wind-control benefits for more than 7 acres.

Each piece of ground is different, so be familiar with the plant hardiness zones for your area. Select a species or mix of species that will do well in your area and in the particular soil and moisture conditions in your fields. Species that have few serious pest problems are best. Do not use any plant material that could become a pest problem, such as the multiflora rose or autumn olive. Select species for a perennial windbreak carefully to make sure your windbreak planting is off to a good start. Your local Cooperative Extension office, Natural Resources Conservation Service (NRCS) office, or local forester can recommend planting materials appropriate for your area. It is highly recommended that you discuss your situation with these resource agencies. They will also know about any federal or state programs developed to encourage the establishment of perennial windbreaks to reduce soil erosion.

The three major drawbacks to establishing a permanent perennial windbreak are (1) the cost of establishment and maintenance, (2) the time required to reach the desired mature height, and (3) the competition in the shadow zone or root zone of the adjacent crop. While these need to be considered, it should be remembered that a permanent windbreak is a long-term investment for both the benefit of the crop and the environment. As with many naturally occurring woodlands among crop fields, the area immediately adjacent to the trees or shrubs can be used for roads to provide access to the field. Brandle et al. (1992) stated that with as little as 1–5% of the land base devoted to windbreaks, a producer can protect a crop, improve yield and quality, and increase profitability.

**Fencing and Other Web-Type Windbreaks**

Wooden-slat or snow fencing can be used as a temporary windbreak. Its use is limited because it is commonly only 4 feet high. It is most often used on very small production areas or for temporary protection. When land is very limited, this type of artificial wind protection may be appropriate and cost-effective, as it can be used for more than one season.

The newer plastic snow fencing such as the Paraweb design fencing may be even more practical than wood fencing. Paraweb windbreaks are being used in a number of countries, most notably New Zealand. These artificial web windbreaks are quite commonly used on high-value crops and have been quite successful. They are designed to be approximately 46% permeable, thus permitting air to pass through, reducing turbulence, and giving good wind reduction over a large area. The plastic or nylon web is securely strung between posts.

A number of manufacturers exist for these products. They are expensive but take up little space and are quick to set up. A further advantage of the web artificial windbreak materials is they do not deplete soil moisture or soil nutrients from nearby crops. Such products usually have a reasonably long life, but repair and replacement costs need to be considered.

**Other Methods for Reducing Wind-Related Problems**

**Organic or Natural Mulches**

Covering the row middles with organic or other natural mulches can greatly reduce the effect of sand or soil movement but will not reduce the force of the wind as effectively as annual in-row grain windbreaks or permanent perennial windbreaks. The row middles can be mulched with straw, such as pine straw, small-grain straw, or chopped switchgrass, or similar materials. One major drawback is the cost and expense of
applying the mulches with only limited protection provided in return.

irrigation

This preventive technique keeps the top layer of soil from drying out. As the soil dries—especially a sandy or muck soil—wind blowing along the soil surface in the 15-mile-per-hour range will cause the soil particles to begin moving. The drier the soil becomes, the more the particles move. By irrigating the soil and keeping it wet, the amount of soil movement can be reduced. Here again, this technique is costly and only a temporary solution. Plants are still subject to wind and its adverse effects. This technique will only temporarily minimize the abrasion caused by moving soil.

Strip Tilling

In strip tilling, different crops or mixes of crops are planted in the field. Instead of having one large open field planted to one crop, there are strips of several different crops, often with different heights and growth characteristics. The uneven surface topography of the field slows wind velocity. This technique is not as effective as other forms of windbreaks and may not be practical for a medium- or large-scale operation.

summary

Wind management is critical to the successful production of high-value crops such as vegetables, strawberries, and cut flowers. The establishment of annual and/or permanent windbreaks must be recognized as a good horticultural practice that involves fertility, water management, weed control, pest control, required maintenance, and management.

When planning a windbreak, keep these thoughts in mind:

- What is the direction of the prevailing winds during the critical windy period, February through June?
- When the wind reaches a velocity approaching 15 miles per hour, soil particles will be moving with potential for abrasion injuries to leaves and fruit.
- When wind velocity exceeds approximately 9 miles per hour, most vegetables respond with physiological changes that result in reduced yields and lower quality.
- A windbreak provides a shelter distance up to 10 times the height of the barrier.
- The barrier should allow for some air movement through it; windbreaks with densities of 40–60% provide the greatest combined benefits of wind reduction and protection.

Brandle et al. very aptly stated, “Windbreaks reduce wind speed and improve the microclimate in sheltered zones. They provide many direct benefits to the producer while maximizing the ecological benefits of ecosystem diversity. They should be an integral part of all vegetable production systems, including plasticulture. While effects of high wind speeds and soil abrasion are quickly evident, other less obvious reductions in yield and crop quality can result from wind stress at relatively low wind speeds. Wind protection systems, either artificial or vegetative, permanent or seasonal, offer benefits in improved microclimate for plant growth. Windbreaks enhance soil warming and improve the water-use-efficiency characteristic of plasticulture. A better understanding of how shelter modifies crop growth will allow design of wind protection systems that achieve the desired modification in microclimate and plant growth, while reducing the expense of windbreak establishment.”