NATURAL RESOURCES CONSERVATION SERVICE

CONSERVATION PRACTICE STANDARD

WINDBREAK/SHELTERBELT ESTABLISHMENT

(**Feet**)

CODE 380

DEFINITION

Windbreaks or shelterbelts are single or multiple rows of trees or shrubs in linear configurations.

PURPOSE

- Reduce soil erosion from wind.
- Protect plants from wind related damage.
- Alter the microenvironment for enhancing plant growth.
- Manage snow deposition.
- Provide shelter for structures, animals, and people.
- Enhance or create wildlife habitat.
- Provide noise screens.
- Provide visual screens.
- Improve air quality by reducing and intercepting air borne particulate matter, chemicals and odors.
- Delineate property and field boundaries.
- Improve irrigation efficiency.
- Increase carbon storage in biomass and soils.

CONDITIONS WHERE PRACTICE APPLIES

Apply this practice on any areas where linear plantings of woody plants are desired and suited for controlling wind, noise, and visual resources. Use other tree/shrub practices when wind, noise and visual problems are not concerns.

CRITERIA

General Criteria Applicable To All Purposes

- Species planted shall be suited for the planned practice purpose(s).
- Refer to NRCS Conservation Practice Standard Tree/Shrub Establishment, Code 612, or to the specifications sheet for tree and shrub planting guidelines including age, size, handling, viability, storage and quality of the planting stock and permanent or temporary cover.
- Species planted must be adapted to the soils, climate and site conditions. The tool to use for this information is the Conservation Tree/Shrub Groups (CTSG) at the webpage above.
- Where possible choose native species over non-native species. If non-native species are used make sure the species chosen is not invasive or considered noxious. Refer to link below for a list of MN/MDA's invasive and noxious plant species.
- All windbreaks will be oriented as close to perpendicular to the troublesome wind as possible regardless of season or direction.
- The location, layout and density of the planting will accomplish the purpose and function intended within a 20-year period.
- For the purposes of this standard, the term 'H' shall mean height in feet of the tallest row of trees at 20 years after planting.
- The maximum design height (H) for the windbreak or shelterbelt shall be the expected height of the tallest row of trees or shrubs at age 20 for the given site. Refer to MN eFOTG, Section II at the webpage below for 20-year tree and shrub heights. http://efotg.nrcs.usda.gov/references/public/MN/TreesShrubsCTSGsubgroups.xls
- Unless otherwise specified, the density of the windbreak shall be between 50 percent and

65 percent and contain a minimum of 1 row of a non-deciduous conifer. Figure 1 on page 6 of the Specification Sheet shows designs for various densities.

- Where possible, choose native species of trees and shrubs over non-native species. If non-native species are chosen, make sure they are not invasive or considered noxious. Refer to the link below for a list of MN/MDA's invasive and noxious plant species.
- http://www.mda.state.mn.us/plants/badplants/noxiouslist.htm

  The webpage below lists invasive terrestrial plants according to MN/DNR.

  http://www.dnr.state.mn.us/invasives/terrestrialplants/index.html
- Site preparation shall be sufficient for establishment and growth of selected species, not contribute to erosion and be appropriate for the site. Refer to NRCS Conservation Practice Standard Tree/Shrub Site Preparation, Code 490 for more information.
- Base spacing between individual plants on the needed growing space, plant type and species, accommodation of equipment and desired characteristics of the stem(s), branches and canopy as required for the specific purpose. Allow at least 4 feet extra width for equipment as necessary. Refer to spacing guides in the Specification Sheet attached to the end of the standard.
- Avoid planting trees or shrubs where they will interfere with structures and above or below ground utilities such as power lines, gas and water lines or septic lines.
- Follow local regulations regarding planting near property lines but trees and shrubs should be at least 20 feet from a property line.
- Where subsurface drains (tile lines) cross through a planting, sealed conduits will be installed a minimum of 100 feet from rows of large spreading trees and 75 feet from all other trees and shrubs.
- Avoid planting in areas of contaminated soil including areas affected by concentrated feedlot runoff; divert feedlot runoff away from the planting.
- Avoid creating blind corners at road intersections.
- When placing openings through a windbreak make openings on an angle to reduce the loss of wind protection. Whenever possible locate access roads at the ends of windbreaks beyond where snow drifts form.
- For all purposes, assess plantings for the potential to cause snow drifting onto public roadways.
  - Appropriate setback distances will be calculated for all plantings on the north and west sides of roadways.
  - Plantings on the south and east sides of roadways will be evaluated for back drifting of snow and creating shade patterns which slow snow and ice melting.
  - Avoid sites that will deposit snow on roadways unless additional plantings are placed upwind to mitigate snow drift problems.
- Protect the planting from adverse impacts such as livestock damage or fire. Use either the NRCS Conservation Practice Standard Fence, Code 382 or Access Control, Code 472.
- If aesthetics is important, use a combination of needle leaf species and broadleaf species with features such as showy flowers, interesting forms and shapes, brilliant fall foliage, persistent colorful fruits or contrasting textures as appropriate.
- To create visual interest, use a mix of tall trees, small trees and shrubs. Use plant cultivars with desired characteristics. Use curvilinear designs and small group plantings adjacent to interior rows to increase visual sight diversity.

Additional Criteria to Reduce Wind Erosion, and Protect and Enhance Plant Growth

- The interval between windbreaks shall be determined using current, approved wind erosion technology, such as the Wind Erosion Prediction System (WEPS) at: http://www.weru.ksu.edu/nrcs/wepsnrcs.html or other currently approved models. Interval widths shall not exceed that permitted by the soil loss tolerance (T) or other planned soil

loss objectives. Calculations shall account for the effects of other practices in the conservation management system.

- The sheltered area is defined as ten times the design height (10H) on the leeward (downwind) side measured from the prevailing wind direction, and two times the design height (2H) on the windward (upwind) side of the windbreak. Growing plants are protected and wind erosion is controlled in the sheltered area provided by the windbreak.
- Base spacing on the level of plant protection needed. Common crops and their annual per acre tolerance to windblown soils are shown in Table 1 on page 10, along with density requirements, recommended number of rows and plant types.
- For wind erosion control, the minimum barrier density is 40 percent and the maximum is 60 percent. This can be achieved through use of properly spaced plants within a single row windbreak comprised of species from Table 2. Table 3 gives spacing recommendations for commonly used windbreak species.
- For the wind erosion control system, temporary measures will be installed as needed such as residue and tillage management, conservation crop rotation, conservation cover, or other practices as appropriate, to supplement the windbreak until it is fully functional.

Additional Criteria to Manage Snow

- Windbreaks for snow management will be located so that snow deposition will not pose a health or safety problem, management constraints or obstruct human or livestock travel paths.
- Where water erosion and/or runoff from melting snow are a hazard, control these erosive forces by supporting practices such as NRCS Conservation Practices Diversion, Code 362; Grassed Waterways, Code 412; or Structures for Water Control, Code 587 or other appropriate practices.

Blowing Snow Management

- The windbreak (living snow fence) will be oriented as close to perpendicular to the snow-bearing wind as possible so that the protected area is on the leeward side. To find the general direction of snow transport, use the Analysis of Snow Climatology Program webpage at: http://climate.umn.edu/snow_fence/Components/Design/introduction.htm and click on Wind Analysis from the menu at the left.
- The minimum barrier density is 50 percent for snow accumulation on roads, highways and ditches, during expected snow-producing months. The barrier density and appropriate minimum set-back distance will be determined on a site-specific basis using the design criteria found in the Living Snow Fence Program on MnDOT's webpage at: . http://climate.umn.edu/snow_fence/Components/Design/introduction.htm and click on "Begin Design Module". Follow the steps.
- An optional design element that increases the effectiveness for this purpose includes a dense trip-row of shrubs planted 40 to 100 feet windward of the windbreak. In this option, the design requires plant-to-plant spacing (within row) at 3 to 10 feet (depending on 20-year heights); or a twin-row high-density design of shrubs planted 3 to 10 feet within row (depending on 20-year heights) and 8 to 16 feet row-to-row spacing. Stagger the placement so no 2 shrubs are planted directly across from each other. The resulting snow catch area will prevent blowing and drifting snow onto the living snow fence.
- Multiple row plantings for snow accumulation will be designed so that snow deposition will not adversely impact plants located in downwind (leeward) rows. Tree and shrub species most suitable for leeward rows include dogwoods, viburnums, lilacs, and honeysuckles; followed by junipers, pines, spruces, red cedar, service berries, hazelnuts, ninebark, sumacs, oaks and maples (see exceptions below).
- Shrubs and trees susceptible to snow load damage (should be avoided in leeward rows) include: plums, chokecherry, nannyberry, pin cherry, buffaloberry, alders, arborvitae (Northern white-cedar), birches, elms, poplars, willows, soft maples such as silver maple and cultivated or varietal maples.

Snow Distribution Management

- For snow distribution across a field, to increase infiltration during snow melt, the minimum windbreak density is 25 percent and the maximum density is 50 percent. Densities are measured during expected snow-producing months. The interval between barriers will not exceed 20H and will depend on the 20-year heights of the plants. Use the Conservation Tree and Shrub Groups (CTSG) to find 20-year plant heights.
- Pruning, renovation and planting are cultural activities used to manage windbreak density for snow distribution purposes.

Additional Criteria to Provide Shelter for Structures, Livestock, and People

- The planting will be oriented as close to perpendicular as possible to the troublesome winds.
- For wind and snow protection, the minimum barrier density will be 65 percent, the minimum 20-year height is 20 feet and the area to be protected will fall within 10H (200 ft). The minimum barrier density can be achieved with:
  - a minimum of 3 rows of non-deciduous conifers or
  - 2 rows of non-deciduous conifers and a dense shrub row.

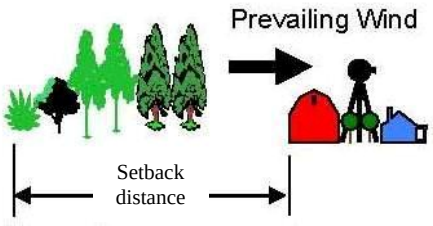
  Non-deciduous conifers include pines, spruces, firs, junipers, cedars, yews and hemlocks. Deciduous conifers are larches and tamaracks.

  Appropriate hardwoods and deciduous conifer species can be substituted for non-deciduous conifers at a ratio of 2 rows to 1. All plantings using this design will contain at least one row of non-deciduous conifer species and a dense shrub row.

  Particularly suitable species of shrubs include: Cornus (dogwood), Corylus (hazels), Crataegus (cragbapple), Prunus (cherries, pears and plums) and Salix (willows). Other species of shrubs may also be suitable.
- If sufficient space is available, recommend a dense single or twin row of shrubs, planted 40 to 100 feet windward of the windbreak, to create a snow trip and snow catch area. The purpose of the snow trip will: Refer to Figure 2, page 7 in the Specifications Sheet for a design of a trip-row and a twin-row windbreak.
  a) reduce snow deposition and potential snow damage of plants within the windbreak;
  b) allow placement of the windbreak closer to the area being protected and;
  c) reduce the minimum number of rows in the windbreak by one.
- Drainage of snowmelt from drifts associated with the windbreak shall not flow across a livestock area and livestock waste shall not flow into the windbreak. Add appropriate waste control practices as necessary.

Set-back Distance for Structures

- The set-back distance from farmstead buildings, all structures or feedlots to the outside row (most windward) of the windbreak will be determined by the Annual Wind Erosion Climatic Factor ("C" Factor) assigned to each county.
  - The minimum setback distance for counties having a "C" Factor greater than 15 will be 175 feet.
  - The minimum setback distance for counties having a "C" Factor less than 10 will be 100 feet.



- A setback distance of 175 feet is desirable in all locations to avoid snow accumulation and avoid turbulence. A minimum set-back of 100 feet is used where property lines or other features will not allow the 175 foot set-back or where winds will be significantly reduced by existing topography or large blocks of existing forest cover.

Additional Criteria to Enhance or Create Wildlife Habitat

- A minimum of 10 rows is required for establishing or creating wildlife habitat with windbreaks. Refer to NRCS Conservation Practice Standard Upland Wildlife Habitat Management, Code 645 for more specific information about windbreaks for wildlife habitat development.
- Design dimensions of the planting shall be adequate for targeted wildlife species.
- Multiple-row shrub windbreaks may be enhance for wildlife by spacing plants within rows as wide apart as guidelines allow to enhance fruit and seed production.
- In multiple-row plantings containing more than 3 rows, the leeward (downwind) rows shall be planted in groups of segments containing 5 or more plants of one species in a series to enhance wildlife values.
- Shrub rows should be located on the outside rows (most windward rows) of the windbreak to create a diverse edge zone for an enhanced woodland edge zone or lane. Use a curvilinear planting design rather than straight rows when planting for wildlife habitat enhancement.
- Between the windbreak rows (depending on competition with primary windbreak species) plant grasses, herbs and/or forbs that provide food and shelter for the targeted wildlife species.
- Use plants of different sizes, growth forms and food bearing capabilities and densities to increase plant diversity.

Additional Criteria for Screens

Noise Screens

- Noise screens shall be at least 65 percent dense and as close to the noise source as possible.
- The minimum design for noise screens is 2 rows of woody plants, one row of shrubs closest to the noise source and one row of tall trees toward the protected area.
- Use the tallest trees practical in the design. However the species recommended must be at least as tall as the noise source.
- For high-speed traffic noise, the screen shall not be less than 65 feet wide where possible. For moderate-speed traffic noise, the barrier width shall not be less than 20 feet wide.
- If needed, select species that are tolerant to noxious emissions, sand, gravel depositions or salt spray from traffic areas. Some suitable plants include: arborvitae (Northern white-cedar), hawthorns, American basswood or linden, sugar or red maples, spruces, viburnums, and firs.
- For non-traffic noise screens, the length of the noise screen should be twice as long as the distance from the noise source to the receiver.
- Plant trees/shrubs using the minimum width between plants. See spacing guidelines under Plans and Specifications on Page 2.
- When possible use plants with dense foliage and persistent branches from the ground up. A few recommended plants are non-deciduous conifers such as: Austrian pine, blue spruce, eastern redcedar, eastern white pine, arborvitae (Northern white-cedar), ponderosa pine, Norway (red) pine, Scotch (Scots) pine, Norway spruce and white spruce. Deciduous woody plants include: Peking cotoneaster, common and Late (Legacy) lilac. Any non-deciduous conifer, suitable for the site conditions, is recommended for year-around noise screens. The species listed here are particularly effective as noise screens. Deciduous woody plants provide less noise reduction benefits during leaf-off conditions. Many other deciduous trees or shrubs, suitable for the site conditions, can be recommended for seasonal noise screens.

Visual Screens

- Visual screens shall be located as close to the observer as possible and have at least 1 row of sufficient density to provide an adequate visual screen. For year around screening, non-deciduous conifers such as pines, firs and spruces will be used.
- The woody plants will be of sufficient height to fully screen the offending view. The screen will be of sufficient width to cover the offending view.

- Appropriate landscape design elements will be used to construct the screen. Such design elements shall consider at least one of the following:
  - color, texture and plant diversity;
  - a mixture of large trees, small trees and various sized shrubs;
  - curvilinear designs and/or small group plantings adjacent to interior rows to increase visual sight diversity;
  - combinations of evergreen species and hardwood species (or cultivars) with features such as showy flowers, brilliant fall foliage, persistent colorful fruits or noteworthy growth forms and shapes to enhance interest.
- Use visual screens to reduce neighbor's views of animal production and waste facilities, which may lead to reduced odor complaints associated with visual stimulus of olfactory senses.
- Use MnDOT's Plant Selector at http://dotapp7.dot.state.mn.us/plant/

  to obtain suggested plants for specific design criteria such as: form, color, texture and other important characteristics in visual screens.

Improve Air Quality by Reducing and Intercepting Air Borne Particulate Matter, Chemicals and Odors

- The windbreak shall have no less than 2-rows; one row consisting of a tall tree species and the second row a dense shrub species. If year-around function is needed, the tall tree species must be a non-deciduous conifer.
- Select and maintain tree and shrub species with foliar and structural characteristics to optimize interception, adsorption and absorption of airborne chemicals or odors. Optimal foliar characteristics include fleshy leaves, dense branches, and leaves with waxy coatings and non-deciduous leaves (leaves remain year-around). Some tree and shrub species suitable for this purpose include: Thuja occidentalis (American arborvitae or northern white-cedar), Pinus resinosa (red pine), Picea spp. (spruces), Abies balsamea (balsam fir), Sorbus americana (American mountain ash), Cornus sericea (redosier dogwood), Crataegus spp. (Hawthorns), Acer rubrum (red maple), Acer saccharum (sugar maple), Juglans nigra (black walnut), Tilia americana (American basswood or linden), Viburnum spp. (viburnums) and Quercus rubra (Northern red oak).
- Adjust windbreak densities to meet air movement needs for naturally ventilated livestock confinement systems.
- If possible, select species based on high leaf surface roughness (plants with leaf hairs, leaf veins, and/or smaller leaf size), complex leaf shapes, large leaf circumference to area ratios and medium to rapid growth rates and branches with lots of leaves. Examples include leaves of conifers such as spruces, firs, pines, yews and larches and leaves of hardwoods such as maples, lindens, some oaks and hawthorns.
- Keep the inner row of windbreak plantings from all buildings and waste storage areas at least 10 times the exhaust fan diameter or 50 feet, whichever is farther.
- Use the widest possible between-row spacings to increase particle surface area contact and foliage light levels.

Air Borne Particulate Matter

- If a series of windbreaks are needed; the windbreak interval shall be less than or equal to10H depending on site conditions and related supporting conservation practices.
- Windbreak density on the upwind (windward) side shall be between 50 percent and 65 percent to reduce the air flow into the source area.
- Windbreak density on the leeward side shall be greater than 65 percent (NTE 80 percent) to intercept particulates.

Odors

- Vegetation shall be maintained to control odor movement and chemical drift. Orientation of the shelterbelt shall be perpendicular to the predominant wind direction and between the source area and the area sensitive to the source.

- Locate shelterbelts upwind (windward) of the odor producing area to disrupt air flow around the odor producing area, increase turbulence in the boundary layer over the area and increase dilution of contaminants in the air, thus reducing odor.

Chemicals

- Locate shelterbelts upwind (windward) of the chemical application area to reduce air movement and subsequent chemical drift.
- Locate shelterbelts downwind (leeward) of the chemically treated fields to intercept fumes, drift and/or chemically treated soil. Species selections should be compatible with pesticides to be used. Maintain a 60 percent or greater density to insure adequate interception of drifting particles.

Additional Criteria for Improving Irrigation Efficiency

- Use a minimum of one-row (conifers. hardwoods or shrubs) to reduce wind effects on sprinkler sprays and slow evaporation from the crop field.
- For sprinkler irrigation systems, the perimeter windbreak shall be at least as tall as the sprinkler heads (irrigation water spray).
- Windbreaks shall not interfere with the operation of the irrigation system. Leave openings for wheel tracks if using windbreaks under a center pivot system. Recommend plants that will fit under the irrigation equipment at maturity.

Additional Criteria for Increasing Carbon Storage in Biomass and Soils

- Select plants that are adapted to the site and have high rates of carbon sequestration. Plant at the full stocking rate for the site. In MN the rate of carbon sequestration is highest with red and white pine forests, then spruce-fir followed by oak-hickory.
- Maximize the width (# of rows) and length of the windbreak to fit the site.
- When using trees and shrubs for greenhouse gas reduction, prediction of carbon sequestration rates shall be made using current approved carbon sequestration modeling technology.
- Maintain optimal water and nutrient needs for the planting.

CONSIDERATIONS

- Use plant material guides to choose tree and shrub species including Conservation Tree and Shrub Groups (CTSG), MnDOT's Plant Selector, NRCS's PLANTS Database and/or the Vegespec Model as appropriate for the purpose, function and design of the practice. These references are available in the EFOTG under Section I, B Plant Selection Tools.
- Older age and medium to larger size planting stock, including bare rooted, transplants, balled and burlap and container grown stock, are recommended in single row and minimum design windbreaks. Death loss is more critical in these designs and larger and older planting stock may provide an advantage in survival rates.
- Favor the use of seedlings certified through the Minnesota Crop Improvement Association (MCIA). Refer to Plant Materials Technical Note #4 for information on certified seedlings.
- When available and appropriate recommend planting stock with known superior traits and named varieties, such as those released through the Plant Materials Program.
- Selection of plants for use in windbreaks should favor species or varieties tolerant to anticipated herbicide use.
- Moisture conservation or supplemental watering may be needed for plant establishment and growth during the establishment period when moisture conditions are too low for plant establishment.
- Where pesticide spray drift from adjacent cropland could adversely effect windbreak plants consider establishing a 10 foot-wide tall grass barrier adjacent to and immediately upwind of the windbreak.
- Avoid plants which may be alternate hosts to undesirable pests for example planting currents (Ribes spp.) near white pines could lead to an outbreak of white pine blister rust.
- Refer to Biology Technical Note #4 "Wildlife Habitat Evaluation System" for wildlife habitat assessment guides for shelterbelts, and field windbreaks.

- All windbreak designs should complement natural features. A good tool to use for visualizing designs is the CanVis Visual Simulation Kit, free CCE approved software which can be found at: http://www.unl.edu/nac/simulation/
- If appropriate, encourage the use of native species. Do not favor native species if they are not capable of providing the designed windbreak function. Refer to Standard 645, Wildlife Upland Habitat Management for information on native trees and shrubs.
- Limit recommending trees and shrubs that have the potential to spread and reproduce off-site.
- Plants established within cropping systems that have root systems which adversely effect crop growth can be root pruned, refer the standard 650, Windbreak/Shelterbelt Renovation.
- Where early wind and snow protection is desired, use close spacing guidelines within the rows, however, thinning or pruning of these close growing trees may be required to maintain the optimal function of the windbreak; refer to NRCS Conservation Practice Standard Windbreak/Shelterbelt Renovation, Code 650.
- If odor control is the primary purpose, design and layout should take into account future expansion facility needs and the placement of natural or artificial barriers near exhaust fans on tunnel-ventilated livestock buildings.
- Windbreaks for odor and chemical control increase in effectiveness as the amount of foliage available for intercept increases. Multiple row, wide plantings offer greater interception potential than do smaller, close planted designs.
- Screens for noise control can be more effective when combined with properly sited earth mounds and/or solid board fences.
- Adding additional tree rows periodically establishes a diversity of age classes and extends the long-term effectiveness of the windbreak/shelterbelt. When designing the windbreak take into account future renovations.
- Increasing carbon storage can be accomplished by eliminating tillage and planting native grasses once the windbreak is established.
- Including a maintenance area around windbreaks allows for easier access for equipment and for activities such as pruning, thinning and weed control.

PLANS AND SPECIFICATIONS

- Specifications for this practice shall be prepared for each site and recorded using the approved job sheet and narrative statements in the conservation plan or other acceptable documentation.
- Documentation shall specify the requirements for installing the practice, such as the kind, amount or quality of materials to be used, or the timing or sequence of installation activities. Requirements for operation and maintenance of the practice shall be incorporated into the site specific job sheet.
- Required supporting data includes mandatory documentation, as above, practice objective(s), soils information, conservation tree and shrub group, maintenance and erosion control, thinning or pruning requirements, tree/shrub planting plan (MN-CONS-7 or other suitable document).

OPERATION AND MAINTENANCE

- Perform the following actions to insure that this practice functions as intended throughout its expected life. These actions include normal repetitive activities in the application and use of the practice (operation) and repair and upkeep of the practice (maintenance):
- Inspect the windbreak periodically to ensure protection and restoration from adverse impacts. Examples of adverse impacts include excessive equipment traffic, pest infestations, drift from pesticide use on adjacent lands, storm damage and fire.
- Livestock shall be controlled or excluded as necessary to achieve and maintain the intended purpose.
- Damaging pests will be monitored and controlled. Repellents, poisons, tubing, netting, fencing and cages of various kinds

may be needed to control rodents and animal damage.

- Replacement of dead trees or shrubs will be required until the windbreak is fully functional and at no time should two adjacent plants be missing throughout the life of the windbreak
- Control vegetative competition until the practice is fully established and functional.
- If using chemicals to control insects or diseases, follow the guidelines in NRCS Conservation Practice Standard Pest Management, Code 595.
- Periodic applications of nutrients and/or irrigation may be needed to maintain plant vigor.
- As applicable, control of wind or concentrated flow erosion shall be continued in the area up-wind or up-gradient of the windbreak to maintain its function. Following severe storms check for evidence of sediment deposit, erosion or concentrated flow channels and take corrective action as necessary.
- Maintain central stem on trees by eliminating forks and multiple leaders. The trees or shrubs will be thinned or pruned to maintain optimal health and function. Use NRCS Conservation Practice Standards Windbreak/Shelterbelt Renovation, Code 650 or Tree/Shrub Pruning Code 660 for these maintenance activities.

RESOURCES

- American Nursery and Landscape Association. 2004. American Standard for Nursery Stock, Washington DC. http://www.anla.org/
- Brandle, J. and Nickerson, H., 1997 Windbreaks for Snow Management. University of NE, Lincoln, NE.
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- Minnesota Inter-agency Living Snowfence Task Force, 1999. Catching the Snow with Living Snowfences. University of MN, MI-7311-S, St. Paul, MN.
- Minnesota Association of Soil and Water Conservation Districts Forestry Committee. Minnesota Tree Handbook. McGregor Printing and Graphics. Tamarack, MN.
- Minnesota Department of Transportation. Living Snow Fences: Control of Blowing and Drifting Snow webpage. http://www.dot.state.mn.us/environment/livingsnowfence/
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- USDA, NRCS National Agroforestry Center, Idaho Resource Conservation and Development Association. 1999. Living Snow Fences. Boise, Idaho. http://www.unl.edu/nac/morepublications/livingsnowfences.pdf
- USDA, NRCS National Agroforestry Center. Windbreak Series. USDA, NRCS, University of Nebraska-Lincoln Extension and North Dakota State University.
  - How Windbreaks Work
  - Windbreak Establishment
  - Windbreaks for Livestock Operations
  - Windbreaks for Rural Living
  - Windbreak Management
  - Windbreaks for Snow Management
  - Windbreaks and Wildlife
  - Windbreaks in Sustainable Agricultural Systems
  - Windbreak Renovation
  - Field Windbreaks
  - Windbreaks for Fruit and Vegetable Crops

  http://www.unl.edu/nac/morepublications.htm
- USDA, NRCS National Agroforestry Center. 2008. Conservation Buffers: Design Guidelines for Buffers, Corridors, and Greenways. General Technical Report SRS-109. http://www.unl.edu/nac/bufferguidelines/docs/conservation_buffers.pdf
- USDA, NRCS Windbreaks for Conservation, 1997. Agriculture Information Bulletin 339.

Table 1 - Crop Sensitivity to Blowing Soil and Windbreak Recommendations

The windbreak should be at least as tall as the crop being protected. Compatible conservation practices, such as cover crops, conservation cover, or other appropriate practices should be used until the windbreak has reached a fully functioning height.

If using permanent compatible soil control practices, the windbreak density can be reduced to 40 percent while maintaining adequate crop protection and avoiding snow drift problems that can result with windbreak densities equaling 60 percent or more.

Non-deciduous conifers include: pines, spruces, firs, junipers, cedars, hemlocks and yews. Not included are larches and tamaracks.

Tolerance to blowing soil (# tons soil/ac.)	**Crop**	**Recommended number of rows and type of woody plants needed to achieve 40 - 60% density to reduce damage from blowing soil**
Tolerant (3 tons)	barley, buckwheat, oats, rye, wheat, flax, millet*	Option 1: If protection is needed more during the growing season rather than at planting, a single row of hardwoods with a 12-foot plant-to-plant spacing will provide adequate protection. Option 2: A single conifer row could also be used with a plant-to-plant spacing of 10 -16 feet. Option 3: A double row of shrubs planted 3 to 10 feet within-row and 6 - 12 feet between row spacing would provide adequate protection. Option 4: If protection is needed at planting, follow the options for low tolerance.
Moderately tolerant (2 tons)	corn, grain sorghum, sunflowers	See recommendations for tolerant above. Use the closest spacings for within-row and between-row spacings.
Low tolerance (1 ton)	apples, asparagus, broccoli, cabbage, cherries, egg plant, grapes, peaches, pears, peppers, soybeans, sweet corn, sweet potatoes	Option 1: A single row of densely spaced non-deciduous conifers. Use a plant-to-plant spacing of 8 – 10 feet. Option 2: Use 2 or more rows with a plant-to-plant spacing from 10 - 16 feet; and row-to-row spacing of 10 - 20 feet. Option 3: A dense shrub row can replace a non-deciduous conifer row if using 2 or more rows in the windbreak. Option 4: Use 2-rows of dense shrubs that are at least as tall as the crop. Use a plant-to-plant spacing of 3 to 10 feet and a row-to-row spacing of 10 to 12 feet depending on the 20-year height of the species.
Intolerant (< 1 ton)	alfalfa, beans, cotton, cucumbers, cabbage, green peas, lettuce, onions, potatoes, spinach, soy beans, squash, sugar beets, tomatoes	See recommendations for low tolerance employing the closest within-row and between-row spacings.

*The economic benefits attributed to windbreaks tend to decrease with grain crops if the windbreaks remove greater than 5 percent of the cropland area.

Table 2 - Recommended Species for Use in Single-row Windbreaks

The following species are suitable for use in single row windbreaks*. See Section II of the eFOTG for additional information on which species are suited to the soils at the site on the webpage below:

http://efotg.nrcs.usda.gov/references/public/MN/TreesShrubsCTSGsubgroups.xls

Black Hills spruce 1/
Bur oak
Carolina (Norway) poplar 2/
Crabapples 1/
Eastern redcedar 1/
Eastern white pine 1/
Hackberry 1/ 3/
Hawthorns 1/
Hickories 1/
Jack pine 1/
Kentucky coffeetree 1/
Lilacs (Chinese, common or purple)
Northwest poplar
Norway spruce 1/
Ponderosa pine 1/
Red pine 1/
Robusta poplar 2/
Scotch pine
Siberian larch 1/ 3/
Siouxland cottonwood
Silver maple 1/
White spruce
Willows 3/

*Ashes (true ash species are in the genus “Fraxinus”) are no longer considered suitable for single-row windbreaks due to the possible threat of the emerald ash borer.
1/ Rarely used in single row field windbreaks in the past, consequently proper management techniques (spacing, pruning) have yet to be determined. This should not discourage use, if landowners are willing.
2/ Fast growing, but relatively short lived (30-40 years).
3/ Young plantings are very susceptible to rabbit damage.

Table 3 – Within-row Plant-to-Plant Spacing Guidelines

This table contains information on the spacing recommendations for commonly used shrubs, small trees, tall trees, and conifers for windbreak plantings; spacings are given in feet. The underlined numbers next to the spacing guidelines correspond to the notes below the table.

Shrubs 3-8 ft.	**Small Trees 8-16 ft.**	**Tall Trees 8-20 ft.**
*Black Chokeberry	*American Mountain Ash 6-12	*Basswood (American Linden) 10-20 5/
*Common Ninebark	*American Plum 6-10 6/	*Black Ash 10-16 9/
Cotoneasters	Apricot 6-10 6/	*Black Walnut 10-20 3/
*Dogwoods	*Common Chokecherry 6-12	*Common Hackberry 10-16 6/
*False Indigo	Crabapples 6-12 1/ 6/	*Eastern Cottonwood 10-20
Lilacs	*Hawthorns 6-10 6/ 2/	*Green Ash 10-16 9/
*Nannyberry Viburnum	Hornbeam	*Hickories
Russian Almond	*Sumacs	*Honeylocust 10-16
*Sandbar Willow	Ussurian Pear 8-16	*Kentucky Coffeetree
*Serviceberry (Juneberry)	*Willows 10-16 4/	Siberian Larch
*Silver Buffaloberry		*Oaks 10-20
*Viburnums (spp)		*Poplars 8-16 4/
		*Silver Maple 10-20 5/
		*White Ash 10-16 9/

Conifers 6-10 ft.	**Conifers 8-16 ft.**
*Eastern Redcedar 2/	Austrian Pine
*Northern white-cedar (Arborvitae)	*Black Hills Spruce
	Blue Spruce 8/
	*Eastern White Pine
	*Jack Pine
	Norway Spruce
	Ponderosa Pine
	*Red Pine
	Scotch Pine
	White Fir
	*White Spruce

* Denotes native species available.
1/ Use fire blight resistant varieties.
2/ Do not plant with apples or crabapples (Malus spp) or within ¼ mile of apple orchards.
3/ Do not plant with or adjacent to a row of conifers because of toxic substance (juglone) secreted by walnut roots.
4/ Relatively short lived trees. Consider as a temporary tree. Fast growing.
5/ Use maximum spacing when possible to reduce within-row crowding and shading of adjacent rows.
6/ Seedlings very susceptible to rabbit damage.
7/ Highly susceptible to aphid damage use only those varieties proven to be resistant to aphids.
8/ Use as a temporary tree; highly susceptible to needle rusts, needle casts and Cytospora canker (after age 10).
9/ Do not plant ashes in single-row windbreaks due to the possible threat of the emerald ash borer.

NRCS Natural Resources Conservation Service

Minnesota

Windbreak/Shelterbelt Establishment

Conservation Practice Specifications *380*

Ver. 8/09

Definition

Windbreaks or shelterbelts (including living snow fences) are single or multiple rows of trees or shrubs in linear configurations.

Purpose

- Reduce soil erosion from wind
- Protect plants from wind related damage
- Alter the microenvironment for enhancing plant growth
- Manage snow deposition
- Provide shelter for structures, animals and people
- Enhance wildlife habitat
- Provide noise screens
- Provide visual screens
- Improve air quality by reducing and intercepting air borne particulate matter, chemicals and odors
- Delineate property and field boundaries
- Improve irrigation efficiency
- Increase carbon storage in biomass and soils

Documentation Specifications

- Specifications for this practice shall be prepared for each site and recorded using the approved job sheets and narrative statements in the conservation plan, or other acceptable documentation.
- Documentation shall specify the requirements for installing the practice, such as the kind, amount or quality of plant materials to be used, the spacing of rows and plants, site preparation activities and other practice requirements as necessary.
- Required supporting data includes mandatory documentation, including: practice objective(s), soils information, conservation tree and shrub group (CTSG), maintenance and erosion control, thinning or pruning requirements, tree/shrub planting plan (MN-ECS-002 or other suitable document).

Density Specifications

- Windbreak design density will vary based on the purpose and planned function of the windbreak. The density of each species of trees or shrubs depends on their growth habit, growth rate and potential height at 20 years of age. Heights may be estimated based on: 1) performance of the individual species (or comparable species) in nearby areas on similar sites, or 2) predetermined and documented heights using Conservation Tree and Shrub Groups (CTSG) found in Section II of the eFOTG. http://efotg.nrcs.usda.gov/references/public/MN/TreesShrubsCTSGsubgroups.xls
- Total windbreak density is a function of the number of rows in the planting, the species and spacing used, and the season (leaf-on versus leaf-off). See Figure 1 on page 7 for examples of windbreak density.

General Spacing Specifications

Spacing Between Rows

- Spacing between adjacent rows can vary or be uniform. If plantings are to be cultivated, plan the between-row spacing wide enough for maintenance equipment to operate freely between rows. Usually this requires about 4 feet more than the recommended width of the windbreak.
- Maximum between-row spacing will depend on site conditions and planned windbreak function but will not exceed 20 feet. Exceptions to these spacings include the use of vegetation as a dense snow catch and where the landowner plans to remove every other row prior to excessive crowding.

Row Types/Heights	**Minimum Between-row Spacing (Row-to-Row) Spacing**
Between Shrubs less than 10 feet in height	10 ft
Between shrubs and small trees from 10 to 25 feet in height	12 ft
Between Small Trees less than 25 ft in height	12 ft
Between small and tall trees greater than 25 ft in height	16 ft
Between tall trees greater than 25 ft in height	16 ft
Between any wide crowned species and conifers	20 ft
Between faster growing species and conifers	20 ft

Spacing Within Rows (Plant-to-Plant Spacing within a row)

- General within-row (plant-to-plant) spacing guidelines are as follows:

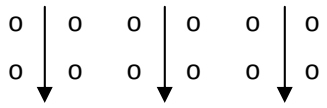
Plant Types 20-year Heights*	**Within-row Spacing in feet**
Shrubs less than 10 feet in height	3 to 6 ft
Shrubs and trees from 10 to 25 feet in height	5 to 16 ft
Trees greater than 25 feet in height	8 to 16 ft

*Species specific within-row spacings are listed in Table 2.

- Where plantings exceed the minimum design criteria, through the use of additional rows, plant to plant spacings up to 20 feet may be planned for appropriate species.
- Closer spacings result in providing protection in the shortest period of time. Where appropriate, plantings with narrow spacings can be designed with a thinning required to achieve the ultimate spacing.
- Within-row spacing for a trip row along with between-row and within-row spacing for high density twin-rows are shown in Figure 2 on page 9.

Plant-to-Plant Spacing in Adjacent Rows

- Spacing all rows at a uniform length creates undesirable gaps in multi-row windbreaks.



- Uniform staggering of multiple rows creates diagonal gaps if the crowns do not meet.

- Use plant species that will develop crown closure within 5 to 10 years. A temporary dense shrub row or herbaceous planting could also be used to cover gaps in young windbreaks.

Species Selection Specifications

- Species must be suitable and adapted to the soils, climate, site conditions and the planned practice purpose. Refer to the EFOTG Section II for more information about Conservation Tree and Shrub Groups by clicking on the link below: http://efotg.nrcs.usda.gov/references/public/MN/TreesShrubsCTSGsubgroups.xls
- Where a portion of a planting site has variable on-site conditions (such as pockets

of high pH soils, high water table soils, an area subject to inundation, depressional areas, wetlands or other environmental condition(s) tree and shrub species should be selected to compensate for the unique site characteristic(s).

- When recommending alternative species within the same row, choose only species that have similar growth habits and their projected height (H) at 20 years of age is within 10%.
- Multiple row plantings (> 2 rows) should contain a variety of species to lessen the chance of loss due to species specific insects or disease.
- In multiple row plantings the species with the shortest 20 year height and slower growing species should be planted in outer rows so they are not overtopped by fast growing and taller species. The between-row spacing must be wide enough so that accumulated snow will not be dumped on the outer rows.
- In multiple row plantings containing more than 3 rows, the leeward rows may be planted in groups or segments containing 5 or more plants of one species in a series to enhance wildlife values.

Planting Stock Specifications

- Only viable, high quality and adapted planting stock will be used. All planting stock will conform to requirements according to current "American Standards for Nursery Stock" adopted by the American Association of Nurserymen (ASA Z60). See Table 1 in the NRCS Conservation Practice Standard Tree/Shrub Establishment, Code 612 for nursery stock quality guidance.
- Planting stock must be of known origin.

Site Preparation Specifications

- Follow the NRCS Conservation Practice Standard Forest Site Preparation, Code 490 for site preparation guidance.
- Appropriate site preparation will be sufficient for establishment and growth of selected species and suitable for the site. Perform necessary site preparation at a time and manner to insure survival and growth of planted species. In all cases plant trees and shrubs into prepared sites free of weeds, grasses, and all other competing herbaceous vegetation.
- Windbreak sites shall be properly prepared based on the soil type and vegetative conditions. Avoid sites that have had recent applications of pesticides harmful to woody species. If pesticides are used apply only when needed, and handle and dispose of properly within federal, state and local regulations. Follow label directions and precautions listed on containers.

Sod and Alfalfa

- In the fall, cultivate (moldboard plow, disk plow, rototiller or similar equipment) the site before planting. If needed to control erosion, seed a temporary cover crop and/or perform tillage on the contour or cross-slope.
- Kill sod by using a non-selective herbicide. These herbicides are most effective when used in the year prior to planting with stock planted into the residue. On heavy soils, tillage is usually necessary to achieve a satisfactory planting when a tree planting machine is used.

Small grain or row crop sites

- If the site is in row crops; cultivate (moldboard plow, disk plow, rototiller or similar equipment) in the fall or in the spring prior to planting. If the site has a plow pan or hard pan in the subsoil, perform a deep disking or ripping operation in the fall. If needed to control erosion, seed a temporary cover crop and/or perform tillage on the contour or cross-slope.
- If the site is in small grain stubble or soybean residue, spring plant without further preparation. If geotextile fabric or other mulch materials are to be installed, till the soil in the spring prior to planting and installing the mulch.

On sites where: it is not practical or possible to operate equipment; where tillage of the site will cause excessive erosion; where potential abrasion of seedlings due to wind blown soil exists; or where tillage of the site is impractical the methods listed below may be used.

- Machine or hand scalp an area at least 36 inches in diameter and place planted stock in the center of the scalped area.
- Rototill a strip at least 36 inches wide the year prior to planting and plant stock in the center of the tilled area.
- Kill the vegetation in a 36-inch diameter or larger area with a non-selective herbicide. This is most effective when done the year prior to planting. Plant the stock in the center of the treated area.
- Sites with undesirable brush will need an initial treatment that physically removes or kills the brush species to facilitate planting of desired stock, and prevents re-encroachment of the brush. Suitable methods include hand-cutting and removal, brush hogging, brush blading, or other equivalent procedure with repeated treatment or use of herbicides to control resprouting.

Cover Crop Specifications

Temporary Cover

- Temporary cover crops may be required for erosion control and weed suppression when seedlings are not available, the normal planting period has passed, chemical residues are likely to carry-over in the soil, steep slopes, erosive soils or other site conditions exist. Temporary cover crops are an interim ground cover and proper site preparation is required prior to planting.

Alternative Temporary Cover Crops

Crop	Rate/acre
Small grains (Oats, Wheat, Barley, Rye)	1 ½ to 2 ½ bu.
Perennial rye	8 lbs.
Timothy	2 to 3 lbs.

Permanent Cover

- Permanent grass cover is important for erosion control, weed suppression, wildlife and other environmental benefits. Between-row seeding should not compete with tree and shrub growth and development. Blue grama and sideoats grama provide effective cover without interfering with windbreak development. Refer to the publication "Warm-Season Grass Cover Between Tree Rows" for more information on using either blue grama, sideoats grama. http://www.plant-materials.nrcs.usda.gov/pubs/ndpmctn6468.pdf.

Warm-Season Grass (PLS lbs/ac)

	Drilled	Broadcast
Blue grama (*Bouteloua gracilis*)	2.5	10
Sideoats grama (*Bouteloua curipendula*)	7.5	30

Planting Specifications

- Refer to the NRCS Conservation Practice Standard Tree/Shrub Establishment, Code 612 for planting guidance.
- All plantings will be done in a manner to promote maximum survival and seedling growth. Plant the seedling in a nearly vertical position with the root collar at or no deeper than 1 inch below the soil surface.
- Protect seedling roots from drying during all operations. Pack soil around newly planted seedlings to eliminate air pockets.
- Plantings using bare rooted stock and non-rooted cuttings should be made in the spring as soon as possible after the frost leaves the ground but no later than June 1.
- Containerized and balled and burlap stock may be planted in frost free ground provided soil moisture is adequate.
- To assure proper alignment of rows and spacing the windbreak should be staked or laid out prior to planting.
- Moisture conservation or supplemental watering shall be provided for plant establishment and growth where natural precipitation is too low for the selected species.

Mulching Specifications

- If using mulch, follow the guidelines in the NRCS Conservation Practice Standard Mulching, Code 484).
- Geo-textile fabric, tree mats and other appropriate organic mulch materials may be used for weed control and moisture conservation for new plantings on all sites.
- Acceptable mulches, fabric, or mat materials must allow for water infiltration and air movement. Fabric mats will be a minimum

of 3 feet by 3 feet in size and properly secured. Manufactured fabrics and tree mats must have a serviceable lifespan of at least 36 months.

- When organic mulches are used the material shall be a minimum 4 inches deep with at least a 2 foot wide radius around the seedling. Organic mulches should be kept at least 6 inches away from the main stem of trees and shrubs to discourage adverse feeding and damage by mice and rodents.

Specifications for Operation and Maintenance

- Perform the following actions to insure that this practice functions as intended throughout its expected life. These actions include normal repetitive activities in the application and use of the practice (operation) and repair and upkeep of the practice (maintenance):
- Inspect the windbreak periodically to ensure protection and restoration from adverse impacts. Examples of adverse impacts include excessive equipment traffic, pest infestations (weeds and insects), pesticide drift from adjacent lands and fire.
- Livestock shall be controlled or excluded as necessary to achieve and maintain the intended purpose. Refer to the NRCS Conservation Practice Standards Fencing, Code 382 or Access Control, Code 472.
- Wildlife damage will be monitored and controlled. Repellents, poisons, tubing, netting and cages of various kinds may be needed to control rodents and animal damage.
- Replacement of dead trees or shrubs will be continued until the windbreak is functional.
- Control vegetative competition until the practice is fully established and functional. Use NRCS Conservation Practice Standard Pest Management, Code 595 or another appropriate practice.
- If using chemicals to control insects or diseases, follow the guidelines in NRCS Conservation Practice Standard Pest Management, Code 595.
- Periodic applications of nutrients may be needed to maintain plant vigor (mainly for carbon sequestration).
- As applicable, control of wind or concentrated flow erosion shall be continued in the area up-wind or up-gradient of the windbreak to maintain its function. Following severe storms check for evidence of sediment deposit, erosion or concentrated flow channels.
- Maintain central stem on trees by eliminating forks and multiple leaders. The trees or shrubs will be thinned or pruned to maintain optimal health and function. Use NRCS Conservation Practice Standards Windbreak/Shelterbelt Renovation, Code 650 or Tree/Shrub Pruning Code 660 for these maintenance activities.

Figure 1 - Examples of Windbreak and Snowfence Density

Height and density of a living snowfence or windbreak will determine how much snow can be stored in the system and where it will be stored.
From: Windbreaks for Snow Management by: James R. Brandle and H. Doak Nickerson

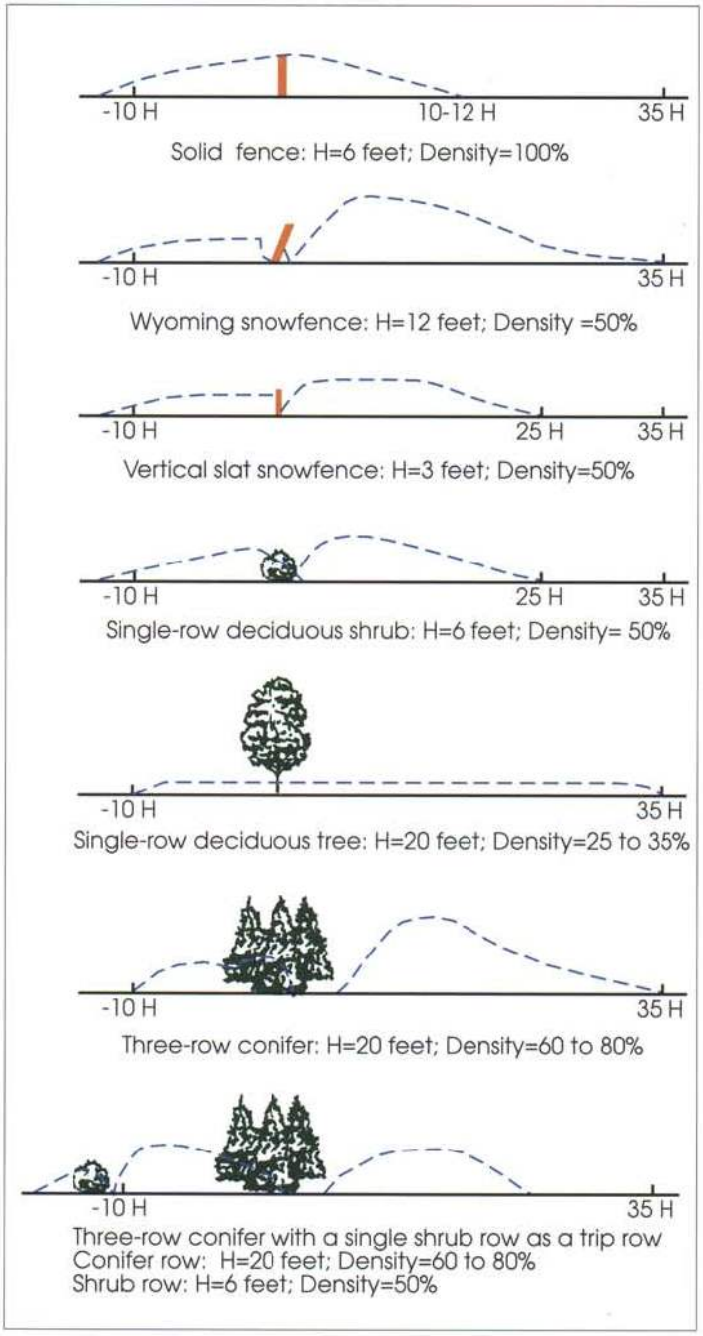
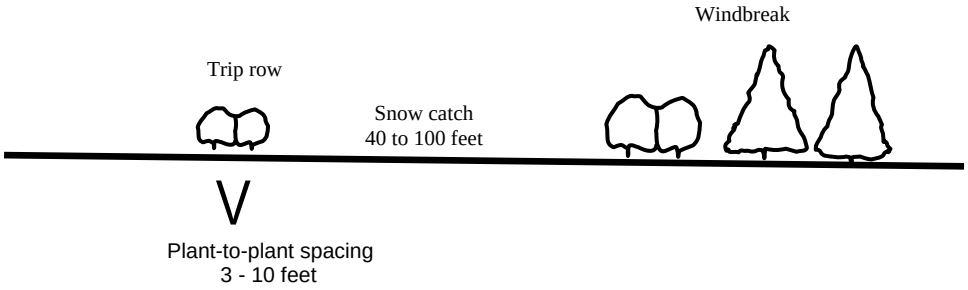


Figure 2: Examples of Trip Row and Twin-Row High Density Windbreak Designs

Optional Trip Row Design



Twin-Row High-Density Design