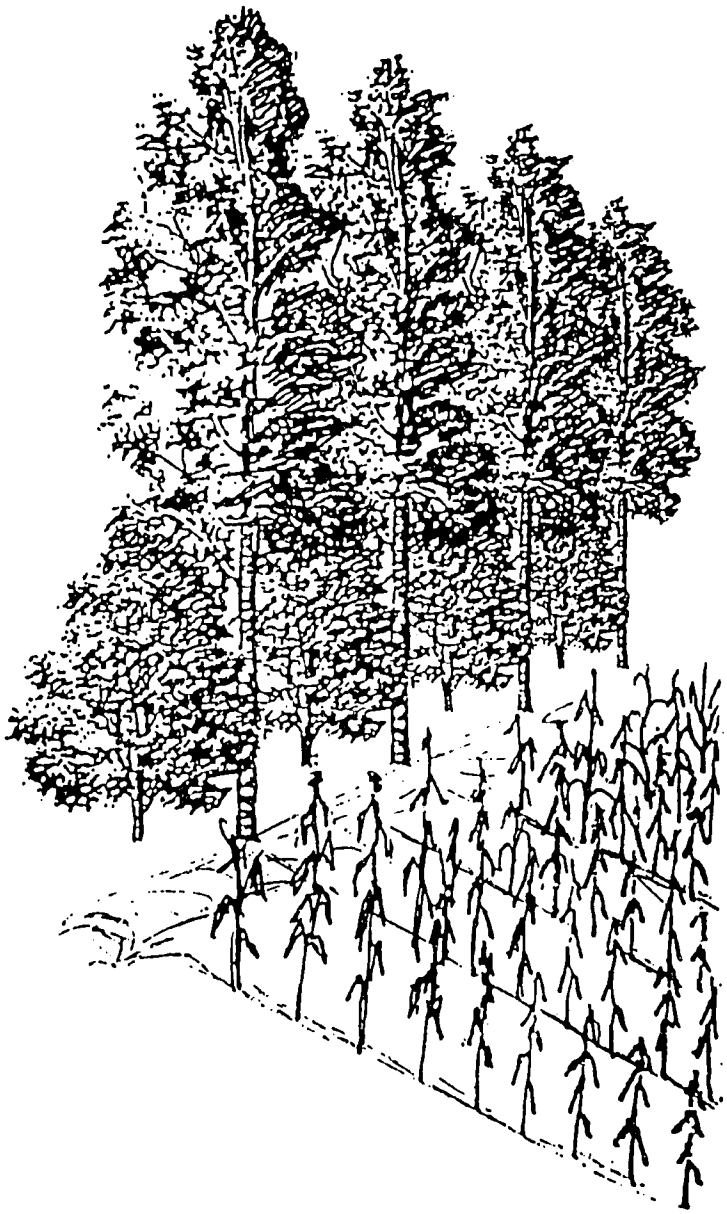
FORESTRY PLANNING & DEVELOPMENT PROJECT
Government of Pakistan-USAID

FARM WINDBREAKS



Technical Note No. 2

September 1990

FARM WINDBREAKS

Technical Note No. 2

September 1990

TECHNICAL NOTE
FPDP No.2

FARM WINDBREAKS

By
Gary G. Naughton[1]

Windbreaks of trees and/or shrubs can substantially improve the productivity of farmlands which are exposed to strong winds. Reducing the speed of the wind conserves soil moisture for growing crops and decreases the energy available to cause soil erosion. In very hot climates, windbreaks may also provide some beneficial shading of field crops. When properly planned and managed, windbreaks will produce large quantities of wood products for sale or home use.

A properly designed farm windbreak can take up as much as 5% of the land under cultivation without causing any net reduction in crop yields. This is because fields under the protection of windbreaks have higher per acre yields than unprotected fields.

The kind of windbreak to be planted on any farm in Pakistan depends upon the geographic location of the farm with respect to the expected severity of the winds, the kinds of soils available, the kinds of trees and shrubs best suited or preferred by the farmer, how much space is available, and whether the land is irrigated or rain-fed.

HOW WINDBREAKS FUNCTION

Windbreaks disturb the normal pattern of wind movement because they are a vertical screen to the free movement of wind. We expect the leeward (down-wind) side of a windbreak to be the place where wind speeds are reduced; but, there is also some reduction of wind velocity on the upwind side of windbreaks. This is because the air is baffled and mixed as it hits the windbreaks, causing a disruptive turbulence pattern which spoils the energy (and velocity) of the wind. This mixing and churning continues as the pressure gradient is baffled by the windbreak and the air leaks through or rolls over the top of the screen.

Some of the airmass passes through the tops of the trees at increased speed (because the area of passage per volume of air is reduced), providing a high pressure airfoil which forces the air upward over the tops of the trees. This air cushion continues to carry the airmass down-wind until it gradually approaches original velocity. For traditional multiple-row windbreaks with two or three rows of tall trees in the center and rows of progressively shorter trees on both sides, this is a point down-wind which is equal to 50 times the height (50H) of the windbreak. In the same situation, some reduction of ground level wind velocity can be detected upwind of the barrier for a distance equal to 10H.

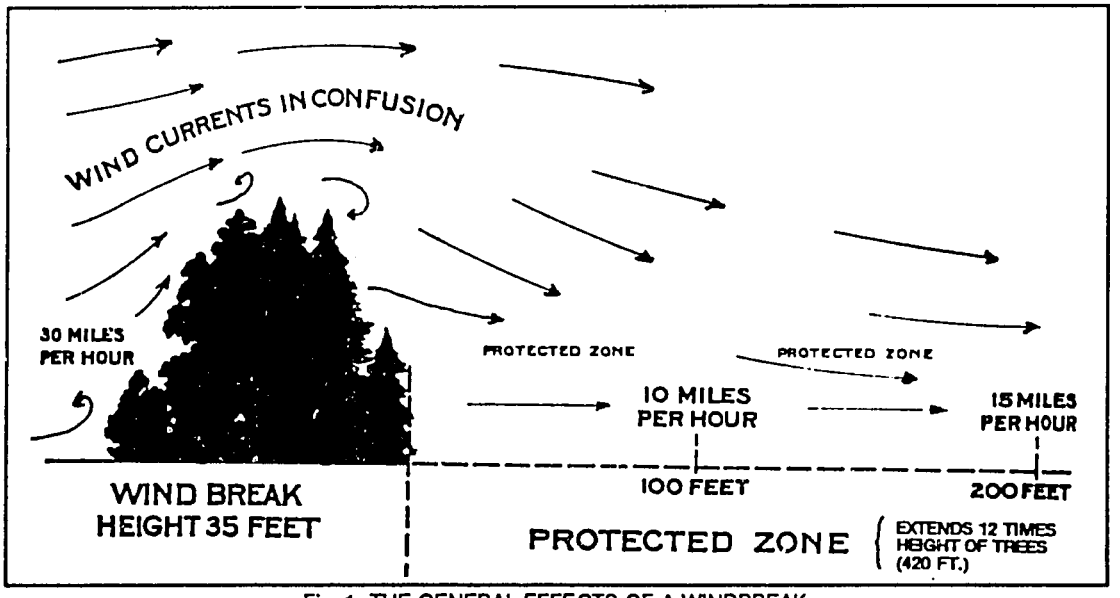


Fig. 1 THE GENERAL EFFECTS OF A WINDBREAK

The best windbreaks approach 100% crown density in the low-profile shrub rows, and 50% density in the tall rows. In field applications, it is not common to attain this ideal crown density. Because of this and other irregularities related to the overall length of the windbreak and variations in size, shape, density, and texture of the trees, we normally expect the downwind effects of windbreaks to cease at about 25H, and the up-wind effects to cease at about 5H.

In Pakistan, because of small field size, we will most often use 2 or 3-row windbreaks, and should expect the effects to reach only about 12H down-wind and 2H up-wind.

---

[1] The author is Field Demonstration/Outreach Forester, Winrock International (Technical Assistance Team), Pakistan Forestry Planning & Development Project, Islamabad.

A windbreak with 50% crown density is more effective than one of either 100% or of 25% density. The acceleration of air through the openings in the crowns provides the high pressure cushion needed to support the air which tumbles over the top. When the barrier is 100% density – like a stone wall – the up-wind air builds up with high pressure while the down-wind air creates a low-pressure void. When the mass of air boils over the top of the barrier, its volume and turbulence force it back to ground level with increased velocity. In the case of windbreaks with less than 50% crown density, the effectiveness is reduced because too much of the air leaks through under pressure.

INFLUENCE ON CROP YIELDS

If the crop yields are carefully measured at various points on a line perpendicular to the center of the windbreak, the following profile graph can be produced. By calculation, it can be shown that the total potential yields for most crops will be 5-10% greater on the field, even though the windbreak itself takes land out of production.

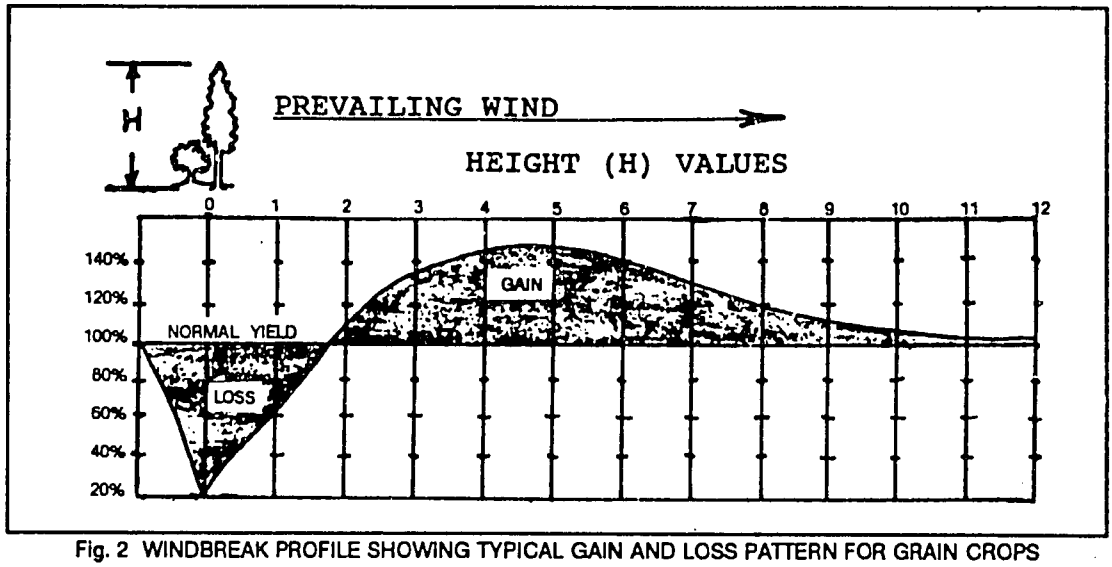


Fig. 2 WINDBREAK PROFILE SHOWING TYPICAL GAIN AND LOSS PATTERN FOR GRAIN CROPS

It is also important to realize that the average farmer will focus on the area next to the trees which produces much less than a normal crop, but will not likely see the large area of the field where the crops are above normal. You may not be able to convince him unless he has kept records of production for several years before the windbreak was planted. To avoid this kind of problem, you should always try to get the farmer to state what his field production totals have averaged in the past, before the windbreak is planted. It also helps if you show him the diagram and explain what is going on, but don't be too surprised when he wants to take out the windbreak after 7 or 8 years. Harvesting of eucalyptus or poplar at this age is not a bad idea anyway because the trees will have economic value. The culture of coppice sprouts from the stumps will provide a low-cost replacement of the windbreak.

Some trees and shrubs have shallow, wide-spreading root systems which compete directly in the root zone of the field crops for water and nutrients. In irrigated fields, this is not a significant problem, but in barani fields it can be serious. A few years after the trees are established, the shallow rooted species can be prevented from causing root competition by digging a trench alongside the trees (about 8 feet from the trunks) and to a depth of about 20 inches. To speed up this process, a standard single shank subsoil ripper mounted on a tractor, can adequately do the job of cutting these roots and preventing the sapping of fields. If the soil is hard, the roots large, or the available power to pull the tool is limited, remember that it is not necessary to cut the full 20 inch depth in one pass. It is common to take two or three passes at gradually increasing depth to do this job. One treatment will last for about 5 years.

Windbreaks are especially valuable for protection of high value orchard and vegetable crops. Wind reduction significantly improves the efficiency and safety of application of pesticides on such areas, and can save substantial amounts of expensive chemicals. Orchard crops will be protected from windfall damage to the fruit, and from wind breakage to the trees when they are heavily laden.

In fields where the soils are waterlogged, the proper selection of species for windbreaks can also have the additional benefit of reducing the waterlogging conditions and improving tillability of the soil.

PRINCIPLES OF WINDBREAK DESIGN

There are many ways to design windbreaks to fit the particular needs or preferences of the farmer. The most important thing to remember is that the farmer must be involved in working out the design so that it is truly his decision. In that way, he will be more satisfied with the results and will feel more personal commitment to the success of the effort. It is important, however, for the forester to point out any difficulties which may arise from the farmer's choice of design, and to attempt to steer him away from problems and toward success.

Orientation: The most effective windbreak is one which is laid out perpendicular to the path of the prevailing wind. In many situations, the winds are variable in direction or may change seasonally. The best choice in these cases is to orient the direction of the windbreak to provide maximum effect during the season when the most damaging winds occur. This problem becomes less serious if the majority of farmers in one area plant windbreaks on their field borders, because the combined network will provide extended protection from a greater variety of wind directions.

Uniformity: Windbreaks function best when they are of uniform height, density, and spacing. This is best obtained by using only one species of trees in any one row of a windbreak, and carefully laying out the spacing between trees. Trees which die should be quickly replaced so that no gaps will occur in the line.

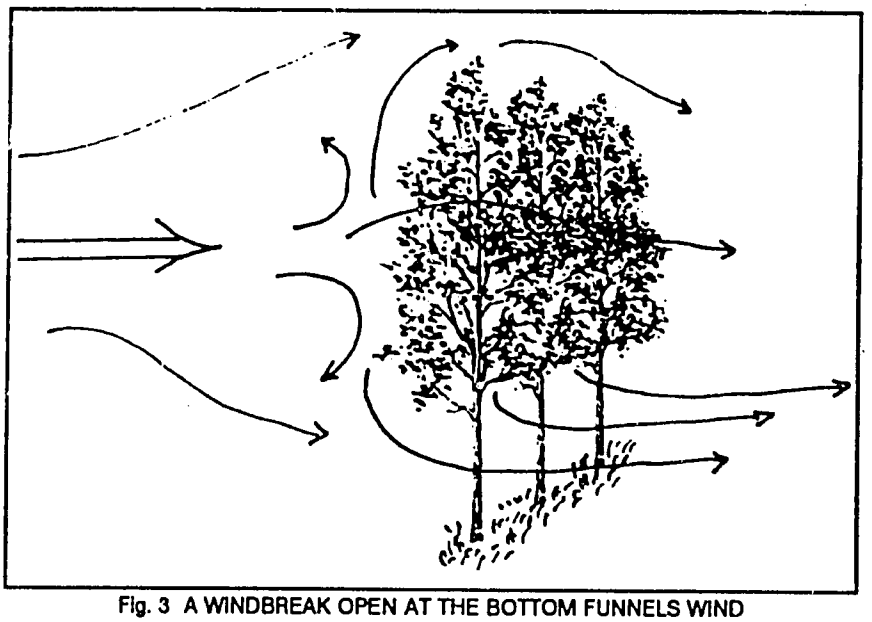


Fig. 3 A WINDBREAK OPEN AT THE BOTTOM FUNNELS WIND UNDER PRESSURE AND DAMAGES CROPS

Density: Good windbreaks have the greatest foliage density close to ground level, and gradually decreasing foliage density as height increases, obtaining an overall average of about 50% to 75% density. This makes the choice of species very important, and also dictates the number of rows which might be needed to obtain the desired effect. Unfortunately, the fast growing, taller trees such as eucalyptus and poplar are also intolerant of shade and tend to have open crowns and limb-free trunks. This means that a single row of such species will not make a suitable windbreak because of the lack of low-level foliage. At least one additional row of a shade tolerant, lower growing tree or shrub should be added to complete the design.

The flow of air (wind) behaves much in the same way as the flow of water. It backs up on the windward side and forms a still area similar to calm water back of a dam. It will rush to flow through openings and around the ends of obstructions with accelerated velocity, finally converging at some point down-wind. This is why the lower level of the windbreak profile should be as compact as possible, to prevent accelerated wind from damaging the surface of the field.

Number of rows: For small fields of less than 250 feet in length (down-wind), a single row of a dense foliage medium sized tree, such as mulberry, will normally be the minimum requirement. Because the down-wind effect is related to average tree height, and is normally taken to be 12H, a 20 foot tall row of mulberry would provide adequate protection out to a distance

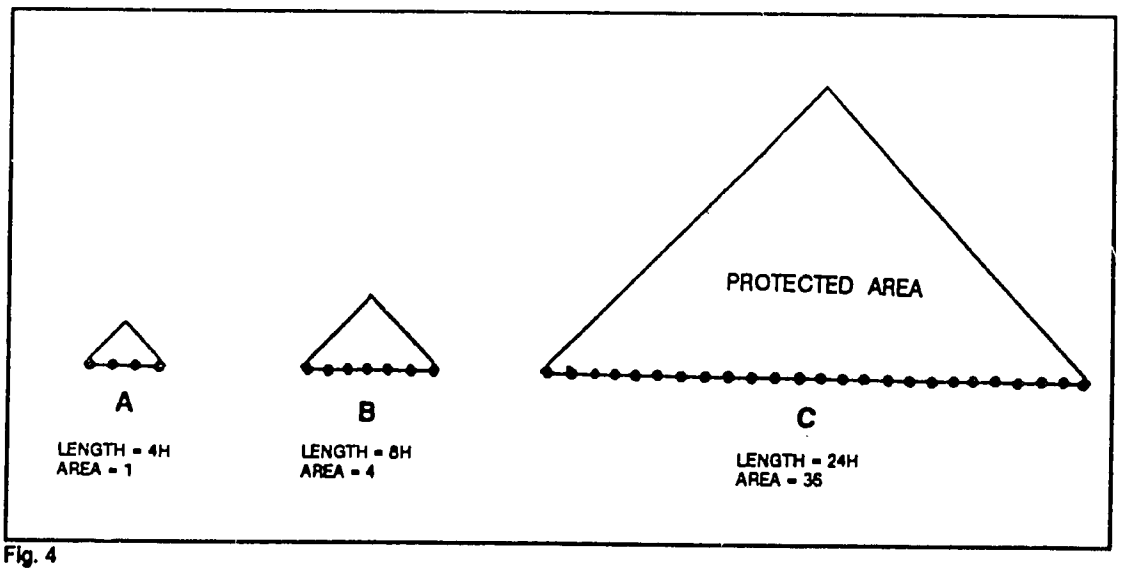


Fig. 4

of 12 X 20 = 240 feet. Larger fields will require greater tree height. When we add tree height by going to one of the taller species, we then must increase to a minimum of two rows in order to have both height and ground level density. Thus, a combination of one row of mulberry and one row of eucalyptus or poplar would do the job in many cases. When planting multiple rows, always place the row with the shortest species in the windward position.

Length: A good field windbreak should extend all the way across the boundary of the field if at all possible. The effectiveness of the zone of protection varies with the square of the length of the wind-break. (This is the theoretical rule based on the assumptions that the winds are of uniform intensity and evenly distributed over an arc of 180 degrees). While the actual field circumstances rarely fit the theoretical model, it is still true that greater length increases protection effects. In cases where the windbreak length is less than 24H, it is desirable to place the windbreaks on all sides of the field, or get the adjoining farmers to also plant windbreaks to extend the effect. One good alternative for short fields is to turn the windbreak at least part-way up the ends of the field to increase the protection from quartering winds.

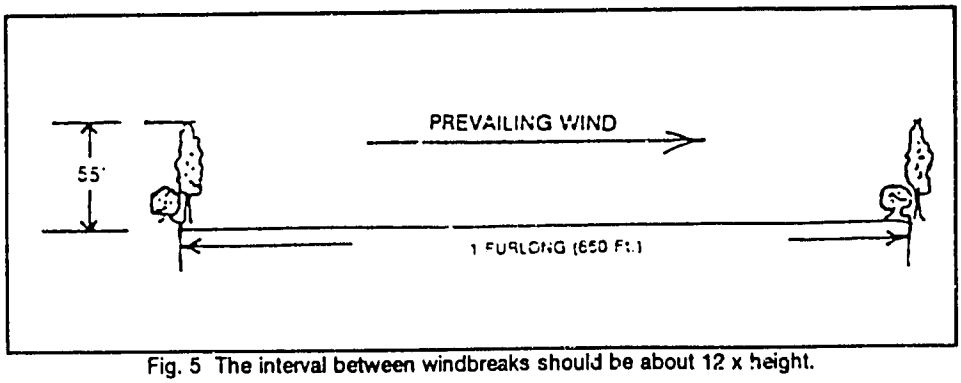


Fig. 5 The interval between windbreaks should be about 12 x height.

Interval: The distance between windbreaks is not generally within the design capabilities of one farmer under conditions in Pakistan; field size is frequently so small that it is time to deal with a new farmer by the time you have gone downwind to the distance where another windbreak is needed. However, this is an "H factor" calculation, and should be kept in the planning regime as much as possible. For example, if you are designing a 2-row windbreak of mulberry and eucalyptus, and the eucalyptus is to be harvested on a 10 year rotation and reproduced by coppice, the expected maximum height will probably be around 60 feet. This means that the maximum attainable effect would be 720 feet downwind (12X60'); the minimum effect after harvest of the eucalyptus would be 300 feet (12X25' tall mulberry). The best choice for the distance downwind to place the next windbreak should fall between these two extremes of 720 and 300, and will probably depend upon the configuration of the field and the preference of the farmer.

Usually, it is better to put the windbreaks at more frequent intervals than the maximum distance calculated, because the positive effects are greater. Most of us, in this example, would probably feel quite comfortable recommending an interval of 400' to 500'.

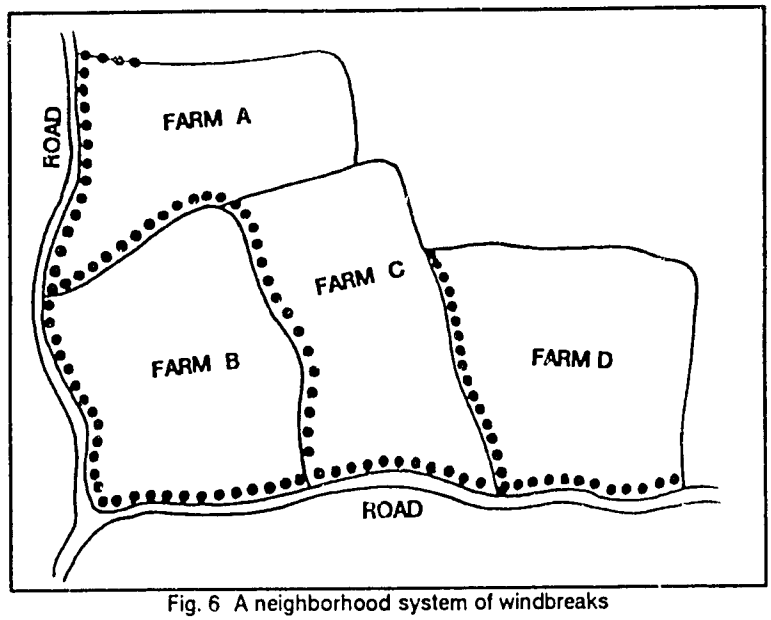


Fig. 6 A neighborhood system of windbreaks

Spacing: To obtain good wind control effects quickly, it is usually best to plant the trees at close spacings of 3'to 5' within the row. While this is too close to carry trees in block plantation for more than 4 or 5 years, the factors of competi-tion are different in the case of 2-row windbreaks because each tree always has at least one-quarter of its growing space in an unrestricted dimension. If more than two rows are to be planted, then the distance between trees of like type can be doubled – as in the case of two rows of poplar and one row of mulberry, the individual poplars in the rows should be spaced out at 8' to 10' and the alternate or "zigzag" pattern should be used between the rows. To maintain proper density control and balanced growth of the trees, it is normally accepted practice to place the distance between rows at 1-1/2 times the space between trees in the row. Thus, 4 feet between trees means 6' between rows, etc.

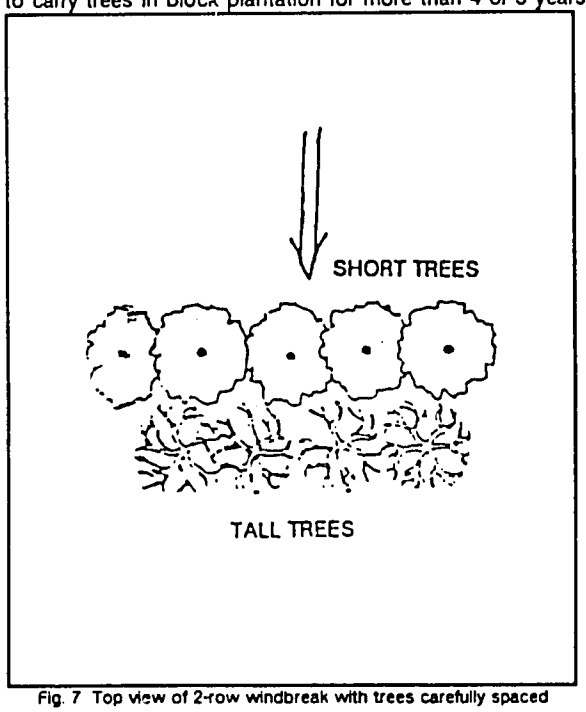


Fig. 7 Top view of 2-row windbreak with trees carefully spaced

You will also want to alter spacing and the number of rows in some cases where deciduous trees are used and the major wind control problem occurs during the dormant season. It is also frequently necessary to increase the distance between trees and between rows when you are planting in a very dry area where the moisture competition between trees will limit their performance. If spacing is extended very far, it then becomes necessary to add rows in order to get the desired windbreak effects.

Species: Based upon climatic conditions, site quality, and farmer preferences, identify two distinct groups of trees which can serve the needs of your area or district. One group must be the fast growing, intolerant, tall species. The second group must be the short to medium sized, shade tolerant species. An alternative group could be the medium to large, slower growing trees, – shisham, for example – which could be used between the other two rows as a long term crop tree.

Remember that in selecting species for windbreaks, you may get very good results from trees that you might not consider for normal forestry purposes in the area. Some examples are: ailanthus, paper mulberry, cypress, juniper, chir pine, tamarix, and caragana. When species selection is based upon growth form of the crown, foliage density, and survival criteria the list can be extended even further for particular areas.

WINDBREAK MANAGEMENT

After proper design and establishment of the windbreak, the farmer needs to pay particular attention to a few key management needs:

Grazing Protection: Domestic livestock, especially goats, need to be kept out of the windbreaks. They are especially damaging to the trees and shrubs which are used in the low-level protection layer of the windbreak. Fortunately, windbreaks are almost always placed around cropland, and cropland is normally protected from stray livestock.

Fire Protection: Woody plants are easily damaged by fire. Even though the plants may not be killed, the usual effect of fire is to reduce the density of the low-level foliage of the plants. This will destroy the ground-level wind control which is so essential to the continued function of the windbreak. Litter will build up rapidly under the windbreak, and may need to be swept out occasionally to reduce the hazard of fire. These leaves and twigs may be used on the adjacent field as additional organic matter for the soil, or may be taken away for fuel.

Pruning: Limbs and branches of windbreak plants should never be pruned. Even dead branches have some beneficial effect in the reduction of wind. This means that windbreak trees may not fetch as much money for timber purposes when they are finally cut; but remember that the real financial benefits come from the protection of the field crops, and that any wood or timber values are strictly secondary to the main purpose.

Harvesting: The tall trees in windbreaks can be periodically harvested for wood and timber products, but only after the low profile trees in the outer row have attained enough height to maintain the windbreak effect while the tall tree row(s) are being replaced by coppice or re-planting. At the time of harvest, be sure to take all of the trees in one row at the same time to maintain the uniformity of the windbreak profile. In the case of poplar or eucalyptus tall rows, we can normally presume a harvest cycle of 8 to 10 years. Expect the eucalyptus to coppice, but expect to re-plant poplar to re-establish the row(s). If stumps are cut flush to the ground, encourage the farmer to routinely select only one or two strong sprouts per stump for the replacements. Ideally, these should be on opposite sides along the axis of the row, in order to increase the wind barrier density.

The low profile row(s) should not be harvested until the trees have reached such size and maturity that they have started to lose lower branches and become open at the bottom. Again, it is important to cut these trees as a unit so that coppice reproduction will not be affected by the lateral shade of adjacent trees in the row. In some situations where the windbreak is very long (more than two furlongs) it is acceptable to remove one-half of the row at a time. In this situation, at least one growing season should lapse before the second half of the row is removed.

Insect and disease: Most windbreaks are relatively free of serious insect and disease pests, if the proper species are planted for the site and growing conditions. Trees grown on field borders have the advantage of more free growing space and will be more vigorous and pest resistant than trees grown in closed stands. Another advantage, especially in the case of windbreaks around fruit orchards, is that the regular spraying schedule for orchard pest control usually provides additional protection to the windbreak trees.

Irrigation: Windbreak trees will perform best if they receive some irrigation at the same time that the adjacent field crops are irrigated. Farmers should be advised that tree roots are especially damaging to the structure of irrigation ditches, and that it is a risky practice to plant the trees in the bottom or on the bunds of the permanent irrigation channels. This can be done successfully, however, in those cases where a special feeder ditch is established just for the sake of the trees, and with the intention of watering the fields through a separate ditch system.

Sericulture: In those cases where mulberry is used as the shade-tolerant low profile row, it may be suitable to harvest leaves for sericulture. This harvesting should be limited to the leeward foliage of the tree (between the rows), and should not be done on the exposed windward side of the plants. The farmer should clearly understand that reduction of the foliage will reduce the effectiveness of the windbreak and that he is exchanging the gains from sericulture for a reduction in field crop income.