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The Spacing Interval for Supplemental Shelterbelts[1]

N. P. Woodruff[2]
Agriculture engineer,
U. S. Department of Agriculture

SHELTERBELTS, walls, snow fences, strips of crops, and other obstacles placed in the path of wind are known generally as surface barriers. The basic definition usually given for this term states that a surface barrier is any obstacle placed in the path of the wind in such a manner that it causes an upward diversion of the air current. This diversion is accompanied by a drag on the wind at approximately the same height as the obstacle. These combined effects lessen the drag on the original ground surface, lower the prevailing surface velocity, and create a pool of relatively calm air within the zone of influence of the obstacle. This zone of influence is limited, of course, and usually does not extend to distances greater than 20 or 30 times the height of a given barrier. Since the requirements for protection usually far exceed this limited influence, it becomes necessary to extend the influence. In the case of shelterbelts this can be accomplished by creating a continuity of properly oriented supporting or supplemental belts. This study is concerned primarily with obtaining information relative to the spacing of the so-called properly oriented continuity of belts.

There are several aspects to the problem of determining the best spacing interval for a system of shelterbelts. The principal reason for planting any shelterbelt is to reduce wind velocities. The amount and type of reduction needed, however, depend upon the object or objects to be protected and the purpose of the protection, i.e., is the reduction in wind desired for the comfort of people or livestock, reduction in home heating loads, control of drifting snow, or for minimizing soil movement by wind.

Limiting the investigations to only one of these purposes, however, does not completely solve the dilemma. For example, determination of the best spacing to control erosion of soil must be concerned also with the susceptibility to erosion of the soil that is to be protected. This varies considerably and it is difficult to prescribe a general formula for velocity reduction required to stop erosion because of factors affecting the vulnerability of the soils. Dryness, texture, roughness, and many other factors are involved. The economic aspect is another factor that must be considered, i.e., what proportion of the cropland can be economically devoted to trees to afford protection for the remaining land. Bates (*1*) has indicated that in the corn belt, 5 percent of the area could be devoted to belts because of the direct benefits to crops and animals. The percentage of area, of course, varies with different crops, climatic conditions, and the intensity of agriculture practiced in a particular region. For example Chepil (*2*) has reported that in the sandy lands of China, single rows of willow belts averaging 12 feet in height are planted every 50 or 60 feet. Here, where an intensive type of agriculture is practiced this close spacing is necessary and economical. It might not apply, however, on large areas such as western Kansas where climatic conditions and economic ratios would not be favorable.

This particular study does not and could not deal with all the above mentioned aspects of the problem. The object of the study is to obtain qualitative information on the mechanical reduction of wind velocity. Previous studies (*3, 4, 5*) have shown that one of the best ways to obtain data on relative results is with a wind tunnel wherein many of the variables can be controlled for sufficient time to make detailed studies. The reliability of results obtained with the tunnel has been tested in previous study (*6*) which showed rather good agreement between model and prototype, provided the models are placed in a tunnel having a turbulent boundary layer of sufficient depth to be similar to atmospheric conditions.

Methods of Study and Procedures

The following variations and combinations of principal and supplemental shelterbelts were tested:

- 7-row principal belt with 3-row supplementals
- 7-row principal belt with 2-row supplementals
- 7-row principal belt with 1-row supplementals
- 3-row principal belt with 1-row supplementals
- 1-row principal belt with 1-row supplementals

The model shelterbelts used in the experiments were fabricated from cedar boughs and green lichen placed in short lengths of aluminum tubing. One 7-row principal belt, three 3-row supplementals, two 2-row supplementals, and three 1-row supplementals were constructed by orienting the "trees" and "shrubs" in a series of holes drilled in plywood bases. The scale used for the models was 1 inch equals 5 feet. Thus, in terms of the prototype condition, the lowest or windward shrub in a 7-row belt would be 7.5 feet and the tallest tree placed as the fifth row windward would be 30 feet. The second, third, fourth, and sixth tree rows would be 15, 20, 25, and 17.5 feet, respectively, in prototype conditions. The seventh row was a shrub row corresponding to 10 feet high. The green lichen was used for the shrubs. The 3-row supplementals consisted of one shrub row

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[2]Western Section of Soil and Water Management, Agricultural Research Service, U. S. Dept. Agric. Kansas State College, Manhattan.

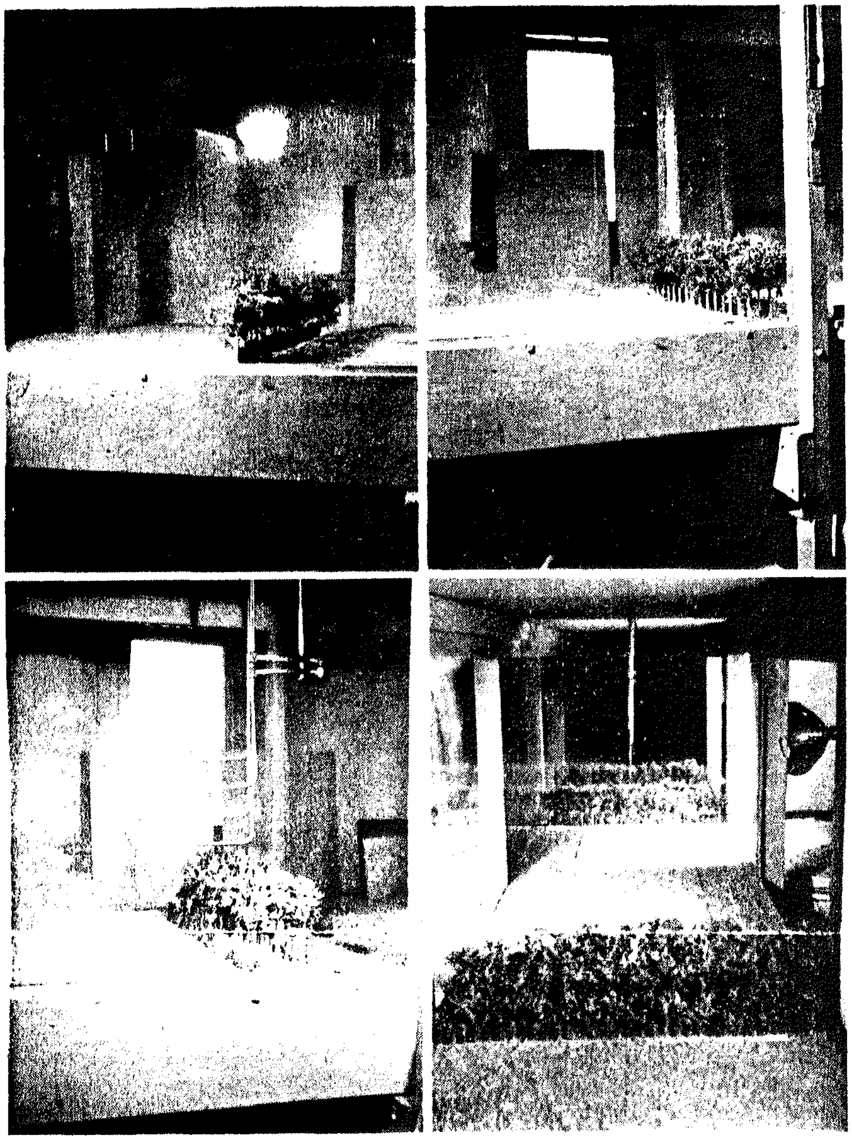


FIG. 1.—One-row, 2-row, and 3-row supplemental belts, and 7-row principal belt followed by two 1-row supplemental belts as they were oriented in tunnel (upper left, upper right, lower left, and lower right, respectively).

and two rows of tall trees. The 2-row supplementals consisted of two rows of tall trees with a row of shrubs placed in the leeward row of trees. The single-row supplementals consisted of a combination of one row of tall trees and shrubs. Spacing between the rows of shrubs and trees was 2 inches on the model, corresponding to 10 feet for field conditions. Spacing within the rows of trees was also 2 inches or 10 feet. Spacing between shrubs in shrub rows was 1 inch or 5 feet. Where combinations of shrubs and trees were used in one row, the spacing for the trees was 2 inches with two shrubs between each tree giving a spacing of approximately 0.67 inch or 3.5 feet in prototype condition. Figure 1 shows views of the various models as they were oriented in the wind tunnel.

The studies of the effect of different spacing intervals on velocity reductions for the various belts were carried out in a laboratory wind tunnel described previously (7). The working section for these particular experiments consisted of a 16-foot horizontal length beginning 40 feet downwind from the blower. The top of the tunnel for this section was constructed to facilitate horizontal movement of a staff of Pitot tubes through the entire 16-foot length. The floor consisted of sieved gravel 2.0-6.4 mm. thus assuring development of a turbulent boundary layer similar to atmospheric conditions.

Horizontal velocity measurements were made at 12 different heights at various locations to the leeward of the belts with a group of 4 Pitot tubes and an alcohol manometer. The Pitot tubes were mounted on a rack and gear carriage to facilitate horizontal movement and on a staff gage equipped with a vernier scale for accurate vertical movement. All combinations and spacing intervals were tested at constant wind speeds of 16.8 and 27.8 mph. measured in the center of the tunnel at a location 12 feet upwind from the windward end of the test section. Testing procedures consisted of running *complete traverses of clear* tunnel velocities through the entire 16-foot length of test section in duplicate at each of the two velocities. Velocities to the leeward of the belts were then obtained at given location and divided by the velocity obtained at the same location in the clear tunnel. These ratios were used to plot profile maps expressing the height above the ground as the dimensionless ratio $\frac{z}{H}$ and the velocity ratio as $\frac{U_b}{U_o}$, where

z = elevation above surface at which velocity is measured.

H = height of tallest tree in belt (6 inches in the model or 30 feet in actual belt).

U_b = velocity aft of belt.

U_o = velocity in open or clear tunnel.

Percentage reductions in velocity are equal to $100\,(1 - \frac{U_b}{U_o})$. Vertical and horizontal distance on the profile maps is shown in terms of belt heights H.

Results

As a prerequisite to evaluating and comparing the effectiveness of the different combinations of shelterbelts it was necessary to establish arbitrary levels of velocity reduction. Levels of 50 and 75 percent were chosen. While these are only arbitrary levels, one or the other should be appropriate for most wind velocity reduction problems.

In running the tunnel tests each combination of belts was first tested with the supplemental belt placed at spacing intervals of approximately 12, 18, and 24 H. Profile maps were drawn from the data obtained in these tests. Areas between the principal and the first supplemental belt and under the 50 and 75 percent reduction contours were determined with a planimeter. These areas were used as indexes of effectiveness and plotted versus the spacing interval. An approximate curve was then drawn and an equation determined for all cases where a definable trend in the data was indicated. In this respect it was found that the 3 points were sufficient to draw the curve and determine the equation in all cases except the 75 percent reduction level for the 7-row principal plus 2-row supplemental and the 50 percent reduction level for the 1-row principal plus 1-row supplemental. Here it was necessary to resort to trial and error methods for establishing the locations. After determining the approximate equations, the critical maximum points on the curves were located by methods of calculus wherein the first derivatives of the functions were set equal to zero and the resulting equations were solved for real roots. These points in combination with the information shown on the contour maps were used to determine the approximate spacing interval to maintain either a 50 or 75 percent reduction between belts. The final location was checked by velocity probings with the Pitot tubes. The spacing interval for the second supplemental was located also by velocity probings with the Pitot tubes. Complete traverses were run for levels of 50 and 75 percent reduction and were considered to be the "best" spacing for a particular system of belts. Areas under these curves also were obtained and used to establish the final spacing-effectiveness curve shown in the upper right corner of the figures which follow.

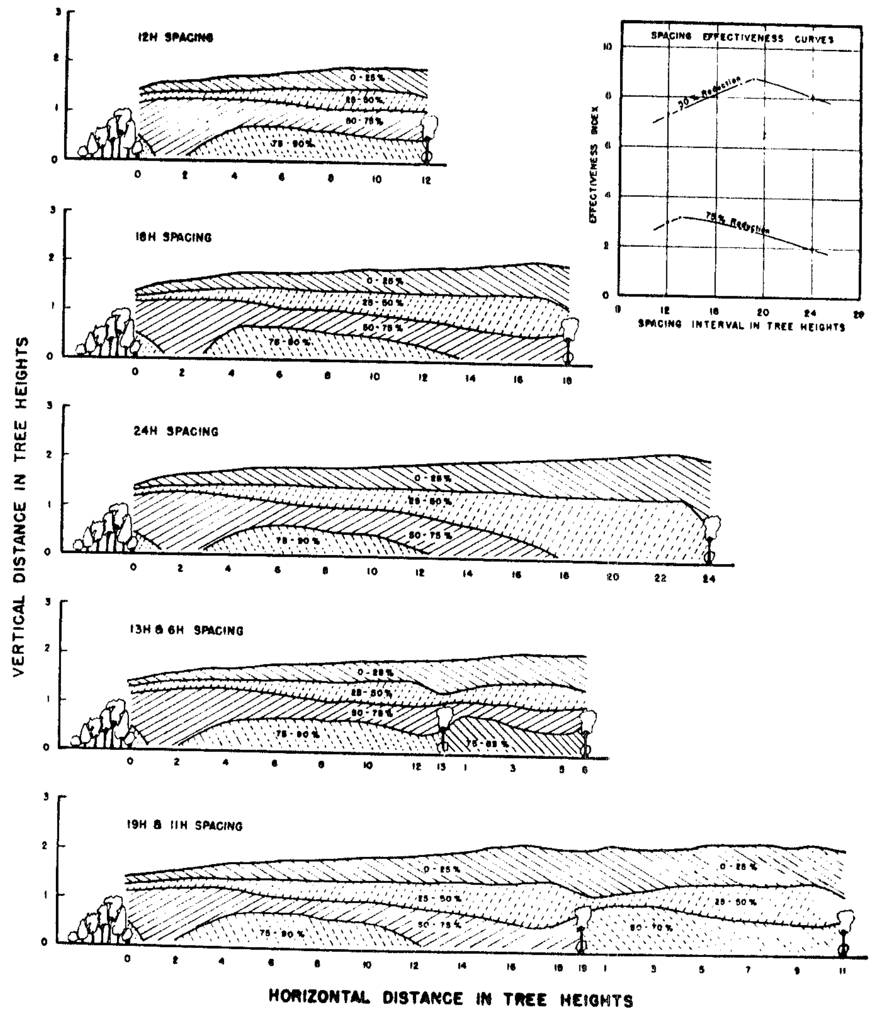


FIG. 2.—Percentage reduction in velocity obtained in vicinity of a 7-row principal belt with a 1-row supplemental belt placed at 12-, 18-, and 24-H spacing intervals. Lower two figures show "best" spacing interval for 75 and 50 percent reductions in velocity. Spacing effectiveness curves are shown in upper right corner.

7-row principal belt with 1-row supplemental.—Figure 2 shows the data obtained on the 7-row principal and 1-row supplemental combination of belts. It is noted that at least a 50 percent reduction in velocity is maintained from tree top to ground level for the 12 H spacing. The level of this reduction begins to drop, however, for the 18 H spacing and finally strikes the ground at approximately 18 H with 24 H spacing.

The approximate equation, derivative, and critical maximum for the spacing-effectiveness curves based on the 12, 18, and 24 H spacing was:

50 percent reduction curve

$I = 4.78 + 0.21\,S - 0.0002\,e^{0.39\,S}$

$y' = 0.21 - 0.000078\,e^{0.39\,S}$

critical maximum = 20.1

75 percent reduction curve

$I = 5.14 - 0.13\,S - 208\,e^{-0.53\,S}$

$y' = 111\,e^{-0.53\,S} - 0.13$

critical maximum = 12.8

where S = spacing interval in tree heights H and I = effectiveness index, and y' = the first derivative of the equation for I.

The final spacing-effectiveness curves (upper right of figure) show a maximum spacing interval of 19 H for a 50 percent reduction in velocity and 13 H for 75 percent reduction. Maximum indexes at these spacings are 8.8 and 3.2 for 50 and 75 percent reduction, respectively. Increased spacing from these values show a decrease in effectiveness. The spacing required to maintain a 50 percent reduction between the principal and first supplemental belt is approximately 1.46 times greater than that required for a 75 percent reduction.

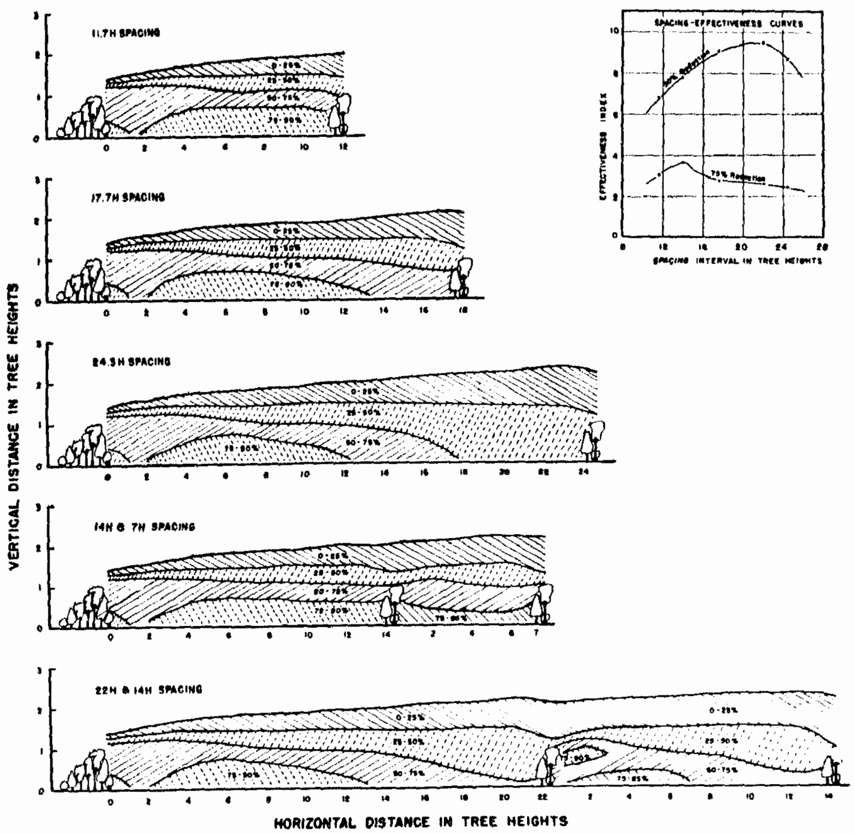
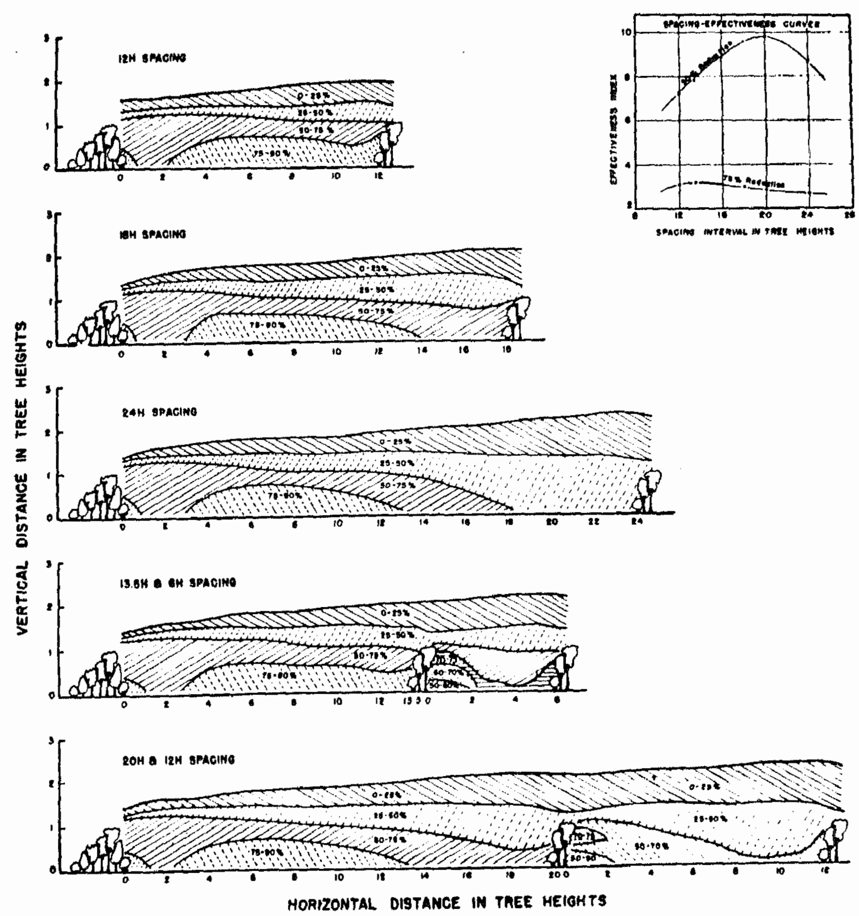


FIG. 3.—Percentage reduction in velocity obtained in vicinity of a 7-row principal belt with a 2-row supplemental belt placed at 11.7-, 17.7-, and 24.3 spacing intervals. Lower two figures show "best" spacing interval for 75 and 50 percent reductions in velocity. Spacing-effectiveness curves are shown in upper right corner.



The spacing between the principal and first supplemental belt is 1.74 times greater than the spacing between the first and second supplemental for a 50 percent reduction, and 2.2 times greater for a 75 percent reduction.

It also should be noted that this combination of belts maintains at least a 25 percent reduction in velocity for the longest, or 24 *H*, spacing tested.

7-row principal belt with 2-row supplemental.—Figure 3 shows data obtained on the 7-row principal and 2-row supplemental combinations of belts. The general shape of the reduction contours is nearly the same as the 7-row plus 1-row combination described above.

The approximate equation, derivative, and critical maximum for the spacing-effectiveness curves based on 11.7, 17.7, and 24.3 *H* spacing was:

50 percent reduction curve

$$I = 1.95 + 0.41\,S - 0.0012\,e^{0.32\,S}$$

$$y' = 0.41 - 0.0004\,e^{0.32\,S}$$

critical maximum = 21.7

75 percent reduction curve

Not determined

The final curve (upper right corner) shows the best spacing for a 50 percent reduction to be at 22 *H* with an index of 9.5, which is higher than the 7- plus 1-row combination. Best 75 percent reduction occurs with a spacing of 14 *H* and an index of 3.7. The spacing required to maintain a 50 percent reduction between the first two belts is approximately 1.57 times greater than that required for a 75 percent reduction. The spacing between the principal and first supplemental belt is approximately 1.6 times greater than the spacing between the first and second supplementals for a 50 percent reduction and 2.0 times greater for a 75 percent reduction.

This combination of belts also shows at least a 25 percent reduc-

FIG. 4.—Percentage reduction in velocity obtained in vicinity of a 7 row principal belt with a 3-row supplemental belt placed at 12-, 18-, and 24-H spacing intervals. Lower two figures show "best" spacing interval for 75 and 50 percent reductions in velocity. Spacing effectiveness curves are shown in upper right corner.

tion in velocity for the longest, or 24.3 H, spacing tested.

7-row principal belt with 3-row supplemental.—Figure 4 shows data obtained on the 7-row principal and 3-row supplemental combinations of belts. The general shape of velocity contours and of the spacing effectiveness curves is very nearly the same as the 7- plus 1-row combination.

The approximate equation, derivative, and critical maximum for the spacing-effectiveness curves based on 12, 18, and 24 H spacing was:

50 percent reduction curve

$$I = 2.80 + 0.38\,S - 0.0000128e^{0.53\,S}$$

$$y' = 0.38 - 0.0000068\,e^{0.53\,S}$$

critical maximum = 20.6

75 percent reduction curve

$$I = 4.03 - 0.056\,S - 220\,e^{-0.59\,S}$$

$$y' = 130\,e^{-0.59\,S} - 0.056$$

critical maximum = 13.1

The final curve (upper right corner) indicates the best spacing for a 50 percent reduction in velocity is 20 H with an index of 9.8, slightly higher than 7- plus 2- and 7- plus 1-row combinations. Best spacing for 75 percent reduction is 13.5 H with an index of 3.2. The spacing required to maintain a 50 percent reduction between the principal and first supplemental belts is approximately 1.48 times greater than that required for a 75 percent reduction. The spacing between the principal and first supplemental belt is approximately 1.7 times greater than the spacing between the first and second supplementals for a 50 percent reduction and 2.2 times greater for a 75 percent reduction.

It will be noted in connection with this combination that it was not possible to maintain a 75 percent reduction throughout the entire distance between the first and second supplemental belt. Apparently, the location and porosity of the 3-row supplemental was such that leakage of air through the first supplemental permitted only 50 to 70 percent reduction immediately aft of the belt.

3-row principal with 1-row supplemental.—Figure 5 shows data obtained on the 3-row principal and 1-row supplemental combination of belts. The 3-row principal belt was not so effective as the 7-row belt. This belt did not provide a uniform 50 percent reduction between itself and the first supplemental belt. It was also impossible to obtain a continuous 75 percent reduction in velocity with this combination. A 40 percent velocity reduction was used, therefore, as the criterion of spacing.

The approximate equation, derivative, and critical maximum for the spacing-effectiveness curve based on 11, 17.6, and 24 H spacing was:

40 percent reduction curve

$$I = 5.8 - 0.05\,S - 278\,e^{-0.625\,S}$$

$$y' = 174\,e^{-0.625\,S} - 0.05$$

critical maximum = 13.0

The final spacing effectiveness curves (upper right corner) indicate that the best spacing to maintain a 40 percent reduction is about 12 H. The effectiveness index associated with this spacing is 5.2. Both this index and the spacing interval are considerably below the values obtained with the 7-row principal belt.

While this 3-row principal did not produce a continuous 50 percent reduction between the first two belts, it did reduce the wind sufficiently to maintain a 50 percent reduction between the first and second supplemental at a 12 H spacing.

Single-row principal with 1-row supplemental.—Figure 6 shows

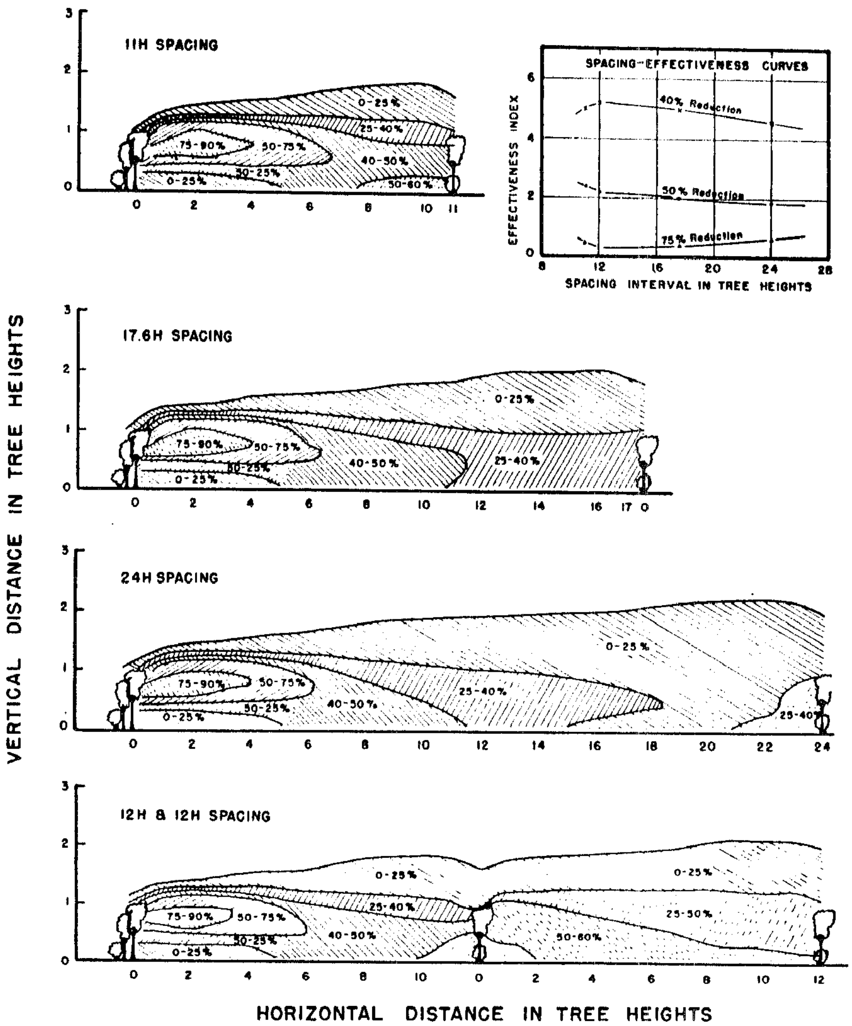


FIG. 5.—Percentage reduction in velocity obtained in vicinity of a 3-row principal belt with a 1-row supplemental belt placed at 11-, 17.6-, and 24-H spacing intervals. Lower figure shows "best" spacing for a 40 percent reduction in velocity. Spacing-effectiveness curves are shown in upper right corner.

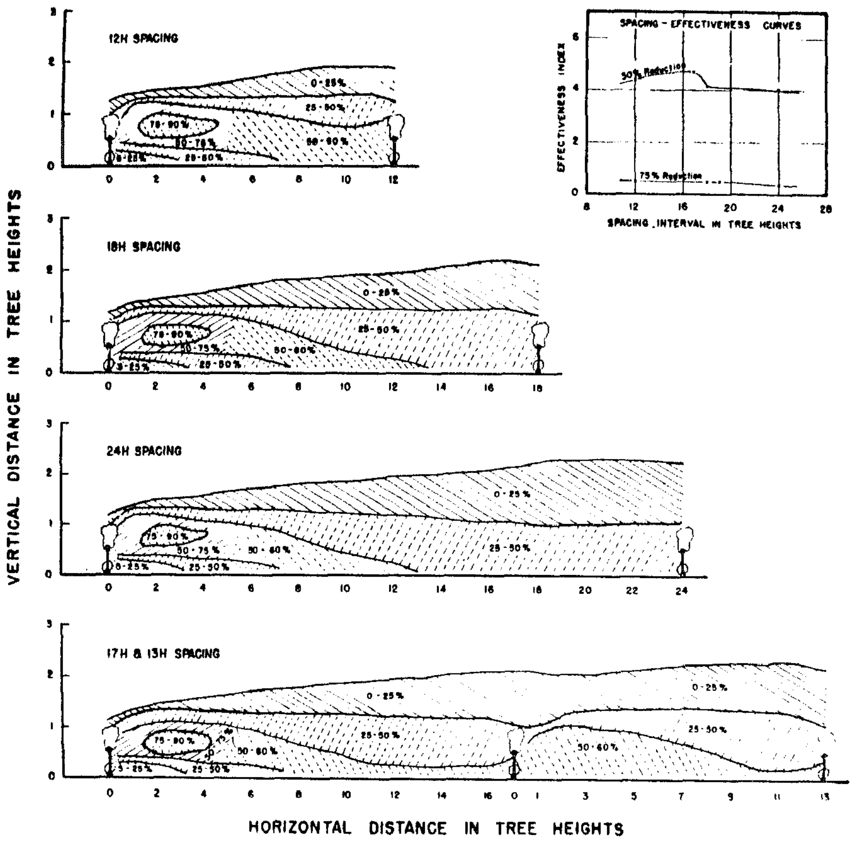


FIG. 6.—Percentage reduction in velocity obtained in vicinity of a single-row principal belt with a 1-row supplemental belt placed at 12-, 18-, and 24-H spacing intervals. Lower figure shows "best" spacing interval for a 50 percent reduction in velocity. Spacing-effectiveness curves are shown in upper right corner.

data obtained on the "narrow" single-row plantings. Velocity patterns immediately to the leeward of the principal belt are similar to those obtained with the 3-row principal. The jetting of air through the narrow, porous belts caused rather low velocity reductions immediately to the leeward. This combination of belts was, however, more effective than the 3-row principal because it was possible to maintain a continuous 50 percent reduction between the belts.

The spacing-effectiveness curves, as determined by trial and error methods, show the best spacing to be about 17 H with an index value of 4.6. A 75 percent reduction curve is also shown, but zones having this much reduction in velocity were relatively small pools immediately aft of the first belt and did not reach the ground level at any location between the belts. The best spacing between the first and second supplemental is 13 H, or about 25 percent less than the spacing between the principal and first supplemental.

Discussion and Conclusions

Evaluation and comparison of the effectiveness of the different systems of belts tested in the experiment can best be made in terms that consider both the level of velocity reduction and the type of protection afforded by a given system of belts. The spacing-effectiveness curves shown on the figures were of considerable value in determining the spacing interval; however, they do not provide sufficient information to give a true evaluation of the merits of a given belt system. A better method is one that considers the desired level of velocity reduction, the location and the net size and extent of the protected area. The level of velocity reduction previously has been chosen as 50 or 75 percent in this study. The size of the protected areas can be evaluated, therefore, in relative terms by determining the areas on the profile maps between belts and under the 50 or 75 percent reduction curves. The extent of protection can be determined in terms of the net distances[3] along the ground between belts having at least 50 or 75 percent reductions in velocity.

Table 1 summarizes the information obtained on all the shelterbelt combinations tested. The data is presented in terms of "best" spacing intervals, areas of protection, and extent of protection.

Table 1 indicates that a 50 percent reduction is obtained for 77.4 percent of the total area between the 7-row principal and two 1-row supplementals. This area is approximately 8 percent greater than the next best combination and about 44 percent greater than the poorest combination, the 3-row principal with 1-row supplementals. The 7-row plus 1-row also has 46.9 percent of the area with a reduction of at least 75 percent or 2.7 percent more than the 7-row with 2-row supplementals. The 7-row plus 1-row areas, however, are slightly smaller in actual size than the 7-row plus 2-row areas. (Cols. 6 and 8.) Since the spacing interval is shorter for the 7- plus 1-row, this indicates that the 50 percent velocity reductions extend to greater heights above the ground for this combination than the 7- plus 2-row. Choices between these two belts would depend, therefore, on whether surface protection or protection to some height above the ground was desired. Other belts would be ranked in the order in which they are listed in the table.

In terms of "best" spacing interval and extent of protection, the system of belts consisting of a 7-row principal with 2-row supplementals gives a spacing interval of 22- and 14-H and 14- and 7-H for a 50 and 75 percent reduction, respectively. This system would utilize a total length of 39.0 heights for the best 50 percent spacing; 34.6 heights, or 88.7 percent of this

[3]Net distance is defined as the length of protected area after deductions for the length of ground used by the belts and for those areas immediately to the leeward of the belt where velocities do not reach the desired level of reduction because of the air jets.

length, would have at least a 50 percent reduction. Similarly, the system would use 24 heights with the best 75 percent spacing and 18.4 *H*, or 76.6 percent of this length, would have a 75 percent reduction. In terms of net distance with a 50 percent reduction, this belt provides protection to a length approximately 6 *H* longer than the 7-plus 1-row, 5 *H* longer than the 7- plus 3-row combination, and 12 and 25 *H* longer than the 1- plus 1-row and the 3- plus 1-row combinations. It also has a slight advantage over the other belts in terms of length having a 75 percent reduction. On a basis of information given by these data, then, the 7-row principal with 2-row supplementals would be the best combination, followed by the 7- plus 1-row, the 7- plus 3-row, the 1- plus 1-row, and the 3- plus 1-row.

The so-called "narrow" plantings tested in this experiment were not so effective as the wider principal belts followed by supplementals. The 3-row principal in particular did not show up well and probably should not be considered for most problems. It is apparent that the rather abrupt top design obtained when placing a shrub row and then two rows of much taller trees is not a good design for maintaining substantial reductions to the lee of the belts. It is possible, however, that if a better arrangement of trees was made within the belts, some better protection could be obtained. The other narrow plantings tested, the single-row belts, were considerably better than the 3-row belts. In terms of the ratio of protected length to total length utilized, the single-row system ranked very well. The spacing intervals for a 50 percent reduction, particularly aft of the first supplemental compared favorably with that obtained with the wider principal belts. A 75 percent reduction could not be maintained with this system. This combination could be used where field arrangements would permit growing of crops needing less protection between the principal and first supplemental. In these cases this system would also have considerable appeal because of the smaller number of trees needed and the consequent reduction in cost and labor required for establishing and maintaining the belt.

In conclusion, it appears that the 7-row principal followed by a system of 1-row supplementals probably would give the greatest proportion of protection at greater distances above the ground level. Possible application of this system would be protection for tall growing crops, orchards, homes, and livestock. On the other hand, the 7-row principal followed by a system of 2-row supplementals would give the best ground protection. Use of this system would be indicated for problems concerned with minimizing soil blowing. The 7-row principal followed by a system of 3-row supplementals would rank third in the group tested. The single-row system would be recommended for special problems with the reservations described in the previous paragraph. The 3-row principal plus 1-row supplementals would not be recommended.

The above conclusions are based on the data obtained in this particular experiment. The study was concerned only with the mechanical reduction of wind velocity and, therefore, ignores the silvicultural problems associated with shelterbelts. Suffice to say that final selection of a shelterbelt system for a particular problem can only be made after careful consideration of both aspects of the problem.

Summary

Wind tunnel studies were conducted to obtain information on the mechanical reduction of wind velocity and a system of shelterbelts consisting of a principal belt followed by supplemental belts.

TABLE 1.—SUMMARY OF INFORMATION AND COMPARISON OF BELT COMBINATIONS TESTED. INDICATED 50 AND 75 PERCENT REDUCTIONS ARE THOSE OBTAINED WITH "BEST" 50 AND "BEST" 75 PERCENT SPACINGS, RESPECTIVELY

Belt combination	"Best" spacing interval between: Prin. and 1st supp. 50%	Prin. and 1st supp. 75%	1st and 2nd supp. 50%	1st and 2nd supp. 75%	Area between belts with reduction of 50%		75%		Total distance in system[2] 50%	75%	Distance used by tree rows[3]	Net-distance protected and percentage of total with reduction of 50%		75%	
	H	*H*	*H*	*H*	H^2	%	H^2	%	*H*	*H*	*H*	*H*	%	*H*	%
7-row prin. plus two 1-row supp.	19	13	11	6	25.0	77.4	10.0	46.9	32.3	21.3	3.0	28.3	87.6	16.3	76.5
7-row prin. plus two 2-row supp.	22	14	14	7	27.2	69.8	10.6	44.2	39.0	24.0	3.7	34.6	88.7	18.4	76.6
7-row prin. plus two 3-row supp.	20	13.5	12	6	23.2	65.0	8.0	34.5	35.7	23.2	4.3	30.1	84.3	13.9	59.9
1-row prin. plus two 1-row supp.	17	[1]	13	—	17.0	56.1	—	—	30.3	......	1.0	22.1	73.0	......	......
3-row prin. plus two 1-row supp.	12	[1]	12	—	8.4	33.6	—	—	25.0	......	1.7	9.3	37.2	......	......

[1]Single and 3-row principals did not produce a continuous 75 percent reduction; therefore, no "best" spacing interval tests were run.

[2]Total distance includes spacing between and within belts plus one-half of a row width added to the outside of both the first and last belt in a system. One row width is the distance between rows and is equal to 0.333H.

[3]Sum of distance between rows in belts plus one-half of a row width to either side of a given belt. A 1-row, 2-row, 3-row and 7-row belt would, therefore, be 0.333H, 0.666H, 1.0H, and 2.333H wide respectively.

Models of 7-, 3-, and 1-row principal belts, and 1-, 2-, and 3-row supplemental belts were used to obtain the information. Results are expressed in terms of percentage reductions of the open wind velocity. Information was obtained with several different spacings of the supplemental belts when used with a principal belt. Some results of tests on the so-called "narrow" plantings, i.e., single rows used without the benefit of a wide principal belt, are also given.

The degree of efficiency of a given system of belts depended somewhat upon the type of protection desired. Of the belts tested, a 7-row principal followed by a system of 1-row supplementals would give the greatest degree of protection extending to the greatest height above ground between belts. This system would be most applicable to problems of protection for tall crops, orchards, farmsteads, and livestock. On the other hand, a 7-row principal belt followed by a system of 2-row supplementals would permit the greatest spacing intervals between belts and would provide protection to the greatest length of ground. Use of this system would be indicated for problems concerned with minimizing soil blowing. A 7-row principal belt followed by a system of 3-row supplemental belts would rank third in the group tested. Single rows of trees used without benefit of a wide principal belt would not reduce wind velocity as much as the wider belts. However, at lower levels of velocity reduction, they would permit fairly long spacing intervals and would provide a relatively high ratio of protected length to total length used by the system. They would be recommended for special problems where less protection from wind is required and where the area used by the belt would be an important factor. The 3-row principal followed by 1-row supplementals did not show up well in the tests and would not be recommended.

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