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Wind and Sandblast Injury to Seedling Green Beans[1]

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ABSTRACT

Seedling green beans were subjected to various combinations of windspeed (20, 30, and 40 mph), abrasive flux (0, 0.2, 0.4, and 0.6 ton per rod width per hour of sand), and duration of exposure (5, 10, and 15 minutes) in a wind tunnel. Wind alone with speeds up to 40 mph caused only slight damage. Introduction of as little as 0.2 ton per rod width per hour of sand into the windstream greatly increased plant injury. However, additional increases in abrasive flux causesd no proportionate increase in plant injury. Plant damage increased linearly and bean yields decreased almost linearly with increase in windspeed and duration of exposure. Although the plants abraded at 20 mph sustained injury, they recovered sufficiently to yield well. The yield of plants abraded at 30 and 40 mph decreased with increased sand flux.

WIND and sandblast injury to vegetable crops is a serious problem in many areas where large acreages of vegetables are grown on sandy soils. Wind alone is capable of causing extensive mechanical injury and desiccation (15, 16). When the wind is laden with sand and soil, it is much more destructive to plants. In the seedling growth stage, much of the soil surface is unprotected and exposed to the sun's radiation. The soil surface dries quickly and becomes more susceptible to blowing. A small amount of erosion makes establishment difficult, damages early growth, and seriously reduces the marketability of certain crops. Extent of injury to a particular plant species will vary with several factors: *(1)* Windspeed, *(2)* abrasive flux, *(3)* growth stage and vitality of the plants, *(4)* temperature and humidity of plant root and aerial environment, and *(5)* duration of exposure. Other factors may include *(6)* size, shape, and density of abrasive, and *(7)* gustiness of wind.

Research investigators have studied the nature of wind erosion including rate of soil movement (2, 3, 21), erodibility (6, 7, 9, 10), and measures for erosion reduction (1, 8, 11, 12, 13, 19). They also have developed a wind erosion equation (11, 18) that combines wind erosion variables and relates them to soil loss.

Woodruff (17) and Lyles and Woodruff (14) made exploratory studies of the effect of soil blowing on winter wheat plants and native grass sedlings. More knowledge is needed about extent of damage caused by specific amounts of soil flux, windspeeds, and duration of exposure under various environmental conditions and stages of plant growth.

This study was made to evaluate extent of damage to a selected plant (green bean) caused by blowing sand at various windspeeds, abrasive fluxes, and duration of exposure.

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PROCEDURE

Green bean (*Phaseolus vulgaris,* L.) plants were grown out-of-doors in 24- by 6- by 9-inch plant flats filled with a sandy loam soil. The plants were fertilized and watered according to recommended cultural practices. Thirteen days after planting the plants were thinned to four uniform plants per box and subjected to various treatments in a laboratory wind tunnel.

The treatment variables were windspeed (20, 30, and 40 mph), duration of exposure (5, 10, and 15 minutes), and abrasive flux (0, 0.2, 0.4, and 0.6 ton per rod width per hour of sand). Abrasive flux of 0.2, 0.4, and 0.6 ton per rod width per hour corresponds to 0.1, 0.2, and 0.3 maximum sediment load at 30 mph (8). The treatments were arranged factorially and replicated three times. Each replication was staggered 2 days at planting to allow ample time for testing in the wind tunnel.

The windspeed in the tunnel was controlled by fan engine speed and fan blade pitch. Windspeed was measured with a pitot tube and inclined alcohol manometer. The pitot tube was positioned 1 foot above the tunnel floor midway between side walls.

Kansas River sand passed through a 1.17-mm screen was used for the abrasive. The sand was introduced into the windstream through the floor of the wind tunnel by an inclined conveyor located about 20 feet windward of the plant test section. A hopper with a rate control mechanism fed the sand onto the lower end of the conveyor.

A bank of VHO fluorescent and incandescent lights was installed to more closely simulate conditions of illumination and radiation that plants would experience under natural conditions.

Plants were brought into the wind tunnel from their outside environment, treatment administered, and scored for damage. During testing, the plants were placed in the floor of the wind tunnel under the lights so that the floor of the wind tunnel, sides of the box, and soil were all flush.

A standard for assessing plant damage was developed by subjecting plants to varying degrees of sandblasting to obtain several boxes of plants manifesting varying degrees of injury. The plants were arranged according to severity of damage, assigned a damage score, and used as a "calibration" to evaluate visual physical damage.

After being tested, the plants were returned to their outside environment and beans were harvested 35, 39, and 45 days later. Fresh whole pod weights were obtained.

RESULTS

Damage

The physical damage caused by the treatments ranged from essentially none with wind at 20 mph and no sand to almost complete destruction of plant leaves by the most severe treatment. Damage scores assigned ranged from 2 to 9. Plants scored 2 experienced some whipping during test but showed no signs of damage. Small areas of tissue damage occurred on plants scored 3. The damaged area had the appearance of being wet. As the damage became more severe, the "wet spots" enlarged and the leaves wilted and eventually became ragged. Leaves of the plants scored 9 appeared much like an inverted umbrella with the supports removed and the edges frayed.

Conditions 1 week after testing of plants that were scored 2, 5, and 9 are illustrated in Fig. 1. Plants of Fig. 1A showed no visual signs of damage. New leaves and older damaged leaves are seen in Fig. 1B. Plants of Fig. 1C had very little evidence of producing new growth. Fig. 2 shows comparative growth of plants depicted in Fig. 1, 3 weeks later.

The extent of damage as affected by the variables (windspeed, abrasive flux, duration of exposure) is shown graphically by Fig. 3. The damage increased linearly with

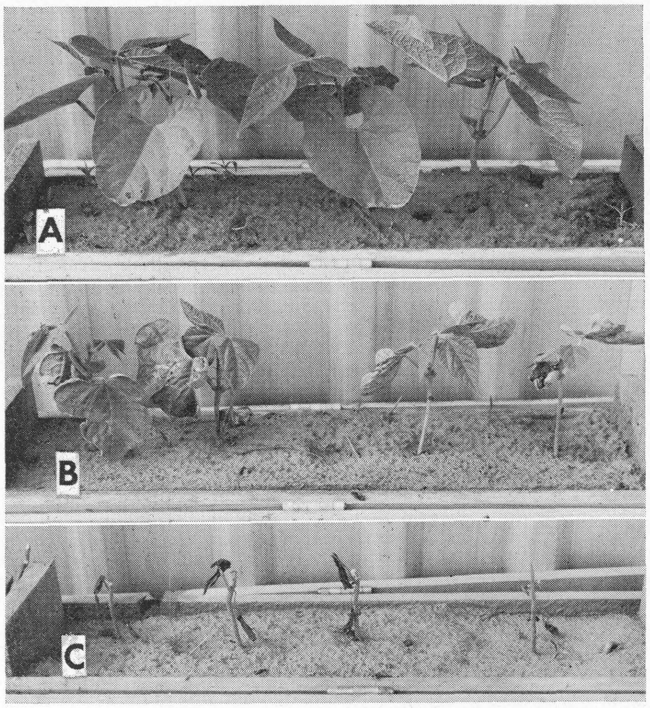

Fig. 1. Bean plants 1 week after treatment with (A) wind only at 20 mph for 5 minutes—damage score 2; (B) 30 mph wind and abrasive flux of 0.2 ton per rod width per hour for 5 minutes—damage score 5; and (C) 40 mph wind and abrasive flux of 0.6 ton per rod width per hour for 15 minutes—damage score 9.

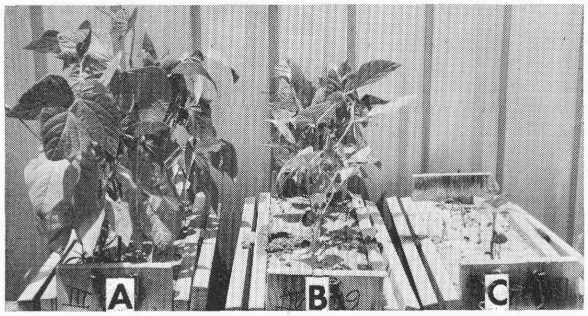

Fig. 2. Comparison of the plants of Fig. 1, 4 weeks after exposure.

windspeed and duration. A small amount of abrasive flux greatly increased the damage, but an increase in flux above the lowest level caused only a slight increase in damage.

Statistical level of significance for each variable is given in Table 1. Damage was affected by interaction of windspeed with abrasive flux as shown in Fig. 4. Its significance likely resulted from the negligible damage to plants tested at 20 and 30 mph with no sand. With no sand at 40 mph the average damage score was 3.9. Damage was affected by interaction of abrasive flux times duration of exposure as shown in Fig. 5 and Table 1. A rapid increase in damage occurred when sand was introduced into the windstream. The increase in damage score in going from wind only to an abrasive flux of 0.2 ton per rod width per hour was 2.3, 3.7, and 4.8 for exposure durations of 5, 10, and 15 minutes, respectively. The increase in damage was much greater for the longer exposures. However, for an additional increase in flux the corresponding increase in damage was greater for shorter exposures. The increase in damage

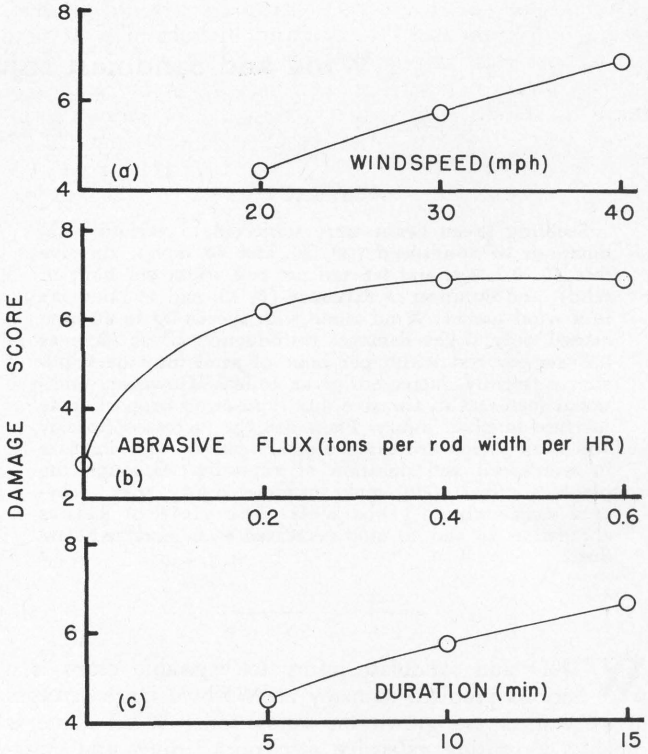

Fig. 3. Damage as affected by (a) windspeed, (b) abrasive flux, and (c) duration of exposure. The plotted data points are averages for various levels of other 2 treatment variables.

Table 1. Summary of analysis of variance on damage score, first harvest, and total harvest.

Factors	df	F value		
		Damage score	First harvest	Total harvest
Windspeed	2	175.12***	26.14***	16.37***
Flux	3	314.17***	39.22***	8.44***
Duration	2	123.37***	9.46***	9.33***
Windspeed × flux	6	4.48**	3.36*	2.83 NS
Windspeed × duration	4	.12NS	1.88NS	1.42NS
Flux × duration	6	7.91***	1.95NS	.74NS
Windspeed × flux × duration	12	1.42NS	1.40NS	.55NS
Error	70	--------	-------	-------

*, **, *** Significant at .01, .001, and .0005 levels. NS - Nonsignificant at .01 level.

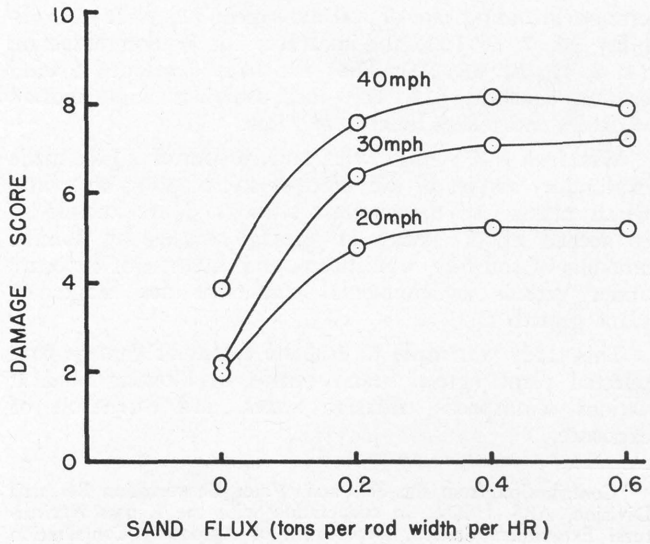

Fig. 4. Damage as affected by abrasive flux and windspeed. The plotted data points are averages for various durations of exposure.

score in going from 0.2 to 0.4 ton per rod width per hour was 0.9, 0.7, and 0.2 for exposure durations of 5, 10, and 15 minutes, respectively.

The plants sustained greater damage as the length of time to abrade with a specific amount of sand was increased, as illustrated by the isoabrasive (100 pounds per rod width) curve of Fig. 5. A 15-minute exposure of 100 pounds of sand per rod width at a rate of 0.2 ton per rod width per hour was much more damaging than a 5-minute exposure at 0.6 ton per rod width per hour.

Yield as Affected by Damage

First harvest and total yield of plants receiving damage scores to about 4 and 5, respectively, were not seriously affected (Fig. 6). However, the yields were drastically reduced with greater damage.

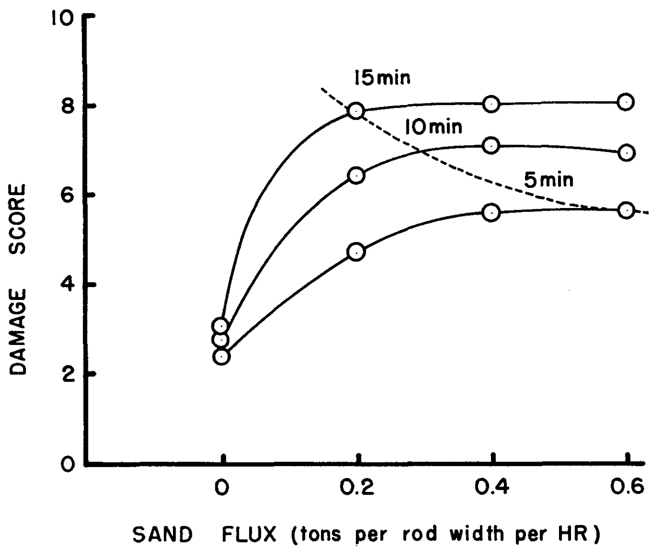

Fig. 5. Damage as affected by abrasive flux and duration of exposure with an isoabrasive (100 pounds per rod width) broken line superimposed. The plotted data points are averages for various levels of windspeed.

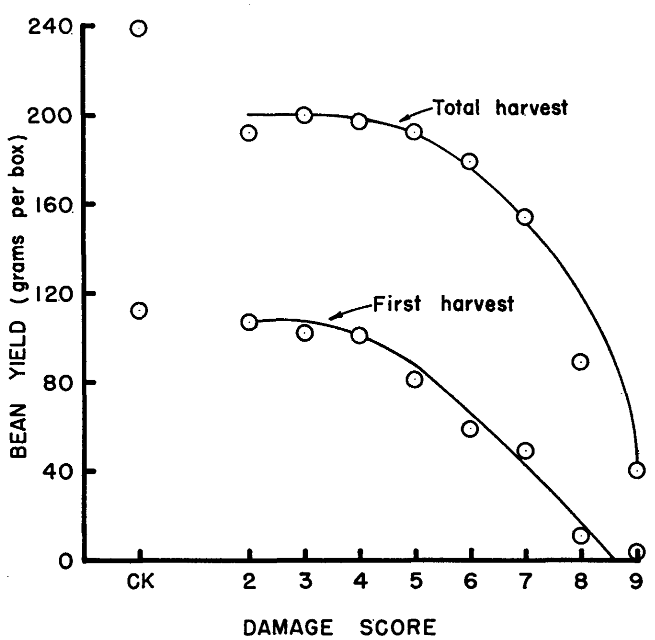

Fig. 6. Yield in relation to damage score.

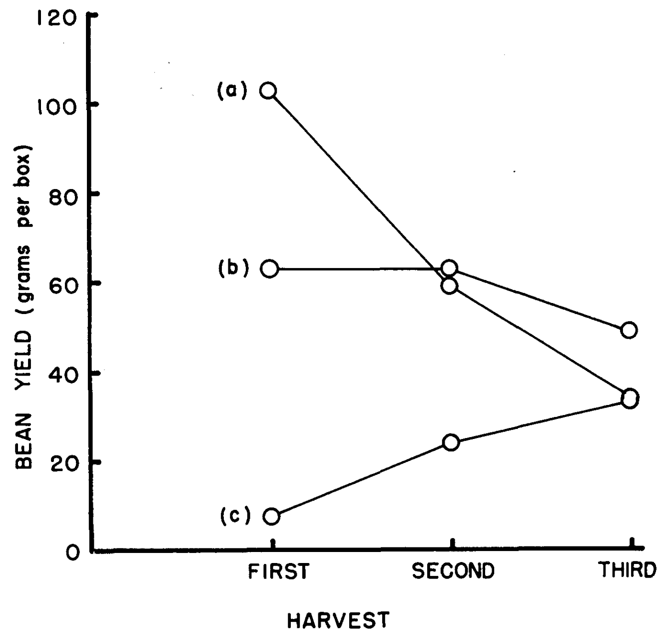

Fig. 7. Yield as affected by damage score and harvest sequence. Curves a, b, and c are average yields of all plants with damage scores of 2, 3, 4; 5, 6, 7; and 8, 9, respectively.

The yield of plants that received only slight damage (scores of 2, 3, and 4) decreased with successive harvest, whereas the yield of plants with severe damage (scores of 8 and 9) increased with successive harvest (Fig. 7). The percent of the total harvest obtained by the first harvest for plants receiving light, medium, and severe damage was 53, 36, and 11, respectively. The total yield of plants receiving damage similar to that shown in Fig. 1A and 1B was equal.

Yield as Affected by Treatment

Bean yields decreased almost linearly with increase in windspeed and duration of exposure, whereas an increase in abrasive flux caused no further yield reductions after the flux reached 0.4 ton per rod width per hour (Fig. 8). Summary of analysis of variance of the yield data (Table 1) indicates highly significant yield-treatment relationships.

The influence of abrasive flux on yield was affected by windspeed as shown in Fig. 9. At 20 mph the bean yield was not greatly affected by abrasive flux. The average damage score of plants at 20 mph was 2.0, 4.8, 5.3, and 5.3 for sand flux of 0, 0.2, 0.4, and 0.6 ton per rod width per hour, respectively. Plants damaged to that extent made sufficient recovery to yield well. At 30 mph an increase in sand flux caused further yield reductions. Yield reductions were still greater, natrually, with higher windspeed.

DISCUSSION AND CONCLUSIONS

This study clearly demonstrates that relatively low rates of sand movement and short periods of exposure can severely damage plant seedlings and cause substantial yield reduction of green beans.

The average diameter of the sand used was slightly larger than found in wind deposits by Chepil (4). Because of its higher specific gravity and sharper edges, sand is more abrasive than most field blown soil material (4).

Quantitative interpretation of these data in terms of field conditions requires information on rates of movement under natural wind conditions and on the intensity-frequency of winds. Rates of sand movement used here are within the range of soil movement for natural wind conditions on fields of below average and average erodibility but are lower than rates for some highly erodible soils. Chepil (5) reported that the rate of soil movement at a distance of 40 rods across wind-eroded fields with a 30-mph wind 5 feet above ground was 0.1, 0.5, and 1.4 tons per rod width per hour for silt loam of below average and average erodibility and loamy sand of below average erodibility, respectively. The rate of dune sand flow for 30-mph winds at 5 feet above the surface have been reported to be as much as 2.0 tons per rod width per hour (2, 5). In terms of total soil loss, rates of 0.2, 0.4, and 0.6 tons per rod width per hour from a field 40 rods long for 15 minutes are equal to 0.2, 0.4, and 0.6 ton per acre, respectively—considerably less than the 5 tons per acre per annum considered tolerable for many conditions (19).

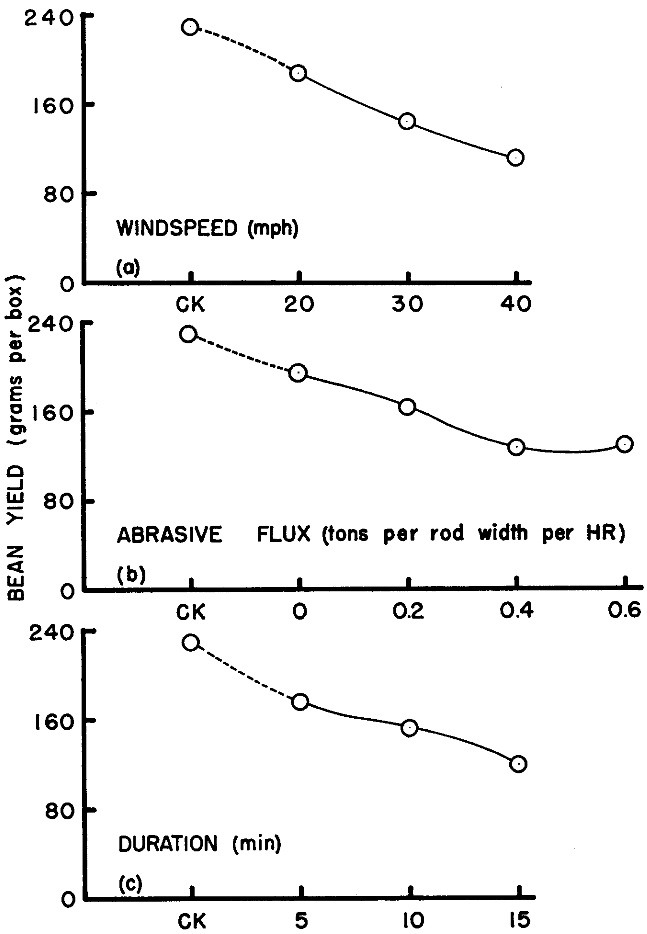

Fig. 8. Yield as affected by (a) windspeed, (b) abrasive flux, and (c) duration of exposure. Data points are averages for various levels of other 2 treatment variables.

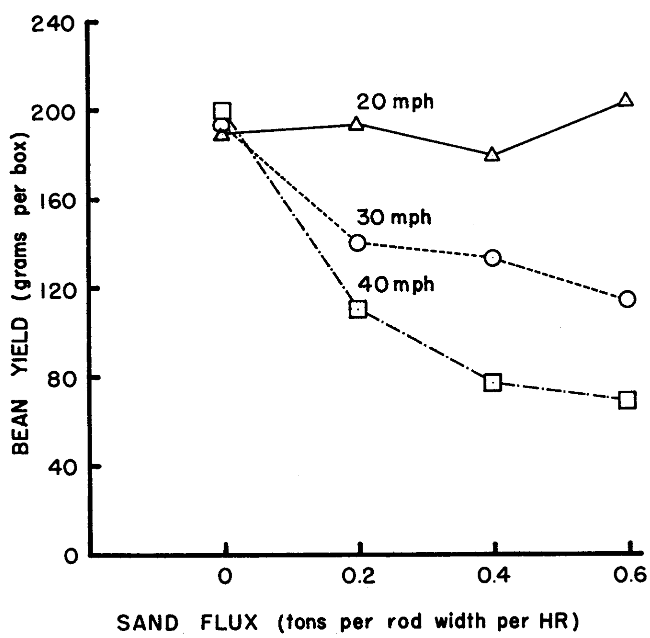

Fig. 9. Yield as affected by abrasive flux and windspeed.

Information on duration and expected frequency of natural winds of velocity sufficient to cause those movement rates is extremely limited. One study of intensity-frequency of Kansas wind by Zingg (21) indicates that at Dodge City, Kansas, winds of 5-minute duration at velocities of 40 mph at 58 feet (about comparabel to a 30-mph wind at 5 feet) would occur about once a year, usually during April, and that winds of that velocity with a duration of 1 hour could be expected about once each 18 months. That information indicates that in southwestern Kansas, where some vegetables are grown, winds of sufficient velocity to cause erosion and of duration equal to those used in this study could be expected nearly every year.

While field data related to this problem are limited, they indicate that wind erosion damage is a possibility that the vegetable grower must consider nearly every year and they emphasize the need to design and develop effective erosion control methods and practices. More research on the problem definitely is needed; however, information now available indicates that barriers, well-anchored vegetative materials, and sprayed-on nonvegetative films probably would be effective in vegetable crops (11, 12). The barriers could be annual crops such as corn, sorghum, or grasses; trees or shrubs such as Siberian elm and privet; or such artificial barriers as snowfences. For maximum protection they should be planted or erected in rows perpendicular to the prevailing wind erosion direction at close intervals (probably no more than 10H apart). Effective vegetative materials include cover crops of rye, wheat, or vetch, and hauled-in mulches such as wheat straw or native hay between vegetable rows. Nonvegetative materials include such byproducts of the petroleum and chemical industries as asphalts and latexes. They must be applied in relatively large, expensive quantities; however, they are effective and their use probably could be justified economically in high-income crops.

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