Annals of Arid Zone 25(4) 245-254, 1986

WIND EROSION AND ITS EFFECTS ON PLANT GROWTH

D. W. FRYREAR

Cropping Systems Research Laboratory, Big Spring, TX 79720, U.S.A.

Damage to crop seedlings by wind blown sand can be expected whenever the soil surface is bare of vegetation or residues and is dry, loose and finely divided and whenever the wind velocity is sufficient to erode the exposed soil. If a sufficient number of particles strike a plant, the entire leaf and stem may be killed.

The response of plants to wind-blown soil particles, ways of reporting the injury to plants in the field and ways of reducing plant injury are discussed in this paper.

Plant response :

Observations of plants subjected to wind damage revealed that in small plants whipped by the wind, approximately 50% of the leaves were folded by the whipping action in the first minute of exposure. Leaf tissue destruction was evident by a darkening of the leaves, particu arly along the edge of the fold. As the injury continued, the entire leaf became dark green and, in a few hours, the damaged tissue was black (Fryrear, 1971). Woodruff (1956) noted that winter wheat plants exposed to high winds and sand appeared to be dead after the exposure, but the plants made remarkable recovery after being returned to the greenhouse and receiving water.

Response during exposure :

Armbrust *et al.* (1974) noted that the photosynthesis decreased and respiration increased which helped account for the reduction in total nonstructural carbohydrates (Table 1.) Under the moisture stress usually associated with severe wind damage, starches may convert more rapidly to sugars, which then become a source of energy for cell repair or respiration. Total dry weight was influenced more by wind than by wind with sand. The higher dry weights for the sand treatments may be the result of tissue repair to the stem. Viable leaf area was not reduced by wind alone, but was significantly reduced with wind and sand treatments.

Finnell (1928) reported that marigolds exposed to wind used considerably more water daily even though the leaf area had been reduced. Grace (1977) made excellent report on plant response to wind alone but data on the physiological responses of plants during sand storms are very limited.

Plant survival :

As the quantity of sand (abrasive flux) striking the plant increases, the survival decreases (Armbrust, 1968; Skidmore, 1966; Fryrear *et al.*, 1975). Longer exposure times and higher wind velocities reduced plant survival (Fryrear *et al.*, 1975; Downes *et al.*, 1977, Skidmore, 1966).

Table 1. Influence of 20-minute exposure of 28 day old wheat seedlings to a 13.4 m/sec wind and various sand rates on total dry wt., viable leaf area, chlorophyll content on mg/g fresh wt basis, dark respiration (Resp), photosynthesis (Photo), ribulose-1, 5 - diphosphate carboxylase activity (RUDP), and total nonstructural carbohydrates (TNC); all expressed as per cent of the check (Armbrust et al., 1974)

Exposure Treatment	Dry wt	Viable leaf area	Resp	Photo	RUDP	TNC
Wind	75	99	98	68	106	71
Wind + 5 kg sand	91	92	124	94	93	55
Wind + 10 kg sand	94	89	151	87	104	71
Wind + 15 kg sand	94	74	98	75	88	33

The TKe concept was developed to describe the relationship between the various exposure parameters and plant survival (Fryrear and Downes, 1975). The formula for TKe is :

$$TKe = \frac{M_s V_s^2 \; T^2}{2680 \; A}$$

M = Mass of sand flux, g/cm/sec

V = Velocity of wind, cm/sec minus 670

T = Duration of exposure, minutes

A = Crop seedling age, days from emergence

The TKe assumes that sand grains will transfer a portion of their kinetic energy as they strike the plant. The magnitude of the kinetic energy will be a fuction of the velocity, density and number of particles of sand and age of the plants. The TKe technique allows the comparison of results from different tunnel tests on different plants to determine the level of protection needed by each crop. The higher the regression coefficient (Slope of line "b"), the more sensitive the crop is to sand damage (Table 2). The influence of wind velocity, abrasive flux, exposure time, and plant age on crop survival were combined in an exposure model for these seven crops (Fig. 1).

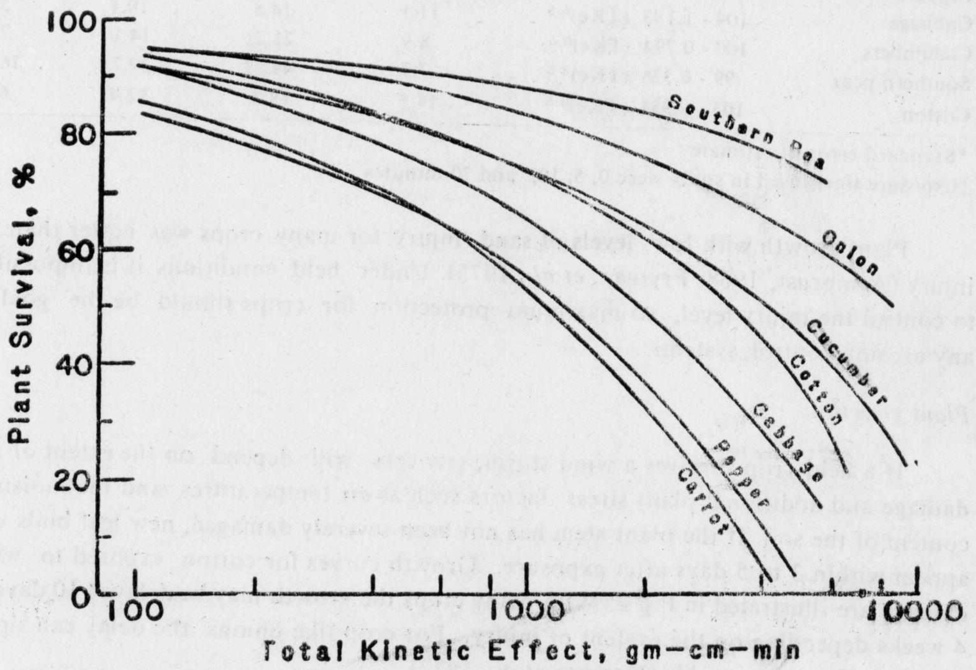

Fig. 1. Per cent survival for seven crops using the relationship Survival = a-b (TKe) $^{0.5}$ (see table 2 for values of constants a and b for each crop). The right end of the individual curves indicates highest value of TKe tested for that crop (Fryrear and Downes, 1975).

Table 2. Computed exposure time (standard treatment of 1,500 cm/sec wind, 0.5 g/cm/sec flux at 6 days of age) required to give 25, 50, or 75 per cent survival for all crops (Fryrear and Downes, 1975)

Crop	Equation	sy.x*	Percent survival 25	50	75
			Exposure time in minutes		
Carrots	$102 - 1.555\ (TKe)^{0.5}$	16.9	11.0	7.5	3.9
Onions	$101 - 0.535\ (TKe)^{0.5}$	12.7	31.0‡	21.4‡	10.9
Peppers	$98 - 1.364\ (TKe)^{0.5}$	27.4	12.0	7.9	3.8
Cabbage	$104 - 1.193\ (TKe)^{0.5}$	11.1	14.8	10.1	5.4
Cucumbers	$100 - 0.794\ (TKe)^{0.5}$	8.9	21.2‡	14.1	7.1
Southern peas	$99 - 0.336\ (TKe)^{0.5}$	7.7	49.3‡	32.7‡	16.0
Cotton	$103 - 0.954\ (TKe)^{0.5}$	14.5	18.3	12.4	6.6

*Standard error of estimate

‡Exposure times used in study were 0, 5, 10, and 20 minutes

Plant growth with low levels of sand injury for many crops was better than no injury (Armbrust, 1968; Fryrear *et al.*, 1975). Under field conditions it is impossible to control the injury level, so maximum protection for crops should be the goal of any erosion control system.

Plant growth :

If a field crop survives a wind storm, recovery will depend on the extent of the damage and additional plant stress factors such as air temperatures and the moisture content of the soil. If the plant stem has not been severely damaged, new leaf buds will appear within 3 to 5 days after exposure. Growth curves for cotton exposed to wind damage are illustrated in Fig 2. With many crops the growth may be delayed 10 days to 4 weeks depending on the exetent of injury. For crop like onions the delay can significantly reduce crop yields (Downes *et al.*, 1977).

Dry matter production, leaf area and plant height, all follow the same basic response to wind damage. The magnitude of the leaf area response is more dramatic because in most cases of severe injury the leaves are destroyed. With plant height the response may not be as dramatic, but the effect may be permanent (Fryrear, 1971).

Crop yields :

Most annual crops do not completely recover, so the farmer must survey his damaged crop and decide if he should replant. The TKe method of describing wind damage can be adapted to most crops, but the calculations can be difficult. Usually the farmer or field technician will have little information on the quantity of sand movement (abrasive flux) or the velocity of the wind as he surveys his damaged crop. To provide a technique for the farmers to quickly assess the extent of wind damage a visual rating system of evaluating damage has been developed. The

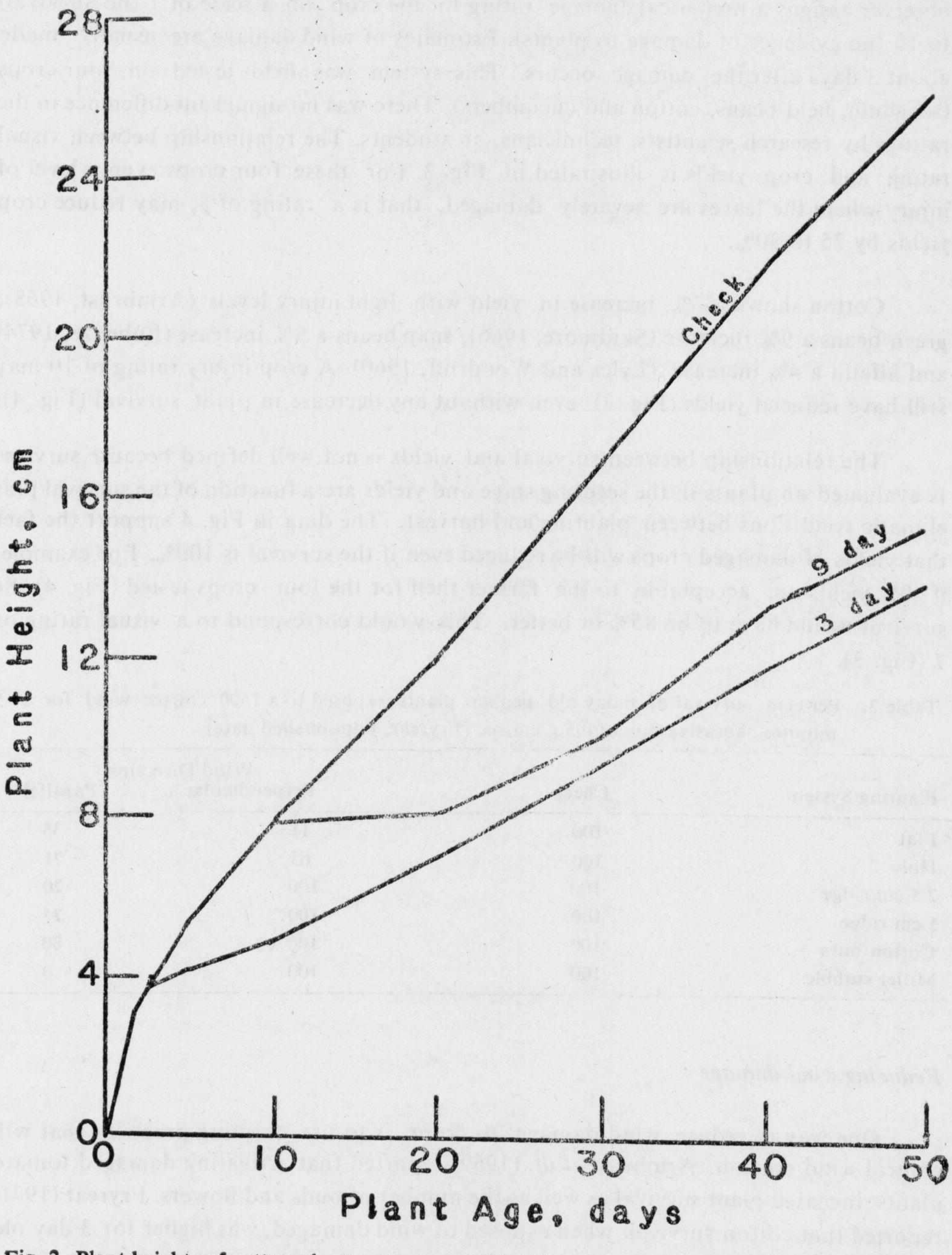

Fig. 2. Plant heights of cotton plants not exposed (check) and exposed at 3 and 9 days of age to a 1350 cm/sec wind, 0.5 g/cm/sec abrasive flux for 10 minutes (Fryrear, 1971).

observer assigns a numerical damage rating to the crop on a scale of 1 (no survival) to 10 (no evidence of damage to plants). Estimates of wind damage are usually made about 3 days after the damage occurs. This system was field tested on four crops (sorghum, field beans, cotton and cucumbers). There was no significant difference in the ratings by research scientists, technicians, or students. The relationship between visual rating and crop yields is illustrated in Fig. 3. For these four crops even a level of injury where the leaves are severely damaged, that is a rating of 8, may reduce crop yields by 25 to 30%.

Cotton shows a 7% increase in yield with light injury levels (Armbrust, 1968), green beans a 9% increase (Skidmore, 1966), snap beans a 9% increase (Bubenze, 1974) and alfalfa a 4% increase (Lyles and Woodruff, 1960). A crop injury rating of 10 may still have reduced yields (Fig. 3) even without any decrease in plant survival (Fig. 4).

The relationship between survival and yields is not well defined because survival is evaluated on plants in the seedling stage and yields are a function of the survival plus climatic conditions between planting and harvest. The data in Fig. 4 support the fact that yields of damaged crops will be reduced even if the survival is 100%. For example, if 60% yields are acceptable to the farmer then for the four crops tested (Fig. 4) the survival would have to be 85% or better. This would correspond to a visual rating of 7 (Fig. 3).

Table 3. Per cent survival of 6-day old pepper plants exposed to a 1500 cm/sec wind for 11.5 minutes, abrasive flux of 0.5 g/cm/sec (Fryrear, unpublished data)

Planting System	Check	Wind Direction Perpendicular	Parallel
Flat	100	11	35
Hole	100	65	71
2.5 cm ridge	100	100	20
5 cm ridge	100	100	25
Cotton burs	100	100	80
Millet stubble	100	100	0

Reducing wind damage :

One way to reduce wind damage to crops is to use farming practices that will control wind erosion. Armbrust *et al.* (1969) reported that irrigating damaged tomato plants inceased plant survival as well as the number of buds and flowers. Fryrear (1971) reported that cotton survival, when exposed to wind damaged, was higher for 3-day old plants on a moist soil than on a dryer soil, but when the plants were exposed at 9 days of age the plant survival on the dry soil was higher than for the moist soil. Evinently, the cells of plants growing in a moist soil are more turgid than the cells of plants on a dry soil, but the difference in turgidity was not apparent until the plants were 9 days old.

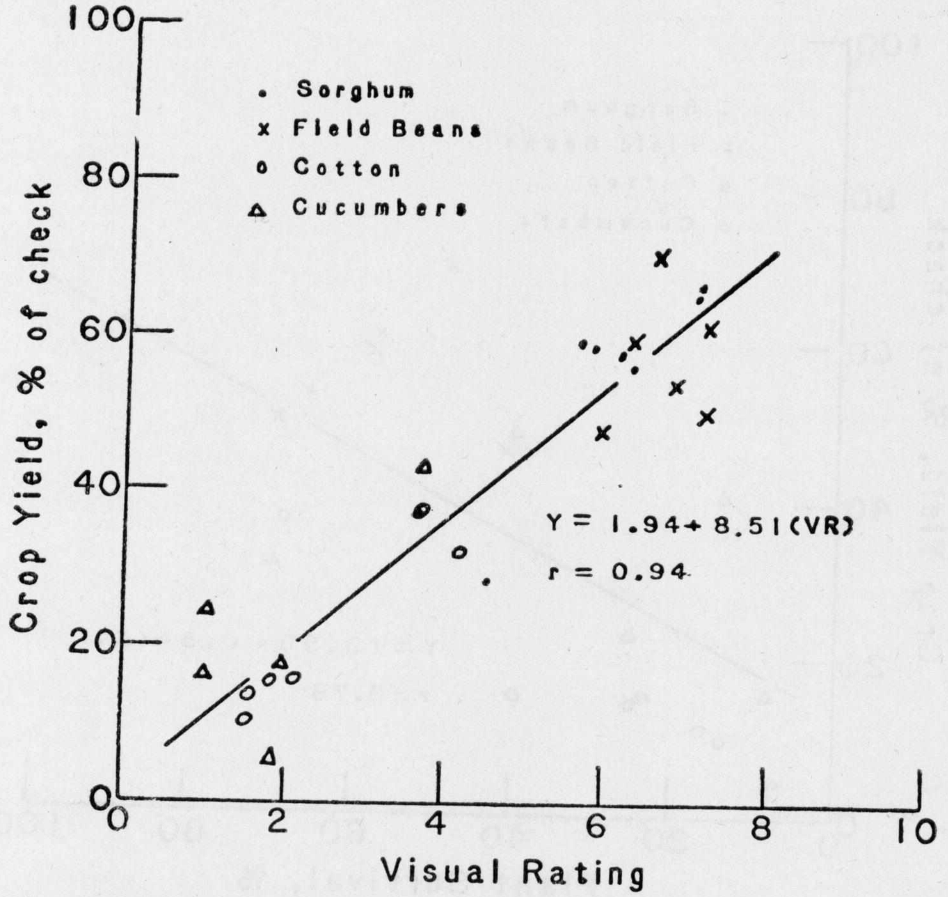

Fig. 3. Crop yields expressed as per cent of check (no wind damage) and visual rating of wind damage to cotton, field beans, sorghum and cucumbers.

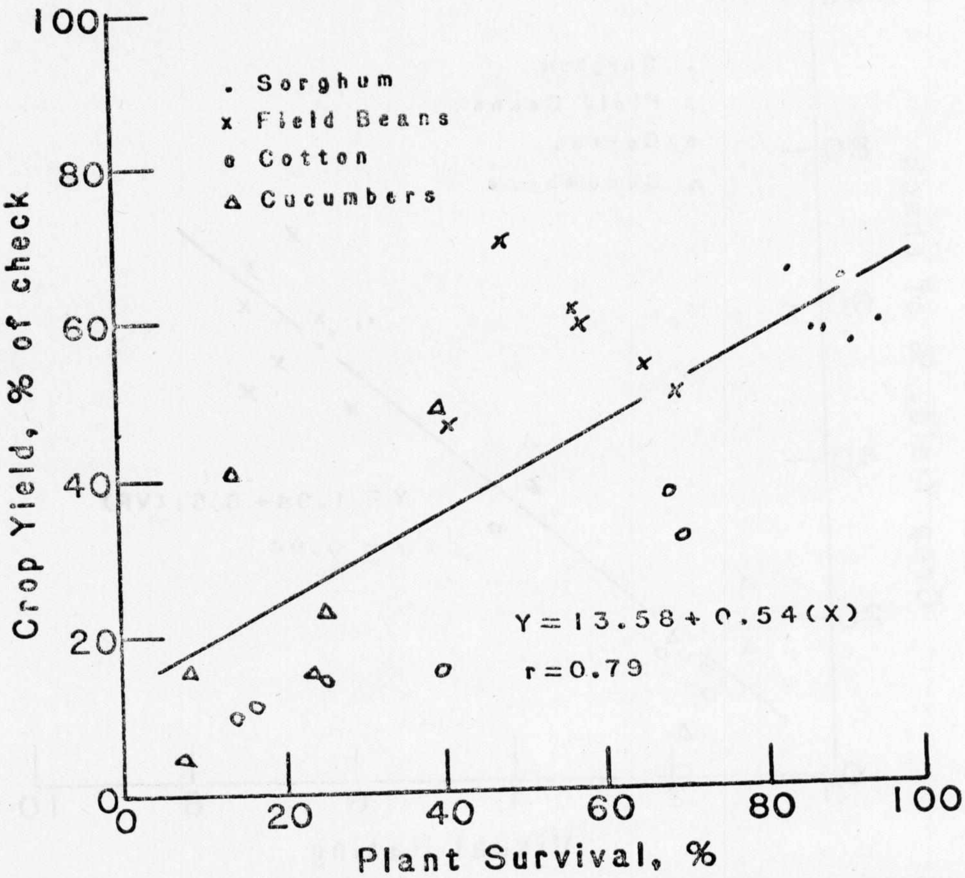

Fig. 4. Relation between survival and yields (expressed as % of check) for four crops exposed to wind and sand damage (Fryrear, unpublished data).

Protecting the crop seedlings with wind strips, crop residues, soil roughness or soil amendments remains the main method of reducing plant injury. Wind strips will reduce plant damage by trapping eroded soil particles and by reducing wind velocities at the soil surface. The wind strips are wind direction sensitive and for maximum effect must be oriented perpendicular to the prevailing erosive wind. Crop residues and surface roughness will reduce plant injury by reducing wind velocity at the soil surface, thus controlling soil particle detachment. Surface residues may not always be available and if the soil is dry, it may not be possible to produce sufficient roughness to control erosion. Tillage to generate soil roughness will not be effective on deep sands or dry soils. Usually some silt and clay must be present in the soil for the soil aggregates to be stable against breakdown by wind and rain. Chemical soil amendments are not cost effective on large areas and must be replaced each year (Armbrust and Dickerson, 1971; Lyles *et al.*, 1974).

Various planting techniques for protecting pepper seedlings have been tested (Table 3). Peppers are one of the most sensitive plants to wind injury, but planting the peppers with a 2.5 cm high ridge upwind of the plants increased survival to 100% when the wind was perpendicular to the row. When the wind was parallel to the row, the ridge tends to concentrate the sand around the pepper plants and survival was only 20%. Survival for a parallel exposure when the soil surface is flat is 35%. The benefits of a surface residue of cotton gin trash or standing millet stubble are also evident in table 3. The pepper plants betweep rows of standing millet stubble were completely destroyed when the wind was parallel to the row. Planting in a 3 cm dia hole 3 cm deep improved plant survival compared to the flat unprotected planting. The hole is not wind direction sensitive, and may not be feasible for all crops.

CONCLUSION

The impact of wind-blown sand injury to crop seedling can be tremendous. Half of the tender crop seedlings like carrots or peppers may be destroyed with less than 10 minutes exposure to blowing sand. While some crops may survive extensive damage, the influence on yields will depend on growing season conditions following the injury to crop harvest. Methods of quantifying crop injury have been developed to aid in indentifying the exent of the protection required for selected crops. If knowledge of wind velocity, sand flux, exposure duration, and plant age are available, seedling survival can be predicted for seven crops. A visual rating scale for farmer to use in evaluating crop yields was developed to aid in the determination of when damaged crops should be replanted.

Using small earthen ridges (2.5 cm high) can significantly increase seedling survival when the wind is perpendicular to the crop row.

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