Reprinted from AGRONOMY JOURNAL
Vol. 69, May-June 1977, p. 523-525



# CHEMICAL TESTS TO EVALUATE PLANT SANDBLAST DAMAGE[1]

D. V. Armbrust[2]

## ABSTRACT

**Plant sandblast damage is currently evaluated by decreases in dry weight, survival, plant height, or yield. A laboratory method would be desirable to decrease the time required to determine plant damage and it might be used to predict plant yields. The objective of this study was to evaluate assays for exosmosed amino acids, exosmosed electrolytes, internal conductivity of plant stems, trypsin inhibitor, and chlorophyll content for their ability as predictors of yield decrease due to wind erosion damage. Greenhouse grown tomatoes (*Lycopersicon esculentum* Mill. 'Bonnie Best') and soybeans (*Glycine max* (L.) Merr. 'Wayne') were exposed to 5 amounts of blowing sand ranging from 0 to 30 kg. Exosmosed amino acids and exosmosed electrolytes can be used to predict fresh and dry weights for up to 20 days after tomatoes and soybeans are damaged. However, final yields cannot be predicted by any of the five assays because of the plants' ability to recover from the damage.**

***Additional index words:*** **Exosmosed amino acids, and electrolytes, Trypsin inhibitor, Chlorohpyll content.**

WIND-erosion plant damage has been evaluated by visual rating, survival, height, plant dry weight, yield decrease, or by combinations of these methods. Although dry weight, height, yield, and survival are related to wind erosion damage (1, 2, 3, 10, 13, 16, 18), a laboratory method of evaluating plant damage would be desirable because it would decrease the amount of time needed to determine damage compared to other methods and it might be used to predict yield decrease and thereby improve management decisions on replanting.

When a windblown soil particle strikes a plant, it ruptures some cell walls, which changes the entire plant's metabolism (4, 5, 12) and kills many cells. The metabolic changes produce measurable compounds, like proteinase inhibitors (11). Death or injury changes cell wall permeability, which can be measured with cold-hardiness tests (7, 9, 14, 15) and reduces the leaf's chlorophyll content.

We report tests herein to evaluate exosmosed electrolytes, exosmosed amino acids, internal conductivity, trypsin inhibitor, and chlorophyll concentration for their ability to predict wind-erosion plant damage to tomatoes and soybeans.

## MATERIALS AND METHODS

Tomatoes (*Lycopersicon esculentum* Mill. 'Bonnie Best') and soybeans [*Glycine max* (L.) Merr. 'Wayne'] were grown in the greenhouse in 18-cm-diam. pots filled with 4 kg of sieved masonry sand (smaller than 3.35 mm). Daylight was extended to 12 hours with a combination of fluorescent and incandescent bulbs. Temperature was maintained above 21 C. Plants were watered daily with 0.2-strength Hoagland nutrient solution and thinned to 4 plants/pot 1 weeks after emergence. Five weeks after emergence, they were exposed for 16 min to wind and sandblast in a wind tunnel with 13.4 m/sec free-stream wind velocity measured 0.3 m upwind of the plants with a pitot-static tube and an inclinegage alcohol manometer. Predetermined amounts of sand (0.420 to 0.297 mm in diam.) were placed on a smooth-bottomed, openended tray directly upwind from the plants. After exposure, the plants were returned to the greenhouse. Soybeans were exposed when first trifoliate was fully expanded and tomatoes when first cluster buds were well formed.

Exposure treatments were: no wind or sand (control), wind only, wind plus 7.5, 15.0, 22.5, and 30.0 kg of sand. A completely random design was used with 3 replications/treatment.

[1] Contribution from ARS-USDA, in cooperation with the Kansas Agric. Exp. Stn. Dep. of Agronomy Contribution No. 1545. Received 26 Jan. 1976.
[2] Soil scientist, ARS-USDA, NCR, Manhattan, KS 66506.

**Table 1. Tomato data indicating significant differences due to exposure to wind and sandblast treatments. Series 1, 2, and 3.†**

| Factor | Check | Wind | Wind + sand (kg) 7.5 | 15.0 | 22.5 | 30.0 |
|---|---|---|---|---|---|---|
| | | Series 1 | | | | |
| Fresh wt. at 10 days (g/pot) | 67.4 a* | 53.5 ab | 41.1 bc | 24.9 cd | 23.7 d | 16.2 d |
| Fresh wt. at 20 days (g/pot) | 93.8 a | 74.0 b | 45.4 c | 42.3 c | 46.6 c | 37.2 c |
| Fresh wt. at 40 days (g/pot) | 181.7 a | 123.9 bc | 139.9 ab | 123.3 bc | 114.4 bc | 88.9 c |
| Dry wt. at 10 days (g/pot) | 8.3 a | 6.6 ab | 5.4 bc | 3.5 cd | 3.4 cd | 2.3 d |
| Dry wt. at 20 days (g/pot) | 14.1 a | 12.1 a | 7.5 b | 6.4 b | 7.5 b | 5.7 b |
| Dry wt. at 40 days (g/pot) | 34.3 a | 24.0 bc | 26.4 ab | 20.3 bc | 20.3 bc | 15.3 c |
| Exosmosed amino acids at 1 day (%)‡ | 22.6 c | 41.1 bc | 61.5 ab | 75.7 a | 88.3 a | 81.8 a |
| Exosmosed amino acids at 7 days (%) | 15.6 c | 14.4 c | 36.9 b | 72.3 a | 80.2 a | 78.2 a |
| Exosmosed electrolyte at 1 day (%) | 34.4 b | 51.9 b | 74.5 a | 76.6 a | 87.5 a | 83.4 a |
| Exosmosed electrolyte at 3 days (%) | 17.8 c | 30.3 bc | 45.3 abc | 56.7 ab | 60.2 ab | 73.0 a |
| Exosmosed electrolyte at 7 days (%) | 24.9 bc | 22.1 c | 49.0 b | 76.1 a | 85.2 a | 81.8 a |
| Internal conductivity at 3 days (mhos/cm $\times 10^3$) | 29.8 c | 30.3 c | 30.1 c | 34.5 a | 31.5 bc | 34.1 ab |
| | | Series 2 | | | | |
| Fresh wt. at 10 days (g/pot) | 15.2 a | 10.6 b | 7.5 c | 8.2 c | 7.2 c | 6.3 c |
| Dry wt. at 10 days (g/pot) | 1.9 a | 1.1 b | 1.0 b | 1.0 b | 1.1 b | 1.0 b |
| Dry wt. at 40 days (g/pot) | 3.0 bc | 3.9 ab | 4.2 a | 3.5 abc | 3.4 abc | 2.5 c |
| Trypsin inhibitor at 3 days (%) | 92.4 a | 95.6 a | 87.9 ab | 70.4 c | 74.2 bc | 90.1 ab |
| | | Series 3 | | | | |
| Fresh wt. at 10 days (g/pot) | 32.1 a | 24.1 ab | 17.8 bc | 16.0 bc | 12.6 c | 16.2 bc |
| Dry wt. at 10 days (g/pot) | 4.7 a | 3.6 ab | 2.6 bc | 2.2 bc | 1.7 c | 2.4 bc |
| Dry wt. at 20 days (g/pot) | 8.7 a | 7.7 ab | 6.4 ab | 6.9 abc | 4.8 c | 6.1 bc |
| Chlorophyll dry wt. at 1 day (mg/g) | 12.3 a | 9.6 ab | 8.0 b | 7.9 b | 8.9 b | 8.4 b |
| Chlorophyll dry wt. at 3 days (mg/g) | 10.9 a | 8.2 b | 6.0 bc | 5.4 bc | 4.5 c | 3.9 c |
| Chlorophyll dry wt. at 7 days (mg/g) | 10.0 a | 7.6 a | 4.2 b | 3.0 b | 3.1 b | 2.9 b |

* Means within a row followed by the same letter do not differ significantly ($P < 0.05$) by Duncan's New Multiple Range Test.
† Assays for exosmosed electrolytes, exosmosed amino acids, and internal conductivity; trypsin inhibitor; and chlorophyll content, respectively.
‡ Percent of total salts or amino acids exosmosed.

**Table 2. Soybean data indicating significant differences due to exposure to wind and sandblast treatments. Series 1, 2, and 3.†**

| Factor | Check | Wind | Wind + sand (kg) 7.5 | 15.0 | 22.5 | 30.0 |
|---|---|---|---|---|---|---|
| | | Series 1 | | | | |
| Fresh wt. at 10 days (g/pot) | 7.3 a* | 7.4 a | 6.5 abc | 5.7 bc | 5.3 c | 7.0 ab |
| Fresh wt. at 20 days (g/pot) | 16.7 a | 15.0 b | 12.8 c | 12.2 c | 13.3 c | 12.2 c |
| Dry wt. at 10 days (g/pot) | 1.4 a | 1.4 a | 1.1 ab | 1.0 b | 1.0 b | 1.2 ab |
| Dry wt. at 20 days (g/pot) | 3.4 a | 3.1 ab | 2.6 c | 2.6 c | 2.8 bc | 2.7 c |
| Exosmosed amino acid at 1 day (%)‡ | 3.6 c | 5.9 bc | 11.2 b | 9.1 b | 18.6 a | 10.6 b |
| Exosmosed electrolytes at 1 day (%) | 7.7 b | 9.0 b | 33.7 a | 28.5 a | 34.4 a | 25.8 a |
| Exosmosed electrolytes at 3 days (%) | 9.8 b | 14.7 b | 19.1 b | 35.5 a | 20.4 b | 13.6 b |
| | | Series 2 | | | | |
| Fresh wt. at 10 days (g/pot) | 6.5 ab | 6.8 a | 5.8 bc | 5.6 c | 4.7 d | 6.1 abc |
| Dry wt. at 10 days (g/pot) | 1.3 a | 1.3 a | 1.0 b | 1.0 b | 0.8 c | 1.1 b |
| | | Series 3 | | | | |
| Fresh wt. at 10 days (g/pot) | 6.9 a | 7.1 a | 6.1 bc | 5.6 c | 5.0 d | 6.5 ab |
| Dry wt. at 10 days (g/pot) | 1.4 a | 1.4 a | 1.1 b | 1.1 b | 1.0 b | 1.1 b |
| Dry wt. at 20 days (g/pot) | 4.0 a | 3.9 a | 3.5 ab | 3.4 ab | 3.2 b | 3.2 b |

* Means within a row followed by the same letter do not differ significantly ($P < 0.05$) by Duncan's New Multiple Range Test.
† Assays for exosmosed electrolytes, exosmosed amino acids, and internal conductivity; trypsin inhibitor; and chlorophyll content, respectively.
‡ Percent of total salts or amino acids exosmosed.

Three series of experiments were conducted with the following assays: 1) exosmosed electrolytes, exosmosed amino acids, and internal conductivity; 2) trypsin inhibitor; and 3) chlorophyll content. Each included tomatoes and soybeans.

Assay samples were taken 1, 3, and 7 days after exposure. Soybean samples were five 6-mm-diam. discs removed from each fully expanded trifoliate. Tomato samples were leaflets removed from the third and fourth leaves above the plant base. Sample weights were 0.5 g. Data recorded included date of first bloom, number of flowers and fruit, and fruit weight. Plant tops were harvested 10, 20, and 40 days after exposure, weighed, dried (70 C for 48 hours), and then reweighed.

Exosmosed electrolytes and exosmosed amino acids were assayed by a combination of Dexter's (7) electrolyte and Siminovitch's (15) amino acid assay. Internal conductivity was determined by Filinger's (9) method. Two no. 7 steel sewing needles 0.6 cm apart were inserted 0.3 cm deep into the stem immediately above the cotyledon node. Conductivity was read on a conductivity bridge. Method II of Erlanger (8) was used to assay trypsin inhibitor, and chlorophyll concentration was determined by Arnon's method (6).

Analysis of variance techniques (17) were used on all data. Significant data are given in Tables 1 and 2. Nonsignificant data ($P < 0.05$) are not reported and were not used in linear regression and correlation analysis (17).

## RESULTS AND DISCUSSION

Exposure to wind and sandblast decreased fresh and dry weights 10 days after exposure in all tests, but plants began to recover by 20 or 40 days after exposure, depending on experimental series and plant species. The plants' ability to recover prevented yield indicators from being significant in any series.

Exosmosed amino acids differed significantly among exposures 1 and 7 days after exposure in tomatoes and 1 day after exposure in soybeans; exosmosed electrolytes differed significantly 1, 3, and 7 days after exposure in tomatoes and 1 and 3 days after exposure in soybeans. Internal conductivities differed significantly 3 days after exposure in tomatoes only, but did not relate to any yield measurement.

Regression and correlation analyses of the significant data (Table 3) indicated that 43% of the regression coefficients were larger than 0.70, and 21% were larger than 0.75. These relationships and their regression equations are given in Table 3. Internal conductivity of the stems did not relate to any yield measurement.

**Table 3. Regression equations and correlation coefficients for assays on wind and sandblast-damaged tomatoes and soybeans.**

Tomato—Series 1

10-day dry wt. (g) = 7.87 − 0.059 (7-day amino acid) r = 0.80
10-day dry wt. (g) = 8.39 − 0.062 (7-day electrolyte) r = 0.78
10-day dry wt. (g) = 9.39 − 0.040 (1-day amino acid) − 0.029 (1-day electrolyte), R = 0.90
10-day dry wt. (g) = 8.03 − 0.047 (7-day amino acid) − 0.014 (1-day electrolyte), R = 0.88

20-day dry wt. (g) = 15.24 − 0.103 (1-day amino acid) r = 0.76
20-day dry wt. (g) = 18.75 − 0.145 (1-day electrolyte) r = 0.84
20-day dry wt. (g) = 14.47 − 0.118 (3-day electrolyte) r = 0.76
20-day dry wt. (g) = 20.00 + 0.062 (1-day amino acid) − 0.220 (1-day electrolyte), R = 0.89
20-day dry wt. (g) = 13.36 − 0.076 (7-day amino acid) − 0.012 (7-day electrolyte), R = 0.91

10-day fresh wt. (g) = 72.60 − 0.562 (1-day amino acid) r = 0.75
10-day fresh wt. (g) = 64.15 − 0.531 (7-day amino acid) r = 0.83
10-day fresh wt. (g) = 68.94 − 0.551 (7-day electrolyte) r = 0.81
10-day fresh wt. (g) = 77.34 − 0.398 (1-day amino acid) − 0.219 (1-day electrolyte), R = 0.89
10-day fresh wt. (g) = 65.84 − 0.401 (7-day amino acid) − 0.144 (7-day electrolyte), R = 0.87

20-day fresh wt. (g) = 97.47 − 0.662 (1-day amino acid) r = 0.76
20-day fresh wt. (g) = 120.65 − 0.942 (1-day electrolyte) r = 0.85
20-day fresh wt. (g) = 129.90 + 0.463 (1-day amino acid) − 1.499 (1-day electrolyte), R = 0.89

Soybean—Series 1

10-day dry wt. (g) = 1.56 − 0.016 (1-day electrolyte) r = 0.98

Tomato—Series 3

10-day dry wt. (g) = 1.28 + 0.309 (7-day chlorophyll mg/g dry wt.) r = 0.76
10-day fresh wt. (g) = 9.39 + 2.026 (7-day chlorophyll mg/g dry wt.) r = 0.75

Although correlation coefficients indicated close relationships between exosmosed amino acids and exosmosed electrolytes and fresh and dry weight production of tomatoes and soybeans (Series 1), and regression equations could be used to predict fresh and dry weight up to 20 days, the two assays had to change widely before they indicated small changes in fresh or dry weight. For example, a 1 g change in the 10-day dry weight of tomatoes required a 16% change in the

1-day exosmosed amino acid or a 13% change in the 1-day exosmosed electrolytes.

Trypsin inhibitors in tomatoes differed significantly 3 days after exposure but not when they were related to fresh or dry weight production or to any yield indicator. Damaged or undamaged soybeans and "Big Boy" tomatoes produced too little trypsin inhibitor to measure by our assay. Green and Ryan (11) found that mechanical damage increased trypsin inhibitor 6 to 10 times in tomatoes and potatoes, and that damage near the main vein increased the inhibitor more than did damage near the leaf edge. However, trypsin inhibitor may not accumulate in wind-erosion damaged plants because rapid death and desiccation of ruptured cells may prevent the inhibitor inducing factor from either being metabolized or from moving into the plants' vascular system. Also, most wind and sandblast damage was to leaf edges, not near main veins.

Chlorophyll contents of tomatoes (dry weight basis) differed significantly at 1, 3, and 7 days after exposure and correlated highly with fresh and dry weight production 10 days after exposure (Table 1) but not with fresh or dry weights or any yield indicators 20 or 40 days after exposure.

In contrast, soybean chlorophyll contents did not differ significantly among exposures.

## SUMMARY

Five chemical assays evaluated for their effectiveness as predictors of yield decreases due to sandblast damage in tomatoes and soybeans indicated that exosmosed amino acids and exosmosed electrolytes are related to fresh and dry weight production up to 20 days after exposure, but they cannot be used as yield predictors due to the plants' ability to recover. Internal conductivity and trypsin inhibitor assays were of no value.

## LITERATURE CITED

1. Adriano, D. C., D. V. Armbrust, and L. S. Murphy. 1969. Foliar absorption of urea by sandblasted wheat seedlings. Agron. J. 61:575-576.
2. Armbrust, D. V. 1968. Windblown soil abrasive injury to cotton plants. Agron. J. 60.622-625.
3. ———, J. D. Dickerson, and J. K. Greig. 1969. Effect of soil moisture on the recovery of sandblasted tomato seedlings. J. Am. Soc. Hort. Sci. 94 (3):214-217.
4. ———, and G. M. Paulsen. 1973. Effect of wind and sandblast injury on nitrate accumulation and on nitrate reductase activity in soybean seedlings. Commun. Soil Sci. Plant Anal. 4 (3):197-204.
5. ———, ———, and R. Ellis, Jr. 1974. Physiological responses to wind- and sandblast-damaged winter wheat plants. Agron. J. 66:421-423.
6. Arnon, D. I. 1949. Copper enzymes in isolated chloroplasts. Plant Physiol. 24:1-15.
7. Dexter, S. T., W. E. Tottingham, and L. F. Graver. 1930. Preliminary results in measuring the hardiness of plants. Plant Physiol. 5:215-223.
8. Erlanger, B. F., N. Kokowsky, and W. Cohen. 1961. The preparation and properties of two new chromogenic substrates of trypsin. Arch. Biochem. Biophys. 95:271-278.
9. Filinger, G. A., and A. B. Cardwell. 1941. A rapid method of determining when a plant is killed by extremes of temperatures. Proc. Am. Soc. Hort. Sci. 39:85-86.
10. Fryrear, D. W. 1971. Survival and growth of cotton plants damaged by windblown sand. Agron. J. 63:638-642.
11. Green, T. R., and C. A. Ryan. 1972. Wound-induced protienase inhibitor in plant leaves: a possible defense mechanism against insects. Science 175:776-777.
12. Greig, J. K., Nabil Bokhari, D. V. Armbrust, and L. C. Anderson. 1974. Residual effects of wind- and sandblast-damage on tomato plants at different stages of development. J. Am. Soc. Hort. Sci. 99:530-534.
13. Lyles, Leon, and N. P. Woodruff. 1960. Abrasive action of windblown soil on plant seedlings. Agron. J. 52:533-536.
14. Siminovitch, D., and D. R. Briggs. 1954. The validity of plasmolysis and desiccation tests for determining frost-hardiness of bark tissue. Plant Physiol. 28:15-34.
15. ———, H. Therrien, F. Gfeller, and B. Rheaume. 1964. The quantitative estimation of frost injury and resistance in black locust, alfalfa, and wheat tissues by determination of amino acids and other ninhydrin-reacting substances released after thawing. Can. J. Bot. 42:637-649.
16. Skidmore, E. L. 1966. Wind and sandblast injury to seedling green beans. Agron. J. 58:311-315.
17. Snedecor, George W. 1956. Statistical methods. Iowa State College Press, 523 p.
18. Woodruff, N. P. 1956. Wind-blown soil abrasive injuries to winter wheat plants. Agron. J. 48:499-504.