80-440-J

Reprinted from *Agronomy Journal*
Vol. 74, Jan.-Feb. 1982, p. 133-135

Physiological Responses to Wind and Sandblast Damage by Grain Sorghum Plants[1]

D. V. Armbrust[2]

ABSTRACT

Yield depression due to physical damage by wind and windblown soil (sandblast damage) is well known. Less well known is the reason for the yield reductions by sandblast damage. The objective of the research was to determine if this yield depression was due to a simple loss of photosynthetically active leaf tissue or to physiological changes within the plant.

Physiological responses of growth chamber grown RS 626 grain sorghum (*Sorghum bicolor* L. Moench) to injury by wind (13.4 m/sec), wind plus sand (10, 20, 30, 40, 50, 60, and 70 kg), and partial defoliation (removal of the distal one-fourth and one-half of each leaf) were evaluated. Wind and wind plus sand treatments were conducted in a wind tunnel. Net photosynthesis, dark respiration, total chlorophyll, dry weight, and leaf area were determined 1, 3, and 7 days after treatment.

Dry weight production increased at low sand levels (< 30 kg) and decreased with higher sand exposure. Reduced growth of sandblasted grain sorghum is caused by loss of viable leaf tissue and physiological changes, which are mainly reduced photosynthesis and increased respiration. It is not clear from this study if these changes result from partial defoliation, short-term high-intensity moisture stress, or a combination of both.

Additional index words: **Net photosynthesis, Dark respiration, Chlorophyll, Partial defoliation.**

THE Soil Conservation Service estimated that from 1 Nov. 1978 to 31 May 1979, 1.1 million ha (2.7 million acres) of cropland in the 10 Great Plains States were damaged by wind erosion (21). Eighty percent of the duststorms (12) occur between 1 January and 31 May, with most occurring during the high wind-velocity months of March, April, and May. Grain sorghum (*Sorghum bicolor* L. Moench) when it emerges in May is vulnerable to wind-erosion damage.

Wind reduced the growth and yield of rape (*Brassica rapa* L.) (22, 23), barley (*Hordeum vulgare* L.) (23), and peas (*Pisum sativum* L.) (23). Windblown soil reduced the yield of cotton (*Gossypium hirsutum* L.) (2, 13), tomatoes (*Lycopersicum esculentum* Mill.) (5, 19), alfalfa (*Medicago sativa* L.) and grasses (16), green beans (*Phaseolus vulgaris* L.) (20), soybeans (*Glycine max* (L.) Merr.) (3, 6), winter wheat (*Triticum aestivum* L. em. Thell) (1, 7, 26), and tobacco (*Nicotiana tabacum* L.) (4) by abrasive injury. Yields of corn (*Zea mays* L.) (10), soybeans (10), tobacco (18), and sugar beets (*Beta vulgaris* L.) (11) were reduced by hail or simulated hail.

In only one of these studies of plants damaged by wind, windblown soil, or hail was any attempt made to assign dry matter and yield reductions to a physio-

[1] Contribution from the USDA-ARS in cooperation with the Kansas Agric. Exp. Stn. Dep. of Agronomy Contribution 80-440-J. Received 24 Nov. 1980.
[2] Soil scientist, ARS-USDA, Kansas State Univ., Manhattan, KS 66506.

Table 1. Total dry-weight production, dry-weight accumulation from 1 to 7 days after treatment, viable leaf area, percentage of viable leaf area, and total chlorophyll content of grain sorghum plants after treatment.†

Treatment	Dry weight	Accumulation	Viable leaf area		Chlorophyll
	g		dm²	%	mg/gfw‡
Control	4.65 c*	3.54 a	8.70 a	100 a	1.01 a
Wind	4.53 c	2.97 abc	7.16 b	89 c	0.86 bc
Wind + 10 kg	5.26 b	3.27 ab	8.32 a	93 b	0.90 b
Wind + 20 kg	5.20 b	3.60 a	6.57 b	80 e	0.77 c
Wind + 30 kg	6.14 a	3.79 a	7.31 b	74 f	0.76 c
Wind + 40 kg	3.84 de	2.68 abc	4.14 d	68 g	0.78 c
Wind + 50 kg	3.65 de	2.56 abc	4.14 d	64 h	0.83 bc
Wind + 60 kg	3.80 de	1.98 bc	3.45 de	62 hi	0.54 d
Wind + 70 kg	3.40 d	1.81 c	3.23 e	61 i	0.56 d
1/4 leaf removal	3.96 d	3.22 abc	6.85 b	85 d	0.87 bc
1/2 leaf removal	2.93 f	2.10 abc	4.98 c	63 hi	0.87 bc

* Means followed by the same letter do not differ significantly (>0.05 by Duncan's New Multiple Range Test).
† Average of three sample dates.
‡ gfw = gram fresh weight.

Table 2. Net photosynthesis rate and dark respiration rate of grain sorghum plants after treatment.†

Treatment	Photosynthesis	Respiration
	mg CO_2/pot/hr	
Control	117.8 ab*	36.7 ab
Wind	123.4 a	34.4 abc
Wind + 10 kg	102.6 bc	39.4 a
Wind + 20 kg	113.1 bc	38.5 ab
Wind + 30 kg	105.0 bc	41.7 a
Wind + 40 kg	98.8 c	28.6 cd
Wind + 50 kg	100.8 c	30.7 c
Wind + 60 kg	65.4 d	22.8 d
Wind + 70 kg	66.6 d	22.2 d
1/4 leaf removal	96.8 c	37.5 ab
1/2 leaf removal	74.4 d	28.4 cd

* Means followed by the same letter do not differ significantly (>0.05 by Duncan's New Multiple Range Test).
† Averages for the three sample dates.

logical change. Winter wheat (7) dry matter reductions were attributed to a combination of viable leaf-area loss, reduced photosynthesis, and increased respiration. In this study, we investigated the photosynthetic and respiratory responses of wind- and sandblast-injured grain sorghum to determine if yield reductions are caused by physiological changes or by reductions in viable leaf area.

MATERIALS AND METHODS

'RS 626' grain sorghum was planted in 18-cm-diam plastic pots filled with 4 kg of masonry sand, sieved to remove all particles larger than 3.35 mm. Pots were placed into a growth chamber to simulate a field with 256,410 plants/ha in 52-cm rows. Plants were grown for 3 weeks at 30 C during a 16-hour day and 25 C night. Radiant energy flux was 1,400 μE m^{-2} sec^{-1} at top of canopy. Pots were watered daily with 0.2-strength Hoagland nutrient solution.

The plants (9-leaf stage) were exposed to wind and sandblast injury in a wind tunnel. All treatments were exposed to a 13.5 m sec^{-1} free-stream wind velocity, measured in the center of the tunnel 0.3 m upwind of the plants with a pitot static tube and incline-gage mamometer. Sand (0.297 to 0.420-mm diam) was introduced into the windstream 6.7 m upstream of the plants at an abrasive flux of 31 g (cm width)$^{-1}$ min^{-1}. After exposure, pots were returned to the growth chamber.

Exposure treatments were: no wind or sand (control); wind only for 60 min; wind plus 10, 20, 30, 40, 50, 60, and 70 kg of sand; and removal of the distal one-fourth and one-half of each leaf.

Four pots with 3 plants/pot were selected randomly from each exposure treatment 1, 3, and 7 days after exposure to determine net photosynthesis rate, dark respiration rate, leaf area, chlorophyll content, fresh weight, and dry weight.

Net carbon exchange in both light and dark was determined with a 30-cm-diam by 60-cm-high plexiglas plant chamber adapted for syringe sampling. Air was circulated upward through the chamber at an average velocity of 2.8 m sec^{-1} by a fan in the heat exchanger. Temperature in the chamber was maintained at 25 ± 2 C. Light at an intensity of 900 μE m^{-2} sec^{-1} was supplied to the chamber by four 300 W, cool-beam, medium spotlights.

Three 10-ml samples of chamber air were taken every 10 min with the lights on until CO_2 was about 200 ppm. Lights were turned off and samples taken every 15 min until CO_2 approached 400 ppm. Syringes were injected into a flowing N_2 stream, which passed through the sample cell of an infrared gas analyzer previously calibrated by injecting known CO_2 samples ranging from 0 to 400 ppm CO_2.

After CO_2 assimilation was measured, plants were cut off at the sand surface, stripped of their leaves, and leaves were separated into viable and dead tissue. Then areas of viable and dead leaf tissue were measured. Viable tissue was cut into 1-cm widths and 1 g was removed for chlorophyll determination. Remaining plant parts were combined, weighed, dried for 48 hours at 70 C, and weighed.

Chlorophyll was extracted from 1-g leaf tissue homogenized with 20 ml of 100% acetone. The homogenate was filtered through Whatman No. 2 filter paper with a Buchner funnel, and a 0.5-ml aliquot was taken for chlorophyll determination by a modification of Arnon (8) and MacKinney (17) methods.

RESULTS

Total dry weight production was significantly increased by plant exposures to wind plus 30 kg or less sand but significantly reduced by exposures to wind plus 40 kg or more sand and leaf tip defoliation (Table 1). Dry matter accumulation (difference between Day 1 and 7) was reduced significantly only when plants were exposed to 60 kg or more sand plus wind. Removing the distal one-half of each leaf decreased dry weight production most, but dry-matter accumulation was not affected.

Viable leaf area was decreased significantly by all treatments, except wind plus 10 kg sand (Table 1). Only the leaf tips were damaged by the wind-only treatment. The lower five leaves were almost totally destroyed, and leaf tips, edges, and areas within upper leaves were damaged when sand was added to the windstream. All treatments significantly reduced viable leaf area (percentage).

All treatments significantly decreased total chlorophyll content. Exposure to wind plus 60 or 70 kg sand decreased plant chlorophyll content almost 50%. New growth was visibly lighter green in all treatments.

Photosynthesis and respiration rates per pot were reduced significantly when plants were exposed to wind plus 40 kg or more sand (Table 2). Removing the distal one-fourth or one-half of each leaf also reduced photosynthesis, but respiration was significantly reduced only when one-half of the leaf was removed.

DISCUSSION

Grain sorghum plants exposed to less than 30 kg sand plus wind had increased dry-weight production, even though leaf area and net photosynthesis were decreased 7 to 26 and 4 to 13%, respectively. Possibly stored carbohydrates were translocated to supply the energy necessary to increase growth. Where dry-weight production decreased, stored energy was not sufficient to make up the decrease in photosynthesis.

Net photosynthesis was reduced 14 to 44% for plants exposed to more than 30 kg sand plus wind, but if calculated on a live leaf-area basis, rate of net photosynthesis increased 48 to 85%. This increase in rates of photosynthesis of the remaining live tissue agreed with those reported in other studies of partial-defoliation effects (7, 14, 24). Removing the distal end of each leaf of grain sorghum did not increase per-area photosynthesis rates, which disagreed with findings of previous studies, as did decrease in chlorophyll content. Others reported increases in chlorophyll content for defoliated corn (24) and sandblasted wheat (7).

Dark respiration per pot increased for four treatments and decreased for six, but dark respiration per viable leaf area increased 12 to 93%, similar to increases reported for sandblasted winter wheat (7). This increase in respiration may have been caused by a short-term moisture stress resulting from the huge demand of plant leaves with broken cells exposed to a high wind velocity. Armbrust et al. (6) reported leaf-water potentials in soybeans increased for 4 to 24 hours after sandblast damage. Increases in respiration rates with moisture stress also have been reported for tomatoes and loblolly pine (*Pinus taeda* L.) (9).

Wilson et al. (25) reported that as plant-water decreased, dark respiration decreased by a factor of 2. Photosynthesis and rate of dry matter accumulation also were reduced. Moisture stress also might account for the decrease in per-pot photosynthesis by reducing the activity of the carboxylating enzymes. Huffaker et al. (15) reported that RUDP carboxylase activity in barley was reduced by moisture stress.

Sandblasting reduces grain sorghum growth by causing a loss of viable leaf area, reducing photosynthesis, and increasing respiration.

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. ———. 1972. Recovery and nutrient content of sandblasted soybean seedlings. Agron. J. 64:707–708.
4. ———. 1979. Wind- and sandblast-damage to tobacco plants at various growth stages. Tob. Sci. 23:117–119.
5. ———, J. D. Dickerson, and J. K. Greig. 1969. Effect of soil moisture on the recovery of sandblasted tomato seedlings. J. Am. Soc. Hort. Sci. 94:214–217.
6. ———, and Gary 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.
7. ———,———, and R. Ellis, Jr. 1974. Physiological responses to wind- and sandblast-damaged winter wheat plants. Agron. J. 66:421–423.
8. Arnon, D. I. 1949. Copper enzymes in isolated chloroplasts. Plant Physiol. 24:1–15.
9. Brix, H. 1962. The effect of water stress on the rates of photosynthesis and respiration in tomato plants and loblolly pine seedlings. Physiol. Plant. 15:10–20.
10. Cameray, M. P., and C. R. Weber. 1953. Effects of certain components of simulated hail injury on soybeans and corn. Iowa State Agric. Exp. Stn. Res. Bull. 400.
11. Carter, J. N., D. J. Traveller, and S. M. Bosma. 1978. Sugar beet yield and seasonal growth characteristics as affected by hail damage and nitrogen level. J. Am. Soc. Sugar Beet Technol. 20:73–83.
12. Chepil, W. S., F. H. Siddoway, and D. V. Armbrust. 1963. Climatic index of wind erosion conditions in the Great Plains. Soil Sci. Soc. Am. Proc. 27:449–452.
13. Fryrear, D. W. 1971. Survival and growth of cotton plants damaged by windblown sand. Agron. J. 63:638–642.
14. Gej, B. 1972. Photosynthetic activity and distribution of ^{14}C-assimilates following partial defoliation in buckwheat and white mustard plants. Acad. Polon. Sci. Bull. Ser. Sci. Biol. 20:63–70.
15. Huffaker, R. C., T. Radin, G. E. Kleinkopf, and E. L. Cox. 1970. Effects of mild water stress on enzymes of nitrate assimilation and of the carboxylative phase of photosynthesis in barley. Crop Sci. 10:471–474.
16. Lyles, Leon, and N. P. Woodruff. 1960. Abrasive action of windblown soil on plant seedlings. Agron. J. 52:533–536.
17. MacKinney, G. 1938. Some absorption spectra of leaf extracts. Plant Physiol. 13:123–140.
18. Pointer, John P., and W. G. Woltz. 1965. Investigations of hail damaged tobacco. North Carolina Agric. Exp. Stn. Res. Bull. 123.
19. Precheur, Robert, J. K. Greig, and D. V. Armbrust. 1978. The effects of wind and wind-plus-sand on tomato plants (*Lycopersicon esculentum* L.). J. Am. Soc. Hort. Sci. 103(3):351–355.
20. Skidmore, E. L. 1966. Wind and sandblast injury to seedling green beans. Agron. J. 58:311–315.
21. USDA. Soil Conservation Service. 1971. Wind erosion conditions—Great Plains.
22. Wadsworth, R. M. 1959. An optimum windspeed for plant growth. Ann. Bot. N. S. 23:195–199.
23. ———. 1960. The effect of artificial wind on the growth rate of plants in water culture. Ann. Bot. N. S. 24:200–211.
24. Wareing, P. F., M. M. Khalifa, and K. J. Treharne. 1968. Rate-limiting processes in photosynthesis at saturating light intensities. Nature (London) 220:453–457.
25. Wilson, D. R., C. H. M. van Bavel, and K. J. McCree. 1980. Carbon balance of water-deficient grain sorghum plants. Crop Sci. 20:153–159.
26. Woodruff, N. P. 1956. Wind-blown soil abrasive injuries to winter wheat plants. Agron. J. 48:499–504.