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Wind-Blown Soil in the Epidemiology of Bacterial Leaf Spot of Alfalfa and Common Blight of Bean

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ABSTRACT

Potted, healthy alfalfa and bean plants were placed in a laboratory wind tunnel and exposed to naturally infested dry field soil blown at regulated air speeds. The plants were then kept on a greenhouse bench for 10-14 days, and the resulting incidence of bacterial leaf spot of alfalfa and common blight of bean was determined. Disease incidence increased as wind speed and exposure time increased and was greater in the row nearest the wind source. Lesions were mostly confined to the lower 10-cm of plant shoots where the blowing particles were most concentrated. Lesions on stems were confined to their windward side.

Bacterial leaf spot incidence increased from 6% after 3-min exposure to soil blown 9.4 m/sec to 26% after 5-min exposure at 13.9 m/sec. Blight incidence in 2-week-old bean plants from exposure to soil blown 13.9 m/sec for 3 and 5 min was 25 and 55%, respectively.

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Researchers (1, 6, 8) have suggested that wind-blown soil and debris not only disseminate bacterial plant pathogens but wound host tissue and permit bacterial penetration. Vakili (7) reported wind-blown, naturally infested soil to be important in the epidemiology of bacterial spot of tomatoes in the field.

Plant injury caused by wind-blown sand or soil is well documented. Wind speeds of 17.9 m/sec (40 mph) without abrasive flux slightly damaged green bean plants but adding 6 g/cm width/min of sand into the wind-stream greatly increased injury and reduced yields up to 53% (5). The average yield reduction of alfalfa exposed to sand blown at 7 wind velocities between 8.9 m/sec (20 mph) and 13.9 m/sec (31 mph) for 12 min was 55% (4).

In Kansas, summer prevailing winds are from the south, and most stem lesions of common blight of beans and bacterial leaf spot of alfalfa occur on their south side, frequently during hot, dry periods. This suggests that wind-blown soil could be an inoculating agent. The effects on the incidence of bacterial leaf spot of alfalfa and common blight of bean from exposing healthy plants to naturally infested soil or artificially infested sand blown at different speeds and durations in a wind tunnel are reported in this paper.

MATERIALS AND METHODS.—A laboratory wind tunnel developed by the Soil Erosion Laboratory, ARS, USDA, and partially described by Zingg & Chepil (9) was used. The tunnel is approx. 9.1 m long, 0.91 m wide, and 0.91 m high. Wind speed was controlled by governor-regulated engine speed and fan louvers and was measured with a pitot tube and inclined alcohol manometer (9). Pots or pans of plants were placed adjacent to the downwind end of the tunnel with the tops of the pots flush with the tunnel floor and with the rows perpendicular to the direction of the blowing soil. Artificially infested sand was metered into the wind-stream from a hopper across the top of the tunnel 3 m upwind from the plants. Naturally infested soil and debris were spread 4 cm deep on a 0.91 m^2 plywood board fastened on the downwind end to the tunnel floor. Rates of soil movement were determined by placing a known weight of soil on the board at the beginning of the treatment and weighing the remainder after treatment. Rates of abrasive flux (g/cm width/min) were calculated as described by Chepil (2). After treatment, plants were placed on greenhouse benches at 22-30 C and 30-60% relative humidity for 10-14 days and evaluated.

Alfalfa (*Medicago sativa* L. 'Ladak') plants were grown in autoclaved sand in bread pans (24.5 X 14 X 7 cm). Each pan contained two rows (approx. 40-50 plants/row) spaced 7.6 cm apart. Bean (*Phaseolus vulgaris* L. 'Pinto U.I. 114') plants (one plant/pot or four plants/pan) were grown in an autoclaved soil:peat:sand (2:1:1) mixture in 15-cm diam plastic pots or bread pans (24.5 X 14 X 7 cm). All plants were grown in the greenhouse and were subjected to various treatments when 2 to 9 wk old.

Isolates used were Xp-S of *Xanthomonas phaseoli* (E. F. Sm.) Dows. obtained from M. L. Schuster, University of Nebraska, Lincoln, and KX-1 of *Xanthomonas alfalfae* (Riker, Jones, & Davis) Dows. from alfalfa. To prepare inoculum, *X. alfalfae* was streaked on potato-glucose agar (PGA) and *X. phaseoli* on yeast extract-glucose-calcium carbonate (YGC) agar (3) and incubated at 30 C for 48-56 hr. Bacterial cells were washed from the medium with sterile distilled water and a suspension containing approx. 17.4 X 10^7 for *X. phaseoli* and approx. 18.6 X 10^7 for *X. alfalfae* was prepared.

Fine river sand was artificially infested by mixing 200 ml of *X. phaseoli* or *X. alfalfae* inoculum with 23

TABLE 1. Effect of wind speed and exposure time to wind-blown Sarpy fine sandy loam naturally infested with *Xanthomonas alfalfae* on bacterial leaf spot incidence in 6-week-old alfalfa plants

Wind speed (m/sec)	Exposure time (min)	Flux rate (g/cm width/min)	Avg % plants infected[y]	
			Row 1[z]	Row 2
9.4	3	1.9	6.0 b	1.8 a
13.9	3	25.1	16.3 d	12.4 c
9.4	5	2.0	6.6 b	7.2 b
13.9	5	22.8	26.0 e	13.1 cd

[y] Numbers followed by the same letter do not differ significantly ($P = 0.01$, Duncan's multiple range test). Control plants subjected to wind-blown autoclaved soil developed no symptoms.

[z] Rows ran perpendicular to direction of blowing soil and row 1 was upwind from row 2.

TABLE 2. Effect of alfalfa plant age on bacterial leaf spot incidence and lesion location resulting from the exposure of healthy plants to naturally infested Sarpy fine sandy loam soil blown 5 min at 13.9 m/sec; soil movement averaged 22 g/cm width/min

Plant age (weeks)	Avg % plants infected[x]					
	Row 1[y]			Row 2		
	Leaf	Stem	Total	Leaf	Stem	Total
3	26	12	35 a	13	4	17 b
6	27	12	38 a	10	1	11 c
9	22	12	34 a	16	0	16 b

[x] Total means followed by the same letter do not differ significantly ($P = 0.05$, Duncan's multiple range test). Control plants subjected to wind-blown, autoclaved soil developed no symptoms.

[y] Rows ran perpendicular to direction of blowing soil and row 1 was upwind from row 2.

kg of screened (18-mesh) sand. The mixture was spread out on paper and dried to approx. 10% of its water-holding capacity to insure an even flow into the tunnel.

Naturally infested Keith silt loam soil obtained from J. H. Kyle at the Garden City, Kansas, Branch Agricultural Experiment Station was used for the common blight experiment. Beans had been grown in that soil the previous five seasons. A mixture of naturally infested Sarpy fine sandy loam soil and debris from an alfalfa field near Manhattan, Kansas, was used for the bacterial leaf spot experiments. The soil was screened (18-mesh) and dried to approx. 10% of its water-holding capacity, as previously described.

Following all experiments, isolations were made from tissue with representative water-soaked lesions. Bacterial cells from representative colonies were inoculated into stems of healthy plants with sterilized dissecting needles to verify pathogenicity.

RESULTS.—Bacterial leaf spot incidence usually increased as wind speed, exposure time, and abrasive flux rate increased and was greater in row 1 (upwind row) than in row 2. Lesions resulting from naturally infested *X. alfalfae* soil blown from a board on the wind tunnel floor were primarily confined to the lower 10-cm of the plant shoots where soil movement was most concentrated. Lesions on stems were confined to their upwind side.

Six percent of 6-wk-old alfalfa plants in the upwind row developed bacterial leaf spot after 3-min exposure to naturally infested soil blown in the wind tunnel with wind speed of 9.4 m/sec (Table 1). The disease incidence increased to 16% at wind speed of 13.9 m/sec. Increasing the exposure time from 3 to 5 min did not increase the disease incidence at 9.4 m/sec wind speed but increased it to 26% at 13.9 m/sec. With one exception, bacterial leaf spot incidence was significantly less in row 2 than in row 1.

To determine the effect of added infected debris on disease incidence, dried alfalfa shoots with severe bacterial leaf spot were ground in Wiley mill (60-mesh) and mixed with the soil prior to treatment. Six-wk-old alfalfa plants were exposed 5 min to naturally infested Sarpy fine sandyloam without or with 0.1% (w/w) of the ground infected debris. Wind speed was 13.9 m/sec and flux rate averaged 22 g/cm width/min. The resulting bacterial leaf spot incidence was 19% in plants exposed to the added debris and 18% in those exposed to infested soil only.

Plant age did not affect bacterial leaf spot incidence significantly (Table 2). The older plants being larger had more area exposed to the blowing soil but had no more lesions than did the younger smaller plants. The larger exposed area of the older plants was apparently offset by the more succulent and injury-susceptible tissue of the younger plants and because soil movement was greater near the soil level.

We could not separate the effects of wind speed and the abrasive flux rate on disease incidence with naturally infested soil because the soil was metered into the top of the tunnel and as air speed increased a greater proportion of the soil particles were blown above the plants. On the other hand, movement rate of soil placed on the tunnel floor depended solely on wind speed.

When artificially infested sand was metered into the wind-stream at 21 g/cm width/min, bacterial leaf spot incidence increased as wind speed and, or, exposure time increased (Table 3). Plants in row 1 exposed 4 min at 13.9 m/sec wind became 96% infected.

Bean common blight data were similar to those for bacterial leaf spot of alfalfa. Blight incidence in 2-wk-old bean plants from exposure to naturally infested soil blown from the tunnel floor by a 13.9 m/sec tunnel wind speed for 3 and 5 min was 25 and 55%, respectively. The soil movement rate was approx. 22 g/cm width/min.

When sand artificially infested with *X. phaseoli* was metered into the top of the wind tunnel at 21 g/cm width/min, blight incidence increased as wind speed, exposure time, or both, increased (Table 4).

TABLE 3. Effect of wind speed and exposure time to fine river sand artificially infested with *Xanthomonas alfalfae* on bacterial leaf spot of 6-week-old alfalfa plants[x]

Exposure time (min)	Wind speed (m/sec)	Avg % of plants infected[y]	
		Row 1[z]	Row 2
2	9.4	51 d	27 b
3	9.4	55 d	39 c
4	9.4	73 e	39 c
2	13.9	43 c	19 a
3	13.9	70 ef	42 c
4	13.9	96 g	78 f

[x] Sand was released into top of wind tunnel at rate of approx. 21 g/cm width/min.

[y] Numbers followed by the same letter do not differ significantly ($P = 0.05$, Duncan's multiple range test). Control plants subjected to wind-blown, autoclaved sand developed no symptoms.

[z] Rows ran perpendicular to direction of blowing sand and row 1 was upwind from row 2.

TABLE 4. Effect of wind speed and exposure time to fine river sand artificially infested with *Xanthomonas phaseoli* on blight incidence in 2-week-old bean plants[y]

Wind speed (m/sec)	Avg % of plants that became infected after the indicated exposure time[z]				
	2 min	3 min	4 min	5 min	6 min
9.4	0 a	9 b	16 c	16 c	19 c
13.9	9 b	25 d	28 d	38 e	53 f

[y] Sand was released into top of wind tunnel at rate of approx. 21 g/cm width/min.

[z] Numbers followed by the same letter do not differ significantly ($P = 0.05$, Duncan's multiple range test). Control plants subjected to wind-blown, autoclaved sand developed no symptoms.

The increase in wind speed from 9.4 to 13.9 m/sec usually accounted for a two- to threefold increase in blight incidence at most exposure periods.

Apparent physical damage to beans and alfalfa by wind-blown soil ranged from none after 2 min exposure at 9.4 m/sec, to severe damage to some leaves from 6 min exposure at 13.9 m/sec. Sand caused considerable plant damage at the 13.9 m/sec wind speed; approximately 5% of the 6-wk-old alfalfa plants were killed and numerous bean leaves were destroyed at exposure periods of 6 min. Severe abrasive damage caused water-soaked spots that persisted for approx. 24 hr after treatments.

DISCUSSION.—Our data confirmed our field observations that wind-blown infested soil is important in Kansas in the epidemiology of bacterial leaf spot of alfalfa and common blight of beans. We believe the wind not only disseminates the pathogen but also is an inoculating agent. Bacterial cells apparently are carried into the plant tissues by wind-driven soil particles. We eliminated free moisture as a factor by watering plants sparingly from trays under pots or pans, being careful not to wet the plants and to keep the plants at low relative humidities.

Experiments with naturally infested soil represent conditions during most growing seasons in Kansas except that plants, especially beans, grown in the greenhouse prior to treatments were not as sturdy as those grown in the field under higher light intensities. This likely accounted for greater mechanical wind damage and disease incidence than would occur in the field. However, we could not use field-grown plants and be certain they were not infected or infested prior to treatment. Wind velocities of 9.4 m/sec and 13.9 m/sec that we used are matched in Kansas as gusts of 13.9 m/sec and higher are common. Such gusts frequently precede summer thunderstorms which also likely enhance infection. As the soil was blown from the tunnel floor, the abrasive flux rate depended on wind speed and therefore it should have been similar to soil movement in the field.

The protection afforded row 2 by row 1 supports our field observations of less bacterial leaf spot in thick than in thin alfalfa stands during dry periods, particularly in the lighter soils. It also suggests possible disease control benefits from tillage practices, direction of rows, and use of strip cropping which tends to check soil avalanching (2) and therefore reduces the inoculum load.

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