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EFFECT OF WIND AND SANDBLAST INJURY ON NITRATE ACCUMULATION AND ON NITRATE REDUCTASE ACTIVITY IN SOYBEAN SEEDLINGS[1]

KEY WORDS: Wind erosion damage, nitrate content

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ABSTRACT

Exposing soybean seedlings to wind or to wind plus sand at a windspeed of 13.4 m/sec for up to 40 minutes decreased nitrate reductase activity and increased nitrate content immediately after exposure. Enzyme activity immediately after exposure was lower in damaged seedlings than in the untreated check, but after 24 hours the check had the lower activity. The enzyme activity and nitrate concentration remained higher in damaged seedlings than in the check for up to 40 days after exposure.

INTRODUCTION

Studies on seedlings of cotton[3,7], tomatoes[5], grass and alfalfa[9], and green beans[12], and on established wheat stands[14] have provided some information on yield reduction and flowering delay caused by sandblast injury. Physiological responses of plants to abrasive injury have been studied little.

Armbrust[4], studying nutrient uptake in sandblasted soybeans, found that nitrate content increased with increased damage and attributed that increase to a decrease in nitrate reductase activity. This study was undertaken to establish the effect of sandblast injury on nitrate reductase activity and on nitrate content of soybean seedlings.

MATERIALS AND METHODS

Ten soybean (*Glycine max* L. Merr. var. 'Wayne') seeds were planted in 4 kg of masonry sand (screened to remove particles larger than 3.35 mm) in each of 210 18-cm-diameter pots in the greenhouse. Seedlings were watered daily with one-tenth-strength Hoagland nutrient solution. There was a 2-day difference in planting, exposing, and sampling the 5- and 40-minute treatments and the first check and the 10- and 20-minute treatments and the second check. Day length was maintained at 14 hours and temperature was 21 C at night to a maximum of 30 C during the day.

Two weeks after emergence, seedlings were thinned to two per pot and at 5 weeks exposed to a windspeed of 13.4 m/sec and wind plus sand (< 1.17 mm) at 3 g/cm width/min for 0, 5, 10, 20, and 40 minutes in an illuminated wind tunnel. A completely randomized factorial design with all treatments replicated three times was used.

Five leaf discs (6-mm diameter) were taken from each leaflet of every fully expanded trifoliate leaf to determine nitrate reductase activity[11,13]. Leaves which emerged after exposure were not sampled. Samples of viable tissue were taken between 10 a.m. and noon immediately after exposure (IAE), and 1, 3, 5, 10, 20, and 40 days after the plants had been exposed to wind and sandblast.

Leaf water and osmotic potentials were measured with thermocouple psychrometers[6] on two tissue samples from the last fully expanded leaflet

in the 10- and 20-minute treatment and related check. The samples were equilibrated 90 minutes at 25 C. Osmotic potentials were determined on ruptured cells of leaf tissue frozen with dry ice.

After leaves had been sampled for nitrate reductase activity, the remainder of the plant shoots were harvested, dried for 24 hours at 70 C, weighed, ground to less than 40-mesh, and analyzed for nitrate[15]. Leaves and stems were separated on other plants 10 days after exposure to determine localization of nitrate.

RESULTS AND DISCUSSION

Nitrate reductase activity decreased immediately after the seedlings were exposed to wind or wind plus sand (Table 1) if leaf tissue was damaged (Table 2); water stress probably caused the decrease (Table 3). Activity then increased and reached a maximum 3 to 10 days after exposure. Nitrate reductase activity began decreasing after 5 to 10 days but remained higher than in the untreated check for 40 days. The return of enzyme activity equal to or greater than the check activity within 24 hours agreed with findings of Huffaker et al.[8,10].

Immediately after the seedlings had been exposed, when enzyme activity was low, nitrate concentration (Table 4) was higher in the shoots of treated plants than in the check. The concentration in treated plants approached that in the check as enzyme activity increased (1 day after exposure). However, the nitrate concentration then became higher than that of the check 5 days after exposure. The rapidity and length of time that the treatments remained above the check depended on severity of damage (Table 2).

The combination of high reductase activity and high nitrate concentration likely was caused by the abrasive injury which reduced the leaf area much more than the plants' ability to take-up nitrate (thereby increasing the nitrate concentration). The higher nitrake concentration, in turn,

TABLE 1

Nitrate Reductase Activity in Viable Leaflets of Soybean Seedlings Exposed to Wind and Wind Plus Sand

Treatment	IAE	Sample time - days after exposure 1	3	5	10	20	40
	micromoles NO_2^-(g fresh wt)$^{-1}$ hr^{-1}						
Check	0.58a*	0.71c	0.72b	0.56d	4.39c	0.91c	0.66c
Wind, 5 minutes	0.56a	0.72c	0.76b	0.69d	5.42c	1.06c	0.68c
Wind + sand, 5 minutes	0.45b	1.91c	4.29a	6.94b	6.94b	1.38b	1.24b
Wind, 40 minutes	0.26c	1.26c	1.80b	3.55c	4.37c	1.40b	1.39b
Wind + sand, 40 minutes	0.29c	12.40a	2.89a	30.52a	24.38a	7.78a	4.91a
Check	0.66a	1.72c	4.54e	3.03c	3.23c	2.56c	0.66d
Wind, 10 minutes	0.10b	1.86c	12.45d	4.96c	3.25c	2.92c	0.81b
Wind + sand, 10 minutes	0.11b	4.60b	37.78a	24.61b	8.20b	6.60b	1.38a
Wind, 20 minutes	0.05b	1.82c	30.08b	26.90a	3.89c	6.30b	0.68b
Wind + sand, 20 minutes	0.16b	3.62b	23.58c	24.04b	26.52a	9.21a	1.33a
Check average	0.62	1.22	2.63	1.79	3.81	1.74	0.65
Treatment average	0.25	3.52	14.20	15.28	10.37	4.58	1.55

* Numbers in each column followed by the same letter are not significantly different at the 1 percent level by Duncan's test.

TABLE 2

Visual Estimate of Percentage Leaf Tissue Damaged by Wind or Wind Plus Sand 3 Days After Exposure

Treatment	Damage
	%
Check	0
Wind, 5 minutes	0
Wind + sand, 5 minutes	17
Wind, 10 minutes	13
Wind + sand, 10 minutes	38
Wind, 20 minutes	35
Wind + sand, 20 minutes	58
Wind, 40 minutes	43
Wind + sand, 40 minutes	88

TABLE 3

Leaf Water Potential and Osmotic Potential of Soybean Leaves Exposed to Wind and Wind Plus Sand

	Leaf water potential**				
	Time interval after exposure				
Treatment	0		1 hr	4 hr	24 hr
Check	-5.0	(-7.4)*	-4.6	-7.8	-9.1
10-minute wind	-7.5	(-9.2)	-4.0	-6.1	-9.4
10-minute wind + sand	-6.0	(-7.1)	-5.4	-9.1	-9.1
20-minute wind	-6.4	(-8.5)	-4.8	-5.2	-9.2
20-minute wind + sand	-17.1	(-18.5)	-17.1	-4.7	-9.1

* Osmotic potential.
** Bars.

TABLE 4

Nitrate Concentrations in Shoots of Soybean Seedlings Exposed to Wind and Wind Plus Sand

Treatment	IAE	Sample time - days after exposure 1	3	5	10	20	40
		micromoles (g dry wt)$^{-1}$					
Check	1.6ef*	3.3a	1.8bc	0.2d	0.01c	0.06b	0.01c
Wind, 5 minutes	6.8b	2.6ab	0.8c	1.2c	0.01c	0.10b	0.01c
Wind + sand, 5 minutes	4.8c	2.0ab	0.7c	0.9c	0.01c	0.07b	0.01c
Wind, 40 minutes	2.9d	2.3ab	0.5c	1.2c	0.08bc	0.24b	0.04b
Wind + sand, 40 minutes	9.0a	1.2b	4.1a	4.0a	2.2a	5.0a	0.10a
Check	0.4f	2.8ab	0.4c	0.1d	0.01c	0.22b	0.01c
Wind, 10 minutes	5.4c	2.4ab	0.7c	1.1c	0.04c	0.18b	0.01c
Wind + sand, 10 minutes	2.9d	1.8ab	3.6ab	3.0b	0.36b	0.30b	0.01c
Wind, 20 minutes	2.5de	1.9ab	1.2c	1.1c	0.38b	0.56b	0.01c
Wind + sand, 20 minutes	2.9d	2.2ab	4.6a	1.2c	0.34b	0.62b	0.01c
Check average	1.0	3.0	1.1	0.15	0.01	0.14	0.01
Treatment average	4.6	2.0	2.0	1.71	0.44	0.88	0.02

* Numbers in each column followed by the same letter are not significantly different at the 5 percent level by Duncan's test.

TABLE 5

Nitrate Concentrations in Leaflets and Stems of Soybean Seedlings 10 Days After Exposure to Wind and Wind Plus Sand. Each Value is the Average of Three Replications

Treatment	Leaflets	Stem
	micromoles (g dry wt)$^{-1}$	
Check	0.01	0.32
Wind, 5 minutes	0.01	1.06
Wind + sand, 5 minutes	0.26	2.53
Wind, 10 minutes	0.15	1.52
Wind + sand, 10 minutes	0.52	1.53
Wind, 20 minutes	0.23	1.02
Wind + sand, 20 minutes	0.68	4.83
Wind, 40 minutes	0.09	0.69
Wind + sand, 40 minutes	4.28	25.55

induced higher enzyme activity. Total enzyme activity was limited by the smaller area of viable photosynthetic leaf tissue (Table 2), which allowed nitrate to accumulate in treated plants (Table 5).

These results indicate that the nitrogen metabolism of plants is very sensitive to physical damage (such as wind erosion or hail) and that amino acid and protein synthesis may be altered or disrupted.

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REFERENCES

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