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Reflectorized Soybean Canopy in Relation to Transpiration and Herbicide Phytotoxicity[1]

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The reflective properties of a vegetative canopy influence its energy balance. Increased albedo results in reduction of net radiation impinging on the plant. This reduction of net radiation often lowers both the leaf temperature and transpiration. Kaolinite, cilite, and other inert, white materials have been used to increase the albedo of plant canopies (ABOU-KHALED et al. 1970, DORAISWAMY and ROSENBERG 1974). ABOU-KHALED et al. (1970) working with orange (*Citrus sinensis* var. Valencia), rubber plant (*Ficus elastica*), and bean (*Phaseolus vulgaris*) found that a coating of kaolinite reduced leaf temperature 3 to 4 C, reduced transpiration 22 to 28%, and increased water use efficiency, particularly under conditions of high light intensity and high atmospheric evaporative demand. Similar results are contained in several published reports on this subject (BARADAS et al. 1976, FUCHS et al. 1976, LEMEUR and ROSENBERG 1976, STANHILL et al. 1976).

The phytotoxic action of soil applied herbicides depends on their uptake by roots and translocation within the plant to the site of toxic action. The above processes are closely associated with the rate of transpiration (MINSHALL 1954, OORSCHOT 1970). The environmental variables that influence rate of transpiration (light intensity, humidity, and temperature) are also known to influence the phytotoxicity of root-absorbed herbicides (ASHTON 1965, OORSCHOT 1965 and 1970).

This study was undertaken to evaluate the ability of kaolinite as a reflectant to reduce soybean [*Glycine max* (L.) Merrill 'Elf'] transpiration and the phytotoxicity of atrazine [2-chloro-4(ethylamino)-6-(isopropylamino)-*s*-triazine] and picloram (4-amino-3,5,6-trichloropicolinic acid).

MATERIALS AND METHODS

Six seeds of soybean were sown on October 10, 1979 in 15 cm diameter black plastic pots containing 420 g of Sharpsburg silty clay loam (Typic Argiudolls). Seedlings were thinned to four per pot after the expansion of the unifoliate leaves. Pots were maintained in a heated greenhouse with natural sunlight plus supple-

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mental light from 1000 watt metal-halide lamps (Day Brite Lighting Division, Emerson Electric Co., U.S.A.) providing total irradiance of 116 Wm^{-2} at the top of the plants. Pots were subirrigated as necessary.

The reflectant material was prepared by mixing 5 g of powdered kaolinite, 70 ml of distilled water and 1 ml of Tween-20 [Polyoxyethylene (20) sorbitan monolaurate, ICI America]. Plants receiving kaolinite treatment had adaxial surfaces of all leaves painted with the white substance. Application rate was about 225 mg kaolinite per dm^2 leaf area (ABOU-KHALED et al. 1970). Plants were treated with kaolinite after the expansion of the second trifoliolate leaves on November 4, and herbicides were applied to the soil surface two days later.

There were 13 herbicide treatments: atrazine to soil ratio of 0.01, 0.05, 0.10, 0.20, 0.30, 0.40 µg/g, and picloram to soil ratio of 0.001, 0.003, 0.005, 0.007, 0.01, 0.03 µg/g; and a control which contained no herbicide. Each of the above treatments consisted of 8 pots, 4 of which received reflectant treatment. A split plot design was used.

During the first 2 days following herbicide application, air temperature and irradiance in the greenhouse were measured 7 times a day (between 0800 and 2000 solar time) at 2 hourly intervals. Also measured were leaf temperatures of plants that received 0.10 and 0.40 µg/g of atrazine; 0.0005 and 0.03 µg/g of picloram; and the control. Air temperature was measured with a mercury thermometer; and leaf temperature with copper-constantan thermocouples. Irradiance was measured 10 cm above the plants with an Eppley Pyranometer (Model PSP, Eppley Lab, Inc. U.S.A.). The effect of herbicide treatments on dry weight reduction of soybean plants was evaluated 10 days after herbicide application, on November 16 for kaolinite treated and untreated plants. Plants were cut at soil level and their dry weight was determined after drying at 90 C for 4 days. A response curve was drawn for each herbicide, with and without kaolinite treatment, to determine the soil herbicide concentration required for 50% reduction in dry weight (GR_{50}).

The effect of kaolinite treatment on transpiration was determined in a second experiment involving 8 pots (1 plant/pot) that received no herbicide treatment. Four of the plants were painted with kaolinite while the remaining four plants were not. Water loss from soil in the pots was prevented by sealing the soil-surfaces with black plastic sheets. Water loss was measured six times (every 2 h) throughout the days of November 7 and 8 (0800 to 1800 solar time) with a top-loading balance. Leaf area was determined just before and immediately after the transpiration study, using an electronic area meter (Model LI30) and an accessory transparent belt conveyor (Model LI 3050A/I) from Lambda Instr. Corp., Lincoln, Nebr., U.S.A. Initial leaf area measurements were made by marking the outline of individual leaves of a plant on sheets of paper, excising the leaf outline, and measuring the area with the instrument. Final leaf area measurements were made on the leaves after removing them from the plants. The leaf area per plant was used to compute transpiration rates of each plant.

Data were statistically analyzed and means were separated with Duncan's Multiple Range Test.

RESULTS AND DISCUSSION

The mean air temperature and mean irradiance in the greenhouse on November 7 and 8 were 25.5 C, 281 Wm^{-2}; 29.2 C, 329 Wm^{-2}, respectively. Transpiration rates were higher for untreated than for the reflectant treated plants on both days and at each analysis time (Table 1). Transpiration was also higher for both treatments on November 8 when both mean air temperature and irradiance were higher. Transpiration increased from 0800 to 1400 h solar time, and then decreased rapidly, perhaps due to stomatal closure in response to water stress, or other diurnal environmental variable. Transpiration was reduced an average of 15% by kaolinite treatment during the two days.

TABLE 1
Effect of kaolinite leaf reflectant treatment on the transpiration rate of 28 day old soybean leaves for 2 consecutive days in the greenhouse.

	Transpiration Rate of Soybean Plants			
	7 Nov.		8 Nov.	
Solar time	Kaolinite treated	Untreated	Kaolinite treated	Untreated
	($gdm^{-2}h^{-1}$)			
0800	0.86a*	1.28b	2.19a	2.42b
1000	1.25a	1.58b	3.17a	3.47b
1200	1.70a	2.09b	3.29a	3.88b
1400	2.99a	3.28b	3.42a	3.98b
1600	0.94a	1.08b	1.23a	1.59b
1800	1.04a	1.21b	1.10a	1.39b

*Means in rows under different dates followed by different letters are significantly different at 5% level using Duncan's Multiple Range Test.

Mean leaf temperatures were also higher for non-reflectant treated as compared to reflectant treated soybeans (Table 2). Leaf temperatures were higher on November 8 than November 7. These differences in leaf temperature undoubtedly explain the differences in transpiration rates between the two treatments. Soybean plants treated with atrazine or picloram exhibited higher leaf temperatures than the controls on both November 7 and 8. Herbicide-treated plants which also received kaolinite treatment were generally associated with lower leaf temperatures than those that only received herbicide treatment (Table 2).

TABLE 2

Leaf temperature of soybean leaves treated with koalinite leaf reflectant treatment, atrazine, and picloram.

		Leaf Temperature of Soybean Plants			
		7 Nov.		8 Nov.	
Herbicide	Rate µg/g	Kaolinite treated	Untreated	Kaolinite treated	Untreated
		(°C)			
Control	--	24.4a*	25.5b	26.5a	27.7c
Atrazine	0.10	25.4b	26.9f	27.2b	29.0f
	0.40	26.0c	27.8h	29.9i	29.3g
Picloram	0.0005	26.2d	27.3g	28.1d	29.7h
	0.30	26.4e	27.9h	28.4e	30.1j

*Means pertaining to a particular date followed by a different letter are significantly different a 5% level using Duncan's Multiple Range Test.

TABLE 3

Effect of atrazine concentration and kaolinite leaf reflectant treatment on soybean dry weight reduction.

	Dry weight reduction	
Rate	Kaolinite treated	Untreated
(µg/g)	(% reduction from control)	
0.01	19.7a*	32.4bcd
0.05	22.4ab	39.4cdef
0.10	29.9abc	47.2efg
0.20	35.5cde	53.5ghi
0.30	42.7defg	59.1hi
0.40	50.8fgh	64.6i

*Means followed by the same letter do not differ significantly at the 5% level using Duncan's Multiple Range Test.

Soybean dry weight was reduced less by atrazine treatment with reflectant than without at each level of atrazine (Table 3). The calculated GR_{50} for atrazine was 0.38 and 0.16 µg/g for reflectant treated and non-reflectant treated plants, respectively. Leaf reflectant treatment also reduced picloram injury to soybeans at each picloram rate (Table 4). The GR_{50} for picloram was 0.03 µg/g for the non-reflectant treated plants. GR_{50} for the reflectant treated plants was greater than the highest concentration employed in this study.

It has been well established that the phytotoxicity of root-absorbed herbicides increases with increased transpiration rate (MINSHALL 1954, OORSCHOT 1970). The increased albedo from the kaolinite leaf treatments caused a decrease in phytotoxicity in this research by decreasing leaf temperature and transpiration rate. If this relationship between crop albedo and herbicide phytotoxicity holds true under field conditions, it could be a factor in herbicide selectivity in crop plants. This could be tested with use of isolines that differ only in leaf color. Golden isolines of barley, for example, have been found to reflect 3.5 to 6% more solar radiation than normal green plants, with corresponding reduction of canopy temperature of 1 to 2 C (AASE 1971, FERGUSON et al. 1973). The relationship between crop albedo and phytotoxicity of root-absorbed herbicides merits further study as it can influence choice of crop varieties/cultivars in cases of probable crop injury due to herbicide persistence.

TABLE 4

Effect of picloram concentration and kaolinite leaf reflectant treatment on soybean dry weight reduction.

	Dry weight reduction	
Rate	Kaolinite treated	Untreated
(μg/g)	--------(% reduction from control)--------	
0.001	2.6a*	4.6a
0.003	14.6b	20.5bc
0.005	22.0bcd	29.6de
0.007	26.8cde	34.6efg
0.010	32.2fg	41.5h
0.030	37.8gh	50.0i

*Means followed by the same letter do not differ significantly at the 5% level using Duncan's Multiple Range Test.

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