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AN EVALUATION OF DIMETHYL SULFOXIDE AS A POSSIBLE ADJUVANT FOR SEVERAL HERBICIDES

Woodland Hurtt

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DEPARTMENT OF THE ARMY
Fort Detrick
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AN EVALUATION OF DIMETHYL SULFOXIDE AS A POSSIBLE ADJUVANT FOR SEVERAL HERBICIDES

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Plant Physiology Division
PLANT SCIENCES LABORATORIES

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ABSTRACT

Dimethyl sulfoxide (DMSO) and Tween 20 were compared as adjuvants for foliar applications of 1,1'-ethylene-2,2'-dipyridylium dibromide (diquat dibromide), 2-methoxy-3,6-dichlorobenzoic acid (dicamba), and 4-amino-3,5,6-trichloropicolinic acid (picloram) to bean plants growing under greenhouse or growth-chamber conditions. Inhibition of growth was the criterion of injury employed in evaluating these data.

Technical grade dicamba (22 µg per plant) without any adjuvant significantly reduced growth of Black Valentine beans ($P = 0.05$). No combination of dicamba plus Tween 20 or DMSO (10 to 80% v/v) significantly enhanced the phytotoxicity of dicamba above that of dicamba alone.

The effect of a commercial formulation of diquat alone and diquat plus 0.5 or 1.0% DMSO on growth of Red Kidney beans was not significantly different from the control because of the sublethal dose of herbicide applied. However, the addition of 5 or 10% DMSO caused an increase in phytotoxicity that was significantly different from either the control or diquat alone. The inflection point in the dose-response relationship occurred at the 20% level of DMSO. This rate of DMSO caused an approximate twofold increase in effect over that of the 5% rate of DMSO and resulted in a 90% inhibition of fresh weight production. Diquat plus 50% DMSO (the highest level employed) was the most phytotoxic treatment but it was not significantly different from the 20 and 30% rates of DMSO.

Various combinations of 0.5% Tween 20, 30% DMSO, and technical grade picloram (12 µg per plant) applied to Black Valentine beans showed that both adjuvants significantly increased the effectiveness of picloram. DMSO, however, offered no advantage over Tween 20. An increase in effect was observed with the three-way combination of picloram plus DMSO plus Tween 20 but it was not significantly better than picloram plus either adjuvant alone when dry weight production was used as a more conservative indicator of plant injury.

I. INTRODUCTION

Studying the influence of adjuvants on the phytotoxicity of herbicides should be part of the continuous search for ways to improve the efficacy of herbicides by making them more phytotoxic or expanding their spectrum of kill. An increase in phytotoxicity is especially desirable since this would make it possible to reduce the rate of application. Assuming an approximately equal rate of loss caused by degradation, volatility, leaching, and soil fixation, it should follow that any potential residue in crops and soil would be reduced by the same factor that the application rate was reduced. If such an assumption of linearity proved to be false, it would nevertheless follow that a reduction in rate of application would result in some degree of reduction in residue levels. Surfactants, however, do not always enhance the effect of herbicides; there are situations in which adjuvants have interacted with a given herbicide and resulted in either no increase in effect or a decrease in effect.

This study was carried out to explore the potential of dimethyl sulfoxide (DMSO) as an adjuvant for two representative auxin-type herbicides and one contact herbicide.

II. METHODS AND MATERIALS

A surfactant (Tween 20) or dimethyl sulfoxide (DMSO) was added to 2-methoxy-3,6-dichlorobenzoic acid (dicamba), 1,1'-ethylene-2,2'-dipyridylium dibromide (diquat dibromide), and 4-amino-3,5,6-trichloropicolinic acid (picloram) to determine their effect on the phytotoxicity of these herbicides to bean plants (*Phaseolus vulgaris* L. var. Black Valentine or Red Kidney) growing in soil under greenhouse or growth-chamber conditions. Each adjuvant was not studied with each herbicide, but in some instances the two adjuvants were used with one herbicide.

The plants that were treated in growth chambers were germinated in 1-quart pots of soil under greenhouse conditions and moved to a growth chamber maintained at 24±1 C, 50±10% RH, and 1,400±150 ft-c with a 16-hour day. The light source was a mixture of cool-white fluorescent lamps and incandescent bulbs. Plants treated in the greenhouse remained under greenhouse conditions for the entire duration of the experiment.

When the plants were 14 days old the primary leaves were treated with ten 10-μl drops of technical grade dicamba, picloram, or a commercial formulation of diquat. At the end of each study, comparative phytotoxicities of the treatments were determined by one or several criteria such as fresh weight, oven-dry weight (95 C for a minimum of 48 hours), or plant height.

III. RESULTS AND DISCUSSION

Black Valentine beans growing in soil were treated with 100 μl of 0.5% Tween 20 plus 10, 40, or 80% DMSO; 10^{-3} M dicamba (22 μg) without adjuvants; dicamba plus 0.5% Tween 20; and dicamba plus 0.5% Tween 20 plus 10, 20, 30, 40, 60, or 80% DMSO. DMSO with Tween 20 did not significantly reduce height (Table 1). The addition of Tween 20 or DMSO to dicamba did not cause a significant difference in height reduction from the plants treated with dicamba without adjuvants. Ten or 80% DMSO with Tween 20 caused a significant reduction in dry and fresh weight when compared with the control. Eighty per cent DMSO, from a statistical standpoint, caused as much reduction in fresh weight as dicamba alone, dicamba with Tween 20, or dicamba with 30, 40, 60, or 80% DMSO with Tween 20. The fresh weight of plants treated with dicamba alone and those treated with dicamba and all levels of DMSO did not differ significantly. Plants treated with 10% DMSO plus 0.5% Tween 20, dicamba alone, dicamba plus 0.5% Tween 20, or dicamba plus 20, 40, 60, or 80% DMSO plus 0.5% Tween 20 did not have significantly different dry weights.

Fourteen-day-old Red Kidney beans growing in soil were treated under greenhouse conditions with 280 μg (cation equivalent) of commercially formulated diquat alone and with diquat plus various concentrations of DMSO. The fresh weight of the plants indicated that there was no significant difference between the control and diquat alone or diquat with 0.5 or 1.0% DMSO (Table 2). A low base line dose of diquat was chosen for this study so that any enhancing effect attributable to the adjuvant would be readily discernible. The addition of 5 or 10% DMSO effected an increase in phytotoxicity that was significantly different from either the control or diquat alone. Although these data were not plotted in the form of a dose-response curve, it is quite apparent in Table 2 that a sharp inflection in such a curve would occur at, or near, the 20% level of DMSO. This level of DMSO caused a 90% inhibition of fresh weight. For comparative purposes, the 5% level of DMSO caused a 46% inhibition of fresh weight. Thus, a fourfold increase in the level of the adjuvant resulted in a twofold increase in phytotoxicity. Although diquat plus the 50% rate of DMSO was the most phytotoxic treatment, it was not significantly different from the 20 and 30% rates of DMSO.

TABLE 1. PHYTOTOXICITY TO BLACK VALENTINE BEANS OF VARIOUS CONCENTRATIONS OF DMSO WITH 0.5% TWEEN 20, DICAMBA ALONE, AND DICAMBA WITH 0.5% TWEEN 20 AND DMSO

Treatment[a]	Height, cm[b,c]	Fresh Weight, g[c]	Dry Weight, g[c]
Control	56.4^{a}	21.63^{a}	3.37^{a}
10% DMSO	50.5^{a}	18.73^{bc}	2.72^{bc}
40% DMSO	50.0^{a}	19.85^{ab}	3.07^{ab}
80% DMSO	51.2^{a}	18.60^{bcd}	2.90^{b}
Dicamba alone	22.2^{b}	17.91^{bcde}	2.34^{c}
Dicamba + Tween 20	20.9^{b}	17.12^{cde}	2.09^{cd}
Dicamba + 10% DMSO	20.4^{b}	15.28^{e}	1.91^{d}
Dicamba + 20% DMSO	22.7^{b}	15.86^{e}	1.96^{cd}
Dicamba + 30% DMSO	24.1^{b}	15.99^{de}	1.92^{d}
Dicamba + 40% DMSO	19.6^{b}	16.24^{cde}	1.96^{cd}
Dicamba + 60% DMSO	21.5^{b}	16.00^{de}	2.19^{cd}
Dicamba + 80% DMSO	24.1^{b}	16.35^{cde}	2.12^{cd}

a. Each primary leaf was treated with five 10-μl drops of solution, for a total treatment of 100 μl per plant. All treatments except dicamba alone contained 0.5% Tween 20. The dicamba solutions were 10^{-2} M and dosage per plant was 22 μg.

b. All measurements were taken above the cotyledonary node and are the mean of 10 replications.

c. Means in columns with identical superscript letters are not significantly different at the 0.05% level.

TABLE 2. EFFECT OF VARIOUS CONCENTRATIONS OF DMSO ON THE PHYTOTOXICITY OF DIQUAT TO RED KIDNEY BEANS GROWN IN SOIL

Treatment[a]	Fresh Weight, g[b,c]
Control	7.34[a]
Diquat alone	6.53[a]
Diquat + 0.5% DMSO	5.79[ab]
Diquat + 1.0% DMSO	5.12[ab]
Diquat + 5.0% DMSO	3.99[b]
Diquat + 10.0% DMSO	3.41[b]
Diquat + 20.0% DMSO	0.71[c]
Diquat + 30.0% DMSO	0.79[c]
Diquat + 50.0% DMSO	0.61[c]

a. Five 10-μl drops of solution were applied to each primary leaf, for a total treatment of 280 μg diquat per plant.
b. Average of five replications.
c. Means with identical superscript letters are not significantly different at the 0.05% level.

Black Valentine beans were treated in the growth chamber with ten 10-μl drops of 30% DMSO, 30% DMSO plus 0.5% Tween 20, 5×10^{-4} M picloram (12 μg), picloram plus 0.5% Tween 20, picloram plus 30% DMSO, or picloram plus 30% DMSO and 0.5% Tween 20. These data are shown in Table 3. Both adjuvants significantly increased the phytotoxicity of picloram. The reduction of growth in height was especially pronounced. As an adjuvant, DMSO was not significantly better than Tween 20 by any of the three criteria employed to assess plant injury. The three-way combination of picloram plus DMSO plus Tween 20 was the most phytotoxic treatment, but it was not significantly better than picloram plus Tween 20.

TABLE 3. PHYTOTOXICITY TO BLACK VALENTINE BEANS OF PICLORAM PLUS ALL COMBINATIONS OF 30% DMSO AND 0.5% TWEEN 20

Treatment[a]	Height, cm[b,c]	Fresh Weight, g[c]	Dry Weight, g[c]
Control	44.8^{ab}	16.91^{a}	2.06^{ab}
DMSO	47.0^{a}	16.40^{a}	2.00^{ab}
DMSO + Tween 20	40.1^{b}	15.51^{a}	1.83^{b}
Picloram	40.2^{b}	17.68^{a}	2.17^{a}
Picloram + Tween 20	16.9^{c}	11.80^{bc}	1.21^{c}
Picloram + DMSO	17.5^{c}	12.94^{b}	1.42^{c}
Picloram + DMSO + Tween 20	15.8^{c}	10.04^{c}	1.20^{c}

a. Five 10-µl drops of solution were applied to each primary leaf, for a total treatment of 100 µl per plant.
b. Average of five replications.
c. Means with identical superscript letters are not significantly different at the 0.05% level.

IV. CONCLUSIONS

The adjuvants, alone or combined, did not significantly enhance the phytotoxicity of dicamba as measured by height or fresh weight.

Of various levels of DMSO added to diquat, 20% DMSO was the optimum concentration and further increases beyond 20% resulted in little or no further increase in phytotoxicity. All levels of DMSO above 1% were significantly better than diquat alone.

Both Tween 20 and DMSO significantly increased the phytotoxicity of picloram. A slight increase in phytotoxicity was obtained when both DMSO and Tween 20 were applied with picloram.

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13. ABSTRACT

Dimethyl sulfoxide (DMSO) and Tween 20 were compared as adjuvants for foliar applications of 1,1'-ethylene-2,2'-dipyridylium dibromide (diquat dibromide), 2-methoxy-3,6-dichlorobenzoic acid (dicamba), and 4-amino-3,5,6-trichloropicolinic acid (picloram) to bean plants growing under greenhouse or growth-chamber conditions. Inhibition of growth was the criterion of injury employed in evaluating these data.

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Various combinations of 0.5% Tween 20, 30% DMSO, and technical grade picloram (12 μg per plant) applied to Black Valentine beans showed that both adjuvants significantly increased the effectiveness of picloram. DMSO, however, offered no advantage over Tween 20. An increase in effect was observed with the three-way combination of picloram plus DMSO plus Tween 20 but it was not significantly better than picloram plus either adjuvant alone when dry weight production was used as a more conservative indicator of plant injury.

14. Key Words

Dimethyl sulfoxide
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Herbicides
Tween 20
Dicamba
Picloram
Diquat
Phytotoxicity