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WEED SCIENCE

The Influence of Malathion on Trifloxysulfuron Absorption and Translocation in Cotton

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ABSTRACT

Multiple crop protection pesticides are frequently applied as a tank-mixture for control of a variety of pests in cotton (*Gossypium hirsutum*). Although chemicals generally act independently, an interaction may occur that can be either beneficial or detrimental to the target crop. The objective of this research was to evaluate the effects of malathion on the absorption and translocation of foliar-applied ^{14}C-trifloxysulfuron (Envoke; Syngenta Crop Protection, Inc.; Greensboro, NC) over a period of 0.25 to 96 h after treatment (HAT) in cotton. Laboratory studies were conducted using ^{14}C-labeled trifloxysulfuron applied alone and in combination with malathion. Greater absorption of radiolabeled trifloxysulfuron occurred in leaves 4 HAT treated with trifloxysulfuron tank-mixed with malathion compared to those treated with trifloxysulfuron alone at the 3-to 4-leaf stage. Translocation of trifloxysulfuron to plant tissue above and below the treated leaf was greater with the tank-mixture. However, increased foliar phytotoxicity (leaf burning) was observed 24 and 96 HAT with trifloxysulfuron tank-mixed with malathion compared to trifloxysulfuron applied alone. These studies suggest malathion could potentially reduce the rate of trifloxysulfuron metabolism in cotton.

INTRODUCTION

Trifloxysulfuron is a sulfonylurea herbicide labeled for postemergence (POST) weed control in cotton (*Gossypium hirsutum*), turf, and sugarcane (*Saccharum officinarum* L.). Trifloxysulfuron applied over-the-top (OT) of cotton at 5 g ha^{-1} is reported to provide control of sicklepod (*Senna obtusifolia* L.), ivyleaf morningglory [*Ipomoea hederacea* (L.) Jacq.], pitted morningglory (*Ipomoea lacunosa* L.), yellow nutsedge (*Cyperus esculentus* L.), common cocklebur (*Xanthium strumarium* L.) and seedling johnsongrass (*Sorghum halepense* L.) (Holloway et al., 2000).

The use of multiple crop protection pesticides is often needed for control of a variety of pests in cotton. Although chemicals generally act independently, an interaction may occur that can be either beneficial or detrimental to the target crop. These effects can be further characterized as synergistic, antagonistic, or additive (Colby, 1967; Flint et al., 1988).

The addition of phosphorus to the soil has been shown to reduce diuron toxicity to cotton and Italian ryegrass (*Lolium multiflorum* Lam.) (Bingham and Upchurch, 1959). The organophosphate insecticides phorate and disulfoton applied in-furrow have been shown to interact with monuron and diuron resulting in severe cotton injury (Hacskaylo et al., 1964; Nash, 1967). Nash stated that three possibilities of pesticide interaction may occur. These can occur either at the site of absorption where one pesticide affects the absorption of the other, within the plant in which one pesticide affects the primary and another pesticide affects a secondary pathway, or both jointly affect a single pathway. Increased rice injury occurred from propanil mixed with certain organophosphate insecticides such as malathion (Bowling and Hudgins, 1966). The insecticides interfered with propanil metabolism in rice through the inhibition of the enzyme aryl acylamidase (Matsunaka, 1968). In contrast, cotton seedlings were safened from clomazone applied preemergence when either disulfoton or phorate was applied in-furrow (Hartfield and Mitchell, 1992; York et al., 1991). Miller et al. (2005) reported that trifloxysulfuron control of several broadleaf weeds may be reduced when tank-mixed with the organophosphate insecticide acephate.

In the early 1990's, increased corn injury was observed with primisulfuron (Holshouser et

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al., 1991; Biediger et al., 1992) and nicosulfuron (Morton et al., 1991; Kapusta and Krausz, 1992; Bailey and Kapusta, 1994) applied to corn treated with the organophosphate insecticide terbufos applied in-furrow at planting. The 15 G formulation of terbufos resulted in more corn injury following a nicosulfuron treatment than the 20 CR formulation (Diehl and Stoller, 1995; Morton et al., 1994). Frazier et al. (1993) reported terbufos did not affect primisulfuron absorption and translocation but the half-life of primisulfuron was increased from 2 to 3.5 h in the terbufos treatments.

Pyrithiobac applied in a tank-mixture with the organophosphate insecticide malathion resulted in greater cotton injury than pyrithiobac alone (Allen and Snipes, 1995). The injury was more severe under a cool environment compared to a warm environment (Allen and Snipes, 1995). Previous research evaluating trifloxysulfuron tank-mixed with seven different cotton insecticides indicated greater cotton injury only from malathion (Minton et al., 2005). However, pyrithiobac and trifloxysulfuron applied 24, 8, 4, 2, 1, 0.5 and 0 h before and after an ultra-low volume application of malathion did not result in cotton injury (Bloodworth et al., 2000; File et al., 2001). The difference from previous research was attributed to the use of ultra-low application volume rather than standard ground application volumes, and a sequential application instead of tank-mixed applications.

Field research indicates increased cotton phytotoxicity with trifloxysulfuron tank-mixed with malathion (Minton et al., 2005). The objective of this research was to evaluate the effects of malathion on the absorption and translocation of trifloxysulfuron in cotton.

MATERIALS AND METHODS

Laboratory studies were conducted in 2000 using formulated and radiolabeled trifloxysulfuron provided by Syngenta Crop Protection (Envoke; Syngenta Crop Protection, Inc.; Greensboro, NC). The (pyridinyl-2-^{14}C) trifloxysulfuron had specific activity of 1724 kBq mg^{-1} and radiochemical purity of 97%. The formulated trifloxysulfuron and malathion (Malathion; Southern Agricultural Insecticides, Inc.; Hendersonville, NC) used were 75WDG and 4.4 EC, respectively.

DP 50 (Delta and Pine Land Co.; Scott, MS) cotton seed were planted in 950-ml plastic cups with Redi-Earth potting soil (Scotts-Sierra Hort Products Co; Marysville, OH) and thinned to one plant per cup 14 days after planting (DAP). Plants were grown in the laboratory under natural light supplemented with metal halide lamps (650 µ mol m^2 s^{-1} photon flux) for a 12-h photoperiod for 28 d then transferred to a growth chamber with a constant temperature of 27 C and 12-h photoperiod. Plants were watered daily and a complete fertilizer (Miracle-Gro, Inc.; Port Washington, NY) solution was applied 14 and 28 DAP to maintain active growth. Postemergence (POST) applications of formulated product of either trifloxysulfuron at 7.5 g ha^{-1} or at 7.5 g ha^{-1} tank-mixed with malathion at 1.3 kg ha^{-1} were applied to uniform 4- to 5-leaf plants 36 DAP. Formulated product applications were made with a CO_2 handheld sprayer delivering 187 L ha^{-1} of water at 252 kPa pressure through a flat-fan spray tip (TeeJet 8003; Spraying Systems Co.; Wheaton, IL) and included a non-ionic surfactant (X-77 Spreader; Loveland Industries; Greenley, CO) at 0.25% (v/v).

Immediately following application of the formulated products, 5 µl of ^{14}C-labeled trifloxysulfuron solution was applied in four 1-µl drops to the adaxial leaf surface of the third oldest leaf of each plant. The 5-µl solution contained 1.3 kBq of ^{14}C- trifloxysulfuron with a nonionic surfactant at 0.25% (v/v). Plants were maintained in a growth chamber until harvest.

Plants were severed at the soil surface 0.25, 4, 8, 24, and 96 h after treatment (HAT) of radiolabeled trifloxysulfuron. The above ground portion of the plants was sectioned into the treated leaf, plant material above the treated leaf, and plant material below the treated leaf. The treated leaves were rinsed in 12 ml of deionized water for 1 min to remove unabsorbed radioactivity. Treated leaves were allowed to dry then rinsed in 12 ml of 1:1 of water:methanol for 1 min to remove radioactivity absorbed in the leaf cuticle. A 1-ml aliquot of each leaf rinse was added to 5.5 ml of scintillation fluid (R.J. Harvey Instrument Corporation; Hillsdale, NJ) and radioactivity was quantified by liquid scintillation spectrometry (LSS) (Beckman Instruments, Inc.; Fullerton, CA). Harvested plant parts were dried at 50 C for 48 h and weighed. Plant parts were ground and 0.1 g of the material was combusted in a biological sample oxidizer (R.J. Harvey Instrument Corporation; Hillsdale, NJ) and radioactivity trapped as $^{14}CO_2$ was quantified by LSS. Radioactivity from leaf rinses and plant parts was expressed as a percentage of the total applied. Prior to the 24 and 96 h harvest intervals, treated cotton plants were visually rated for phytotoxicity on a scale of 0 (no injury) to 100 (plant death).

The study design was completely randomized with three replications and the experiment was repeated. Trial effects were not significant, therefore data were pooled over the experiment. Data were subjected to analysis of variance using the general linear models procedure of the Statistical Analysis System (version 8.02; SAS Institute Inc.; Cary, NC).

RESULTS AND DISCUSSION

Recovery of radioactivity was > 93% for all treatments (Table 1). The amount of unabsorbed trifloxysulfuron decreased from 91 to 92% at 15 min after treatment to 66 to 67% 48 HAT. The addition of malathion did not affect trifloxysulfuron on the leaf surface for most treatments. However, 4 HAT trifloxysulfuron alone had 91.9% unabsorbed solution remaining on the leaf surface as compared to 85.7% of trifloxysulfuron plus malathion. Askew and Wilcut (2002) reported that 70% of trifloxysulfuron applied to cotton remained unabsorbed when averaged over 4, 24, and 72 h. Kreuz and Fonne'-Pfister (1992) observed similar results with primisulfuron and malathion in corn. The absorption of ^{14}C-primisulfuron 24 HAT was 21.3 $\pm$ 3.2% in the absence and 24.9% $\pm$ 3.5% in the presence of malathion. Similar or higher levels of primisulfuron and nicosulfuron absorption in various plant species has occurred in other studies (Obrigawitch et al., 1990; Simpson et al., 1994; Manley et al., 1999; Gallaher et al., 1999).

Trifloxysulfuron in the treated leaf 24 and 96 HAT was significantly greater when applied alone compared to when applied with malathion. Also, more trifloxysulfuron was found in the plant tissue

Table 1. Distribution of ^{14}C- trifloxysulfuron and ^{14}C- trifloxysulfuron plus malathion at different time intervals following application to cotton plants.[z]

Treatment	TL[y] water wash	TL methanol wash	TL	Plant above TL	Plant below TL	Total % applied
	0.25 hour after treatment					
	% of applied[x]					
trifloxysulfuron	91.8	3.8*	1.3	0.4	0.3	97.6
trifloxysulfuron + malathion	90.5	2.4*	2.1	0.1	0.4	95.5
	4 hours after treatment					
	% of applied[x]					
trifloxysulfuron	91.9*	3.2	2.8	0.3	0.2	98.4
trifloxysulfuron + malathion	85.7*	4.7	3.4	0.1	0.5	94.4
	8 hours after treatment					
	% of applied[x]					
trifloxysulfuron	81.6	3.4	9.2	0.2	0.3*	94.7
trifloxysulfuron + malathion	82.3	3.8	8.5	0.1	2.5*	97.2
	24 hours after treatment					
	% of applied[x]					
trifloxysulfuron	74.0	2.8	16.3*	0.3	0.4*	93.8
trifloxysulfuron + malathion	74.9	3.1	12.0*	0.8	1.5*	92.3
	96 hours after treatment					
	% of applied[x]					
trifloxysulfuron	66.9	3.1	22.3*	0.6*	0.6*	93.5
trifloxysulfuron + malathion	66.1	3.0	19.7*	2.4*	2.4*	93.6

[z] Means followed by asterisks are significantly different at the 0.05 level of probability.

[y] TL=Treated leaf.

[x] Percent of applied was based on 95.1% of ^{14}C trifloxysulfuron recovered.

below the treated leaf with the tank-mixture at 8, 24, and 96 HAT. This resulted in 1.5 to 2.4% of the total recovered trifloxysulfuron being translocated to the plant tissue below the treated leaf with the malathion combination compared to 0.3 to 0.6% without malathion. Greater translocation of trifloxysulfuron to the plant tissue above the treated leaf occurred in the presence of malathion at 96 HAT. Simpson et al. (1994) determined that translocation of absorbed nicosulfuron out of the treated corn leaf was less than 5%. Other studies showed that 20 to 44% of absorbed nicosulfuron was translocated in johnsongrass and smooth pigweed (Obrigawitch et al,. 1990; Manley et al., 1999). Manley et al. (1999) stated that translocation could be a contributing factor to nicosulfuron selectivity since this herbicide did not translocate in tolerant corn but was partitioned out of the treated leaf in susceptible pigweed and johnsongrass. Weierich et al. (1977) reported increased translocation of terbacil in peppermint (*Mentha piperita* L.) leaves when the organophosphate insecticide fonofos was applied. Other research demonstrated that malathion did not influence the absorption and translocation of thifensulfuron in soybeans and corn (Ahrens and Panaram, 1997). Metabolism of thifensulfuron was reduced with malathion and there was a synergistic increase in injury to soybeans and corn.

Increased foliar phytotoxicity (leaf burning) was observed 24 and 96 HAT with trifloxysulfuron tank-mixed with malathion compared to trifloxysulfuron applied alone (Table 2). Porterfield et al. (2002) reported trifloxysulfuron at 7.5 g ha^{-1} caused 7 to 9% injury to seven different cotton cultivars 1 to 2 wk after treatment. The increased translocation of the radiolabeled trifloxysulfuron with the tank-mixture may have occurred due to injury to the plant cuticle and greater movement of material into the leaf. Previous research indicates reduced metabolism of sulfonylurea herbicides by many plant species in the presence of organophosphate insecticides (Christopher et al., 1994; Frazier et al., 1993; Kreuz and Fonne'-Pfister, 1992).

Table 2. Effect of trifloxysulfuron and trifloxysulfuron tank-mixed with malathion on cotton phytotoxicity.[z]

Treatment[y,x]	Rate	Phytotoxicity 24 HAT[w]	Phytotoxicity 96 HAT
	g/ha	%	%
trifloxysulfuron	7.5	3*	4*
trifloxysulfuron + malathion	7.5 1289	8*	14*

[z] Means followed by asterisks are significantly different at the 0.05 level of probability.

[y] All treatments applied with 0.25% v/v nonionic surfactant.

[x] Trifloxysulfuron 75 WG, malathion 4.4 EC.

[w] HAT-hours after treatment.

CONCLUSIONS

These studies suggest malathion tank-mixed with trifloxysulfuron increases cotton injury and could potentially reduce the rate of trifloxysulfuron metabolism in cotton. However, additional metabolism studies would be required to confirm this possibility.

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