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EFFECTS OF WEED DENSITY, HERBICIDE ANTIDOTES, AND SOIL ADSORPTION ON HERBICIDE BIOACTIVITY

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EFFECTS OF WEED DENSITY, HERBICIDE ANTIDOTES,
AND SOIL ADSORPTION ON HERBICIDE BIOACTIVITY.

by

Mark E. Winkle

A DISSERTATION

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TITLE

Effects of Weed Density, Herbicide Antidotes, and Soil

Adsorption on Herbicide Bioactivity

BY

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A. Effects of Weed Density on Herbicide Uptake and Bioactivity

Abstract. Effects of differential weed densities on herbicide bioactivity and uptake by plants were examined in greenhouse and field research. Experiments were conducted to compare the bioactivity of atrazine [2-chloro-4-(ethylamino)-6-(isopropylamino)-s-triazine] on white mustard (Brassica hirta Moench) planted at various densities and alachlor [2-chloro-2',6'-diethyl-N-(methoxymethyl)acetanilide] on foxtail millet [Setaria italica (L.) Moench] planted at various densities. Increasing concentrations of atrazine and alachlor were required to produce equivalent fresh weight reductions at increasing densities of white mustard and foxtail millet. As seeding rate increased the rate of ^{14}C-herbicide absorbed per plant decreased at each application rate of both herbicides. Uptake of ^{14}C-alachlor by foxtail millet seedlings germinating in petri dishes increased at higher alachlor concentrations and decreased at increased seeding rates. Field experiments conducted in 1977 and 1979 showed that high versus low 'Rox Orange' forage sorghum [Sorghum bicolor (L.) Moench] densities required more alachlor for equivalent weed control in corn. EPTC (S-ethyl dipropylthiocarbamate) plus R-25788 (N,N-diallyl-2,2-dichloroacetamide) was more effective than alachlor or metolachlor [2-chloro-N-(2-ethyl-6-methylphenyl)-N-(2-methoxy-1-methylethyl)acetamide] in controlling Rox Orange. At the highest weed densities used, alachlor decreased Rox Orange plant population but not yield, indicating the plastic reaction of individual plants to population density causing constant final yield at high densities.

Introduction

Kira et al. (4,5) reported that the plastic reaction of individual plants to increasing density may exactly compensate for an increasing number of plants per unit area to give a constant final yield. In other words, as the number of plants per unit area increased, plant yield decreased so that the yield per unit area tends to remain constant. This relationship was observed earlier by Wiggins (7) in narrow row soybean production. Harper and Gajic (2) reported that due to intraspecific competition in *Agrostemma*, the seed weight decreased as *Agrostemma* population increased.

More recently, Hoffman and Lavy (3) demonstrated in greenhouse research that oats (*Avena sativa* L.) and soybeans [*Glycine max* (L.) Merr.] were less sensitive to atrazine at high versus low plant populations. In a ^{14}C-labeled atrazine study, herbicide uptake per plant was decreased 50% by increasing the soybean population from one to six plants per pot. They concluded that herbicide rates for optimum weed control may have to be increased with increasing weed populations.

Burrill and Appleby (1) demonstrated under greenhouse and microfield conditions that control of Italian ryegrass (*Lolium multiforum* Lam.) decreased with diuron [3-(3,4-dichlorophenyl)-1,1-dimethylurea] as plant density increased. Greenhouse research showed that dry-weight reduction from 0.6 ppmw of diuron decreased from 88 to 35% as the density of Italian ryegrass increased from 10 to 100 plants per pot. They theorized that less herbicide was available for each plant as population increased. Both Hoffman and Lavy (3) and Burrill and Appleby (1) used a root absorbed herbicide.

Objectives of this research were to test the hypothesis that weed density could affect herbicide bioactivity in the greenhouse and field

with either a root absorbed or a shoot absorbed herbicide, to measure the effects of weed population on herbicide absorption per plant in greenhouse and laboratory studies, and to investigate the plasticity of final yield in the field.

Materials and Methods

General bioassay procedure. White mustard and foxtail millet were selected to represent broadleaf and grass weeds, respectively. Plants were grown in 10 cm polyethylene pots which contained 450 g of Sharpsburg silty clay loam (sicl). The soil was air-dried and sieved through a 2 mm screen. Atrazine, a root uptake herbicide and alachlor, a shoot uptake herbicide were utilized in all bioassay experiments. Herbicide treatments used in the bioassays were applied to the soil in a paper bag with methanol as a carrier. Methanol was allowed to evaporate 2 to 3 h before the herbicide was incorporated into the soil by inverting each bag 20 times. Atrazine treatments were applied to the entire soil volume; whereas, alachlor treatments were applied only to the top 1/4 of the soil volume. All pots were watered by alternate surface watering and subirrigation. Bioassays were conducted in a fiberglass greenhouse maintained at 27 $\pm$ 4 C. Supplementary lighting provided a day length of 14 h of 150 uEinsteins $m^{-2}s^{-1}$ photosynthetically active irradiance.

The experimental design was a randomized complete block with three replications. Each experiment was repeated at least twice. Analyses of variance were computed on all data. Differences among treatments were tested with Duncan's multiple range tests at the 0.05% level of significance.

Greenhouse bioassay. White mustard was seeded at densities of 1, 10, and 50 seeds/pot, and foxtail millet was seeded at 10, 20, 80, and 320

seeds per pot into Sharpsburg sicl. Preliminary studies indicated a 90% germination rate for both plant species. As a result, white mustard and foxtail millet were overplanted 10% and were thinned to the appropriate density at lower seeding rates. Atrazine and alachlor were tested for bioactivity to white mustard and foxtail millet, respectively. Atrazine concentrations were 0, 0.1, 0.2, 0.4, and 0.8 ppmw. Alachlor concentrations were 0, 0.2, 0.4, 0.8, and 1.0 ppmw. Plant yields were determined after the 30 day period by harvesting the top-growth. Fresh weight yields were recorded for each pot.

^{14}C-uptake. Trace amounts of ^{14}C-ring labeled atrazine and alachlor were used to study seedling absorption of the herbicides by foxtail millet and white mustard, respectively. Specific activities of the ring-labeled herbicides were 8.0 and 24.9 uCi/mg for alachlor and atrazine, respectively. Both labeled herbicides had a radiochemical purity of 98%. Labeled herbicide at 2.3×10^{-1} uCi was added to individual pots with the appropriate cold herbicide. Final atrazine and alachlor treatment concentrations were 0.4 and 0.8 ppmw for both plant species. Foxtail millet was seeded at densities of 20 and 80 seeds per pot and white mustard was seeded at 5 and 25 seeds per pot. Both plant species were grown in a 5 cm polyethylene pot containing 170 g of Sharpsburg sicl for 21 days. All top-growth above the soil surface in each pot was harvested, weighed, and placed in a small coin bag. Soil was then washed away from root portions of plants. These roots were then combined, weighed, and also placed in separate bags. All plant samples were dried in a 100 C oven for 48 h. Dried plant samples were pellatized and subsequently combusted by an automatic sample oxidizer prior to liquid scintillation analysis. Each sample was counted for 10 minutes or 100,000 counts using a liquid scintillation counter. Root and shoot data were combined and expressed

as total uptake per plant. Total disintegrations per minute (dpm) absorbed were determined for each seeding rate. Subsequent analysis of herbicide uptake per seedling was then calculated.

^{14}C-petri dish study. Ring labeled ^{14}C-alachlor was used to study uptake per seedling by foxtail millet at three densities in two studies. Foxtail millet densities were 5, 10, and 50 seeds/petri dish. Labeled alachlor at 1.8 uCi was added with the appropriate herbicide concentration to each petri dish in 8 ml of aqueous solution. Petri dishes with the appropriate alachlor-foxtail millet combination were grown in a seed germinator maintained between 22 and 30 C. Supplementary lighting provided a day length of 14 h in the range of 5 uEinsteins $m^{-2}s^{-1}$ photosynthetically active irradiance. This study measured the daily uptake of ^{14}C-labeled alachlor (1.2 ppm) by foxtail millet at densities of 5, 10, and 50 seeds/dish. Preliminary studies showed no differences in either root or shoot length after 7 days for foxtail millet seedlings grown at 5, 10, and 50 seedlings/petri dish at 1.2 ppm alachlor concentration. Seedlings were harvested daily for 7 days, washed with distilled water, and dried in a 100 C oven for 48 h. Dried seedlings were pellatized and subsequently combusted by a sample oxidizer prior to liquid scintillation analysis. All data were expressed as nanograms of alachlor taken up per seed.

Both petri dish studies were a completely randomized design with three replications. Each experiment was repeated three times.

1977 field research. Field research, conducted at the Lincoln Agronomy Farm, was undertaken to study the control of several Rox Orange forage sorghum densities in corn using an acetanilide herbicide on a Sharpsburg sicl. Rox Orange was used because seed is available and it

is virtually identical in growth habit and competitiveness to shattercane [Sorghum bicolor (L.) Moench] a problem weed in Nebraska (6). Rox Orange was uniformily seeded at densities of 0, 1,000, 10,000, and 100,000 seeds per 71 m^2 plot area. Rox Orange was then incorporated by shallow tandem discing and harrowing. Germination was greater than 69% for the 100,000 seeds per 71 m^2 plot and 82% for the Rox Orange seeding rates less than 10,000. A blanket treatment of atrazine at 2.2 kg/ha was applied to keep the broadleaf population at a minimum. Formulated alachlor was applied at rates of 0, 1.7, 3.4, and 6.7 kg/ha. Herbicide treatments were applied with a tractor sprayer which delivered 187 L/ha at 2.1 kg/cm^2 pressure. Plot area was then tandem disced to incorporate the herbicide and prepare a seedbed. 'NB-611' corn was then planted in 76 cm rows at 43,250 plants/ha. Rox Orange stand, Rox Orange yield, and corn grain yield were subsequently taken. The experimental design was a randomized complete block with four replications.

1979 field research. In 1979, a field study similar to that described in 1977 was conducted with the following changes: Metolachlor another acetanilide herbicide, was tested at 0, 1.7, 3.4, and 6.7 kg/ha in addition to alachlor at the same rates; EPTC + R-25788 was tested at 2.4, 4.8, and 9.6 kg/ha; a seeding rate of 50,000 Rox Orange seed per plot was added; plot size was reduced from 71 m^2 to 57 m^2; and corn forage yield rather than grain yield was determined. Due to early competitive effects of Rox Orange on corn, actual corn seed yield would have been difficult to obtain at the 50,000 and 100,000 seeding rate.

Results and Discussion

Greenhouse bioassay. Fresh weight of white mustard at the 1 and 10 plants/pot seeding rates decreased as atrazine concentrations increased

(Figure A1). At the 50 plant/pot seeding rate, fresh weight increased from 0 to 0.2 ppmw atrazine and decreased thereafter. A significant reduction in mustard fresh weight resulted when no atrazine was applied as the seeding rate increased from 1 to 50 seeds/pot indicating severe interplant competition. At the 0.2 ppmw concentration of atrazine, white mustard fresh weight was significantly greater for the 50 than for the 10 or 1 seeding rate. At the atrazine concentration of 0.4 ppmw, white mustard fresh weight was significantly higher for the 10 and 50 plant/pot seeding rate than for the 1 plant/pot seeding rate. Fresh weight of all white mustard seeding rates was reduced to virtually 0 at the highest atrazine concentration of 0.8 ppmw (Figure A1).

Fresh weight, expressed in grams/pot, of four foxtail millet densities was statistically identical for all seeding rates at the zero alachlor level but decreased as alachlor concentrations increased from 0 to 1.0 ppmw (Figure A2). At foxtail millet densities of 10, 20, and 80 seeds/pot, fresh weight of millet was reduced to the same statistical level. As the alachlor concentration increased to 0.8 ppmw, fresh weight of these three seeding rates were reduced to 0. At 320 seeds/pot, foxtail millet fresh weight was not significantly reduced until 0.4 ppmw as compared to the check plants. Foxtail millet fresh weight at this highest seeding rate was significantly greater than the fresh weight from the 10 and 20 seed/pot rate at all alachlor rates greater than zero and was significantly greater than the 80 seed/pot rate at 3 of the 4 rates greater than zero. No significant reduction in fresh weight was observed at the highest seeding rate as alachlor concentration increased from 0.4 to 1.0 ppmw (Figure A2).

In both greenhouse bioassays, herbicide bioactivity was dependent upon weed population. This agrees with Hoffman and Lavy's (3) research