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Physiological behavior of root-absorbed flumioxazin in peanut, ivyleaf morningglory (*Ipomoea hederacea*), and sicklepod (*Senna obtusifolia*)

Andrew J. Price
Corresponding author. National Soil Dynamics Laboratory, U.S. Department of Agriculture, Agricultural Research Service, 411 South Donahue Drive, Auburn, AL 36832; aprice@ars.usda.gov

John W. Wilcut
Department of Crop Science, North Carolina State University, Raleigh, NC 27695-7620

John R. Cranmer
Valent USA Corporation, Suite 250-3, 1135 Kildaire Farm Road, Cary, NC 27511

Previous research has shown that flumioxazin has the potential to cause peanut injury. In response to this concern, laboratory and greenhouse experiments were conducted to investigate the influence of temperature on germination of flumioxazin-treated peanut seed and the effect of interval between flumioxazin application and irrigation on peanut emergence and injury. Laboratory experiments using ^{14}C-flumioxazin were also conducted to investigate differential tolerance exhibited by peanut, ivyleaf morningglory, and sicklepod to flumioxazin. Flumioxazin treatments containing either water-dispersible granular or wettable powder formulation at 1.4 μmol L^{-1} did not influence germination compared with nontreated peanut across all temperature regimes (15 to 40 C). Peanut treated with either formulations of flumioxazin preemergence and receiving irrigation at emergence and 2 and 4 d after emergence were injured between 40 and 60%. Peanut treated at 8 and 12 d after emergence were injured between 25 and 15%, respectively. Total ^{14}C absorbed by ivyleaf mornigglory was 57% of applied whereas sicklepod absorbed 46%, 72 h after treatment (HAT). Peanut absorbed > 74% of applied ^{14}C 72 HAT. The majority of absorbed ^{14}C remained in roots of sicklepod, ivyleaf morningglory, and peanut at all harvest times. Ivyleaf morningglory contained 41% of the parent herbicide 72 HAT whereas sicklepod and peanut contained only 24 and 11% parent compound, respectively. Regression slopes indicated slower flumioxazin metabolism by ivyleaf morningglory (a susceptible species) compared with sicklepod and peanut (tolerant species).

Nomenclature: Flumioxazin; ivyleaf morningglory, [*Ipomoea hederacea* (L.) Jacq.] IPOHE; sicklepod, [*Senna obtusifolia* (L.) Irwin and Barneby] CASOB; peanut, *Arachis hypogaea* L. 'NC 10C'.

Key words: Absorption, translocation, metabolism.

Flumioxazin was registered for preemergence (PRE) use in peanut in 2001 (Anonymous 2002a, 2002b). Considerable peanut injury resulted in 2001 from flumioxazin usage in the mid-Atlantic and Southeast United States (D. L. Jordan, C. W. Swann, E. Prostko, personal communication). Because of this injury concern, the flumioxazin product formulation was changed in 2002 from a water-dispersible granule (WDG) to a wettable powder (WP), whereas percentage active ingredient remained unchanged (Anonymous 2002a, 2002b). The change in formulation was likely because of an untested hypothesis that injury was caused by the lack of water solubility of the WDG formulation and subsequent application of higher than the labeled amount of active ingredient to some plants. Current recommendations for usage in North Carolina peanut production suggest restricting hectarage treated with flumioxazin until complete understanding of injury potential (Jordan 2002).

Previous research has shown that flumioxazin has the potential to injure peanut (Askew et al. 1999; Burke et al. 2002; Wilcut et al. 2001). Burke et al. (2002) reported 50 to 67% peanut injury and reduced yield at one North Carolina location from flumioxazin. However, injury was less than 2% at two other locations within the same study and yields were unaffected. The authors of these studies hypothesized that injury was likely increased by cool, wet conditions at time of peanut emergence. Wilcut et al. (2001) reported little difference in peanut variety response to flumioxazin PRE; however, injury was significant (≥ 15%) in 1997. Scott et al. (2001) reported 10% peanut injury at one North Carolina location from flumioxazin-containing treatments but injury was not visibly apparent at a later rating. In Texas, trifluralin plus flumioxazin applied PRE stunted peanut ≤ 16% (Grichar and Colburn 1996). However, no peanut injury was noted 6 to 8 wk after treatment. In a preliminary greenhouse study, Vencill (2002) reported that injury was related to planting depth and flumioxazin placement depth. Swann (2002) reported between 43 and 68% injury in two studies conducted in Virginia in 2000 and 2001, respectively. Injury decreased, to less than 9% in both studies, and yield was unaffected compared with other registered peanut treatments. Also, injury was reduced in these studies when a rain event occurred between flumioxazin application and preceded crop emergence.

Flumioxazin acts by inhibiting protoporphyrinogen oxidase (protox) (protoporphyrin IX:oxygen oxidoreductase, EC 1.3.3.4) (Anonymous 1988; Cranmer et al. 2000). Inhibition of this enzyme induces accumulation of protoporphyrin IX because of uncontrolled autooxidation of the substrate (Dayan et al. 1997a; Duke et al. 1991). As protoporphyrin IX accumulates and is photoenergized by light, toxic oxygen radicals are generated, which lead to degradation of plasmalemma and tonoplast membrane lipids causing irre-

versible damage of their membrane function and structure in susceptible plants.

Acifluorfen and sulfentrazone are herbicides that are also protox inhibitors. Previous research showed that soybean [*Glycine max* (L.) Merr.] exhibited tolerance to acifluorfen because of limited absorption compared with susceptible weed species (Ritter and Coble 1981). However, tolerance of sicklepod to sulfentrazone was because of increased metabolism compared with susceptible coffee senna (*Cassia occidentalis* L.) (Dayan et al. 1996). In another study, Dayan et al. (1997b) reported no differences in absorption and translocation of sulfentrazone between relatively tolerant and less tolerant soybean cultivars. Soybean tolerance to sulfentrazone was because of differential metabolism and differential tolerance to herbicide-induced peroxidative stress. Differential tolerance is expressed by *Ipomoea* spp. (susceptible) and sicklepod (tolerant) to flumioxazin PRE, two weed species commonly found in Southeastern peanut cropping systems (Anonymous 2001).

Air temperature has been shown to affect CGA-248757 and flumiclorac activity, two protox-inhibiting herbicides (Fausey and Renner 2001). Efficacy for both herbicides on common lambsquarters (*Chenopodium album* L.) and redroot pigweed (*Amaranthus retroflexus* L.) increased with an increase in temperature from 10 to 40 C possibly because of reduced foliar adsorption. Tolerance mechanisms of peanut and mechanisms for *Ipomoea* spp. susceptibility to root-absorbed flumioxazin are unknown. Also, elucidation of peanut physiological behavior to root-absorbed flumioxazin may offer insight into peanut injury observed in the field.

In response to peanut injury observed with flumioxazin, use experiments were conducted to investigate the influence of temperature on flumioxazin-treated peanut seed germination, as well as the influence of increasing intervals between soil-applied of flumioxazin PRE and irrigation on peanut emergence and injury. Experiments were also conducted to investigate the basis for differential tolerance of peanut, ivyleaf morningglory, and sicklepod to root-absorbed flumioxazin.

Methods and Materials

Temperature Experiment

The effect of temperature on flumioxazin-treated peanut seed germination was evaluated. Five peanut seeds ('NC 10C') were evenly spaced 5 cm deep in 500-cm^3 lidded glass containers[1] filled with oven-dried steam-sterilized sand. The containers were arranged on a thermogradient table (Larsen 1965) in six lanes corresponding to temperatures of 15, 20, 25, 30, 35, and 40 C, with five replicate containers per temperature lane. Experiments performed on the gradient table precluded randomization because the zones of temperature were fixed in position (Larsen 1965). Nontreated peanuts received 100 ml of distilled water. Flumioxazin-treated peanuts received a 100 ml solution spiked with 1.44 $\mu mol\ L^{-1}$ flumioxazin in either WP or WDG formulation. This concentration is approximately 2,000 times the concentration found in field solution (approximately 0.0007 $\mu mol\ L^{-1}$) and was used as a concentration higher than could be accidentally applied in the field because of the potential insolubility of the WDG formulation. This value is based on a registered rate (71 g ha^{-1}) and the volume of water in the top 7.6 cm of soil at field capacity, assuming 20% moisture by weight and no herbicide absorption by the soil (Weber et al. 2000). Germination was recorded each day until the experiment was terminated 15 d after initiation. The study was repeated in time.

Data variance was inspected visually by plotting residuals to confirm homogeneity of variance before statistical analysis. Both nontransformed and arcsine-transformed data were examined, and transformation did not improve homogeneity. Analysis of variance (ANOVA) was therefore performed on nontransformed percent germination data. Trial repetition and linear, quadratic, and higher-order polynomial effects of percent germination over time were tested by partitioning sums of squares (Draper and Smith 1981). Regression analysis was performed when indicated by ANOVA. Nonlinear models were used if ANOVA indicated that higher-order polynomial effects of percent germination were more significant than linear or quadratic estimates. Estimation used the Gauss–Newton algorithm, a nonlinear least squares technique (SAS 1998).

Simulated Irrigation Experiment

The effect of irrigation timing in relation to application of flumioxazin on peanut emergence and injury was evaluated. Ten peanut seeds (NC 10C) were sown at four seeds per linear 30 cm, 5 cm deep in 5-L flats containing dry sandy loam soil, the typical seeding rate and soil in which peanut are grown in the mid-Atlantic and Southeastern Coastal Plain (Jordan 2002). Flats were placed in a greenhouse maintained at approximately 30 $\pm$ 5 C. The soil was collected from a nonfarmed, herbicide-free area at the Peanut Belt Research Station located near Lewiston, NC. There was a 16-h photoperiod of natural and supplemental metal halide lighting yielding an average midday photosynthetic flux density of 700 $\mu mol\ m^{-2}\ s^{-1}$. Treatments consisted of a factorial treatment arrangement of two flumioxazin formulations and six irrigation timings. Immediately after planting, soil was treated with either WDG or WP formulations of flumioxazin PRE at 71 g ai ha^{-1}. A single 1.3-cm simulated irrigation treatment applied using wide-angle, full-cone nozzles[2] in a custom-built rainfall apparatus was then applied once (1) immediately after flumioxazin application, (2) peanut emergence (10 d after planting [DAP]), (3) emergence plus 2 d, (4) emergence plus 4 d, (5) emergence plus 8 d, and (6) emergence plus 12 d. A nontreated comparison was also included. Pots were subirrigated outside of rainfall events. Peanut emergence from soil surface was evaluated visually daily and reported as total emergence. Peanut injury was rated visually at emergence and 5 d after emergence for peanut receiving irrigation immediately after flumioxazin application and 5 and 10 d after each postemergence (POST) irrigation treatment on a 0 to 100 scale (Frans et al. 1986). Plants were harvested 32 DAP, dried, and weighed. Treatments were completely randomized, and the study was repeated in time.

All data were subjected to ANOVA that reflected the factorial treatment arrangement. Treatments were considered fixed effects whereas trial effects were considered random variables. Nontransformed data for visual evaluations were presented because arcsine square-root transformation did not affect data interpretation. ANOVA was conducted with and without the nontreated control to ensure the control

did not bias the conclusions, because visually estimated injury ratings were zero. Conclusions are on the basis of the inclusion of the nontreated control in the analysis. Means for appropriate main effects and interactions were separated using Fisher's Protected LSD test at $P = 0.05$. When interactions occurred, data were presented separately and when interactions did not occur, data were combined.

Plant Material and Growth Conditions for Physiology Experiments

Peanut (NC 10C), ivyleaf morningglory, and sicklepod were grown in 0.5-L pots containing sand in a greenhouse maintained at approximately 30 ± 5 C. There was a 16-h photoperiod of natural and supplemental metal halide lighting yielding an average midday photosynthetic flux density of 700 μmol m^{-2} s^{-1}. When plants emerged, they were moved into a growth chamber at a constant temperature of 26 C and approximately 50% relative humidity. Lighting was provided by fluorescent and incandescent lamps yielding a total illumination of 500 μmol m^{-2} s^{-1}. Treatments were arranged in a randomized complete block design with three replications to evaluate absorption, translocation, and metabolism of flumioxazin. This study was repeated.

Absorption and Translocation

Peanut plant (3.8 or 7.6 cm in height) roots were treated with [phenyl-^{14}C] flumioxazin.[3] A microsyringe was used to deliver ten 1-μL droplets of ^{14}C-flumioxazin in high performance liquid chromatography–grade water containing 1,850 Bq ^{14}C-flumioxazin (specific activity ^{14}C-flumioxazin was 106 mCi $mmol^{-1}$, 94.2% radiopurity) into 10 ml of 50% Hoagland solution contained in 30-ml glass vials. Ivyleaf morningglory and sicklepod at the cotyledon stage were treated with 1,850 Bq of ^{14}C-flumioxazin placed similarly into 3 ml of 50% Hoagland solution contained in 5-ml glass vials. Treated plants were harvested 4, 24, 48, and 72 h after treatment (HAT).

At harvest, the treated roots from each plant were washed slowly with 10 ml of methanol:water (1:1, v/v) and 0.25% (v/v) nonionic solution[4] to remove nonabsorbed herbicide from the root surface. A 1-ml aliquot from each solution was added to 25 ml of scintillation cocktail[5] and quantified by liquid scintillation spectroscopy[6] (LSS). Ivyleaf morningglory and sicklepod were then sectioned into roots, stem, and leaves. Peanut plants were sectioned into leaves and stem, hypocotyl and cotyledon, and roots. These parts were placed into paper bags and dried at 65 C for at least 72 h. The plant parts were then ground with a coffee grinder.[7] A 100- to 200-mg subsample was oxidized in a biological oxidizer,[8] where ^{14}C was trapped in scintillation cocktail, and radioactivity quantified by LSS.

Data were subjected to ANOVA with sums of squares partitioned to reflect a split-plot treatment structure and trial effects. The four harvest timings were considered main plots, the three species were considered subplots, and the plant portions and washes were considered subsubplots. Residuals were plotted, and logarithmic transformations conducted on data when variance increased as means increased. After ANOVA, treatment or log-transformed treatment means were compared using Fisher's Protected LSD test at the 5% probability level. When main effects were significant, regressions were used to explain the relationship of measured response with time.

Metabolism

Plants were treated and harvested as described previously. However, only one peanut size (7.6 cm in height) was used to measure metabolism. At harvest, partitioned plant parts were placed immediately in a freezer at −30 C until further analysis. Plant portions were ground in a tissue homoginizer[9] with 10 ml of acetonitrile. The homogenate was then rinsed into a vacuum filtration apparatus with an additional 10 to 15 ml of solvent. The remaining extracted plant material was oxidized and nonextracted ^{14}C quantified as described previously. The filtrate was evaporated to near dryness and then brought to 0.5 ml volume with acetonitrile, shaken, and stored at 4 C until further analysis. One hundred and fifty microliters of each sample was spotted on a 20- by 20-cm silica gel thin layer chromatography plate[10] and developed to a 16-cm solvent front to separate the parent herbicide from possible metabolites. The solvent consisted of benzene:acetone (2:1, v/v). Plates were partitioned into nine 2-cm-wide lanes. A standard of 10 μl stock radiolabeled herbicide solution was spotted on the first lane of each plate. The remaining eight lanes received a single replicate of a treated plant portion sample from each of the three species for the two runs of the studies. Potential metabolites were identified and quantified using a radiochromatogram scanner[11] that determined radioactive positions and corresponding R_f values. Peak area was calculated using Win-Scan software[12] with smoothing set to 13-point cubic and background excluded from peak area calculation. Comparing R_f values from a ^{14}C-flumioxazin standard and the retention times within samples identified the nonmetabolized ^{14}C-flumioxazin parent. Methodology was a modification of those supplied by Valent USA.[3] Statistical procedures were similar to those described previously for absorption and translocation data.

Results and Discussion

Temperature Experiment

Germination resulting from constant temperature treatments was described by a parabolic model of the form:

$$y = \beta_0 + \beta_1 \text{temp} + \beta_2 \text{temp}^2 \quad [1]$$

where β_0, β_1, and β_2 are the intercept, first- and second-order regression coefficients, respectively, and y is the cumulative germination at temperature temp. A parabolic model was used to describe peanut germination because the constant temperature allowed direct correlation of germination response. Germination was not influenced by flumioxazin treatment compared with nontreated peanut across all temperature regimens ($P > 0.05$); therefore, data were pooled across formulation (Figure 1). Germination occurred during the entire experimental range of 15 to 40 C, with optimum germination occurring at 30 C (100%). Extension recommendations suggest peanut be planted into soils that are ≥ 18 C for germination to proceed at an acceptable rate (Jordan 2002).

These results show that stand reduction observed after a PRE application of flumioxazin under cool wet conditions

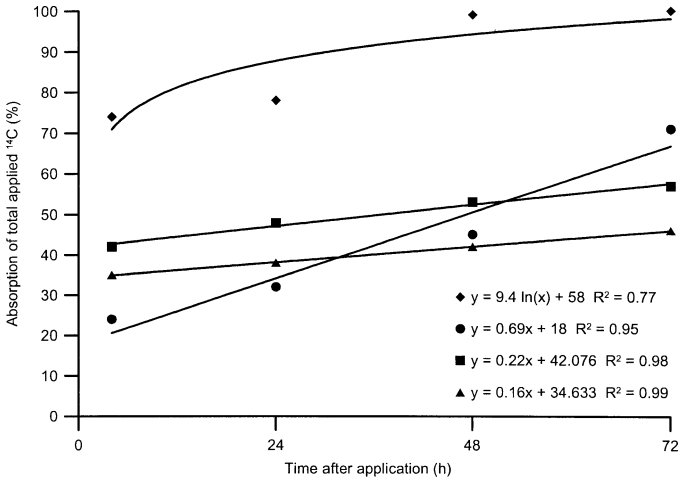

FIGURE 1. Relationship of constant temperature and cumulative germination peanut seed at 10 d after planting.

is likely not because of decreased peanut germination. Thus, injury observed after peanut emergence is likely because of activation of flumioxazin-induced peroxidation by sunlight or splashing of flumioxazin-treated soil onto emerging peanut seedlings. Cotton injury from splashing of treated soil onto foliage has been observed after flumioxazin POST-directed spray treatments (Wilcut et al. 2000). Because these experiments were conducted in pure sand and herbicide binding would likely increase and herbicide availability decreased with increasing clay or organic matter content, soil type would likely not influence observed results. Field research has shown that peanut response to flumioxazin was not influenced by variety which suggest these results could be important across all varieties of peanut (Main et al. 2001; Murphree et al. 2002).

Simulated Irrigation Experiment

Flumioxazin formulation or experimental repetition did not influence peanut emergence or injury at either rating; therefore, data were combined. Timing of irrigation event was not significant for emergence ($P > 0.05$) (data not shown). Timing of irrigation treatment was significant for peanut injury and peanut seedling dry weight ($P < 0.05$). At the first evaluation (5 DAT), peanut irrigated immediately after PRE application were injured 3% (Table 1). Peanut irrigated at emergence, 2, or 4 d after emergence were injured between 40 and 60%. Peanut irrigated at 8 or 12 d after emergence were injured less (25 and 15%, respectively). At the second evaluation (10 DAT), peanut irrigated immediately after PRE application had no visible injury. However, peanut irrigated at emergence, 2, and 4 d after emergence were still injured 30 to 50%. Peanut irrigated at 8 or 12 d after emergence were injured 15 and 5%, respectively.

Peanut dry weight reflected injury levels (Table 1). Peanut irrigated immediately after PRE application or 12 d after emergence weighed 5.1 or 4.5 g, respectively, similar to untreated (4.8 g) at 32 DAP. Peanut irrigated at emergence, 2, 4, or 8 d after emergence weighed less, between 0.75 and 1.9 g with no differences among these treatments.

These results agree with observations by Swann (2002) that splashing of flumioxazin-treated soil or surface water containing flumioxazin onto emerged peanut seedlings causes injury if rainfall did not occur between flumioxazin application and peanut emergence. Rainfall before emergence would likely move flumioxazin from the soil surface into the soil profile and reduce potential of injury due to rain splash.

Absorption and Translocation

Growth stage by repetition and harvest timing by run interactions were not significant ($P > 0.05$); therefore, data were pooled across experimental repetitions. The main effects of harvest time, species, and plant portion significantly influenced the absorption and translocation of ^{14}C by peanut, ivyleaf morningglory, and sicklepod ($P < 0.05$). As a result, the influence of harvest time, species, and plant portion within species are presented separately.

At 4 HAT, absorption of applied ^{14}C was 42 and 35% by ivyleaf morningglory and sicklepod, respectively (Figure 2). Total ^{14}C absorbed by ivyleaf morningglory 72 HAT was 57% whereas sicklepod absorbed 46%. Most herbicide was absorbed within the first 4 HAT for both weed species and both species exhibited linear ^{14}C absorption with time. A majority of absorbed ^{14}C remained in the roots for both sicklepod and ivyleaf morningglory (Figures 3 and 4). Sicklepod translocated 5% of absorbed ^{14}C to stem and 18% to leaves 72 HAT (Figure 3). Ivyleaf morningglory translo-

TABLE 1. Injury observed on greenhouse grown peanut 5 and 10 DAT and peanut dry weight 32 DAP from flumioxazin PRE treatment and receiving irrigation (1.27 cm) at various treatment timing.[a,b]

Irrigation treatment timing	Injury		Dry weight per plant
	5 DAT	10 DAT	
	%		g
Immediately after flumioxazin PRE treatment	3	0	5.1
Peanut emergence	60	55	0.8
Peanut emergence plus 2 d	50	40	0.9
Peanut emergence plus 4 d	40	30	1.4
Peanut emergence plus 8 d	25	15	1.9
Peanut emergence plus 12 d	15	5	4.5
Nontreated	0	0	4.8
LSD	13	11	2.2

[a] Data averaged over trials. LSD conducted at $P = 0.05$.
[b] Abbreviations: DAT, days after treatment; DAP, days after planting; PRE, preemergence.

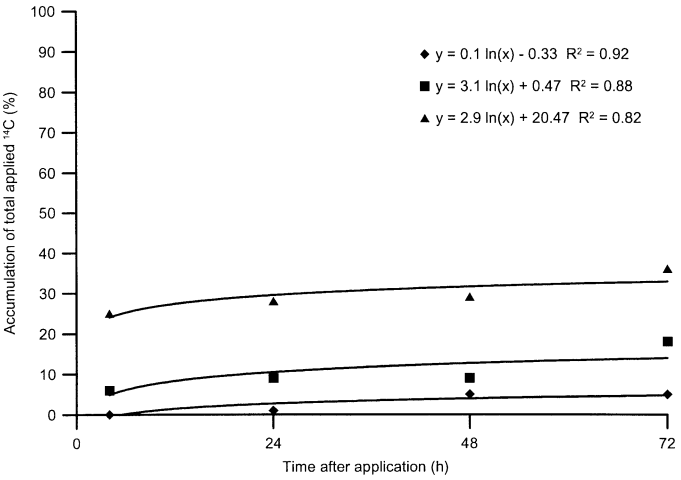

FIGURE 2. Total plant absorption of ^{14}C-flumioxazin by larger peanut (◆), smaller peanut (●), ivyleaf morningglory (■), and sicklepod (▲) with time reported as percent applied.

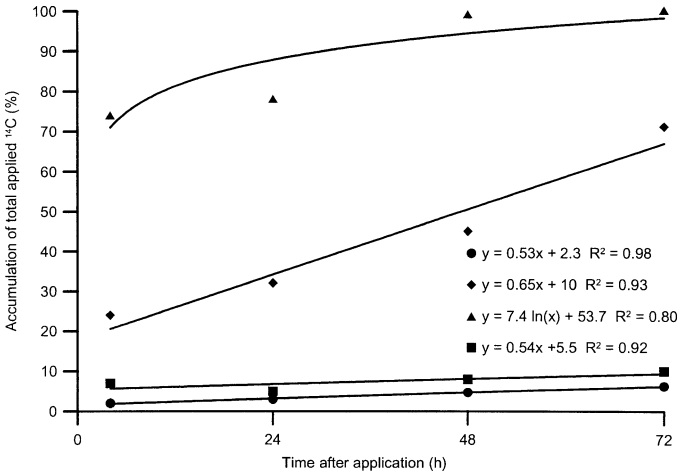

FIGURE 4. Accumulation of ^{14}C-flumioxazin in leaves (◆), stem (■), and roots (▲) of morningglory reported as percent applied.

cated absorbed ^{14}C similarly to stem (9%) and less (7%) to leaves 72 HAT (Figure 4).

Smaller peanut (3.8 cm tall) absorbed 24% of applied ^{14}C 4 HAT and absorption increased to 72% 72 HAT (Figure 2). Larger peanut (7.6 cm tall) absorbed more than twice the applied ^{14}C at 4 HAT (74%) compared with smaller peanut and absorbed 99% of the applied ^{14}C 72 HAT. Most ^{14}C was absorbed within the first 4 HAT for larger peanut. Smaller peanut exhibited linear ^{14}C absorption with time. Larger peanut likely absorbed ^{14}C more rapidly because of increased transpiration and subsequent increase in solution absorption by roots compared with smaller peanut.

The majority of absorbed ^{14}C remained in the roots for both peanut sizes (Figure 5). ANOVA showed no differences in accumulation during time of ^{14}C in larger and smaller peanut leaves and stems or hypocotyls and cotyledon, therefore, data are combined for presentation. Peanut translocated 10% of absorbed ^{14}C to leaves and stem and 6% to hypocotyl and cotyledon 72 HAT (Figure 5).

Order of absorption of ^{14}C for the three species including two peanut sizes was larger peanut (7.6 cm in height) > smaller peanut (3.8 cm in height) > ivyleaf morningglory > sicklepod. Because more absorption occurred in peanut, a tolerant plant, compared with ivyleaf morningglory, a susceptible plant, these data suggest that differential response exhibited by these species to root-absorbed flumioxazin is not related to absorption. In addition, all three species exhibited limited acropetal translocation to tissue in which flumioxazin caused peroxidation could be expressed. This suggests that differential response by plants to root-absorbed flumioxazin is not related to translocation in these species.

Metabolism

Experimental run by main effect interactions were not significant for the two studies ($P > 0.05$), thus data were combined. The main effects of harvest time and species significantly influenced metabolism of absorbed ^{14}C-flumioxazin ($P < 0.05$); therefore, species and harvest time are presented separately. However, differences between accumulation of metabolites in plant parts were not discernible ($P > 0.05$). Recovery of applied radioactivity was > 95%. Of the recovered radioactivity, 10% remained bound in the plant debris after extraction. Thus, the amount of herbicide me-

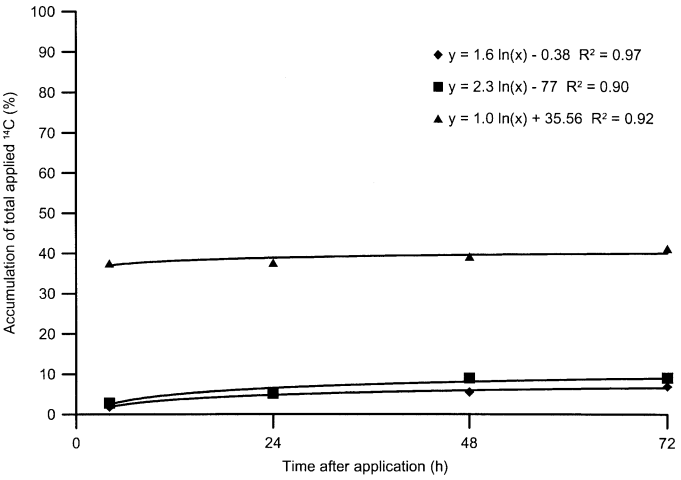

FIGURE 3. Accumulation of ^{14}C-flumioxazin in leaves (◆), stem (■), and roots (▲) of sicklepod reported as percent applied.

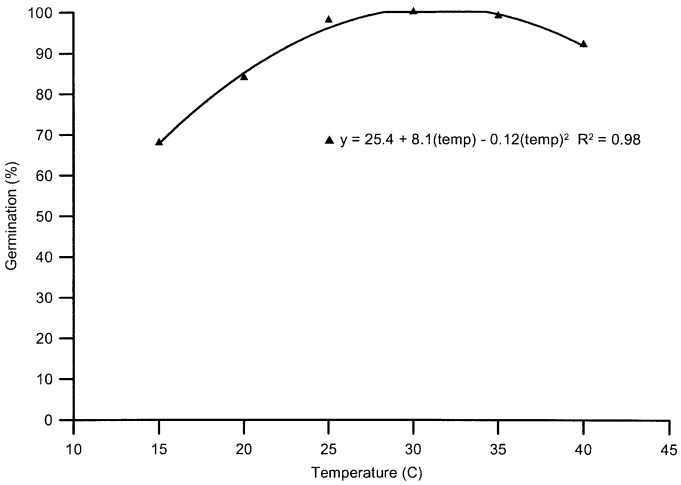

FIGURE 5. Accumulation of ^{14}C-flumioxazin in leaves and stem (●), hypocotyl and cotyledon (■), and roots of 3.8-cm-tall (▲) and 7.6-cm-tall (◆) peanut reported as percent applied.

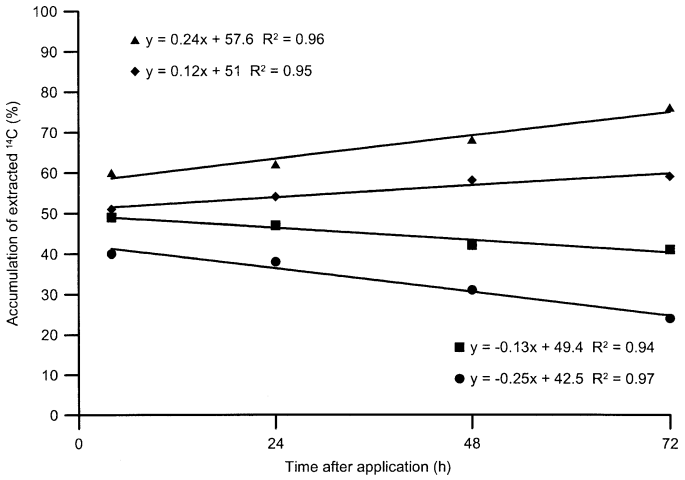

FIGURE 6. Accumulation of metabolites (▲) and parent flumioxazin (●) in sicklepod as well as accumulation of metabolites (◆) and parent flumioxazin (■) in ivyleaf morningglory reported as percent extracted.

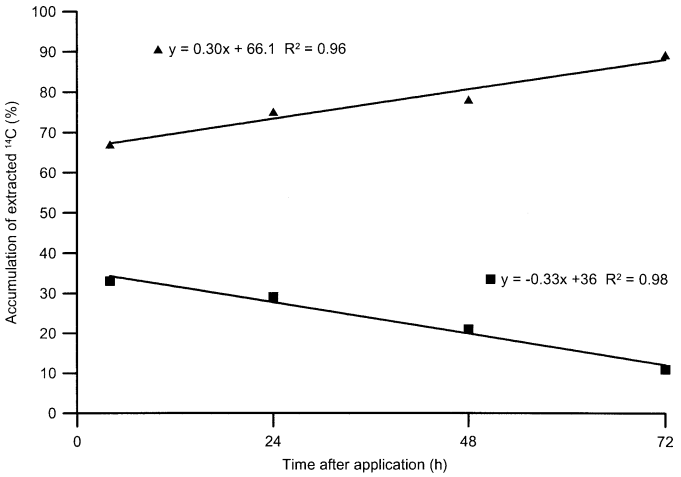

FIGURE 7. Accumulation of metabolites (▲) and parent flumioxazin (■) in peanut reported as percent extracted.

tabolism in the stem or leaves was the sum of extracted metabolites and is reported as percent extracted.

Most metabolism occurred within the first 4 h in sicklepod, ivyleaf morningglory, and peanut (Figures 6 and 7). Sicklepod and peanut metabolized flumioxazin rapidly with only 40 and 33% of absorbed flumioxazin remaining as parent herbicide, respectively, at 4 HAT (Figures 6 and 7). However, in ivyleaf morningglory, 49% of the flumioxazin remained as herbicide 4 HAT and 41% 72 HAT (Figure 6). By 72 HAT, sicklepod and peanut contained only 24 and 11% parent compound, respectively. Regression slopes also indicated slower metabolism by ivyleaf morningglory compared with sicklepod and peanut.

Visual symptoms of peroxidation of tissue began to appear in the leaves of ivyleaf morningglory 48 HAT and plants were near death 72 HAT. No visible injury was apparent in peanut or sicklepod. Extrapolated half-life of flumioxazin is 0.8, 1.3, and 2.5 d for peanut, sicklepod, and morningglory. These data suggest that differential metabolism is the main factor influencing flumioxazin activity in ivyleaf morningglory, sicklepod, and peanut. Our results are in agreement with Dayan et al. (1996, 1997b).

Because peanut were shown to metabolize root-absorbed flumioxazin more than three times as quickly as susceptible ivyleaf morningglory, these studies suggest that flumioxazin root-absorbed will likely be metabolized by peanut before visible injury occurs. These studies further suggest that flumioxazin injury on seedling peanut is likely caused by rainfall occurring after flumioxazin application and peanut emergence, if rainfall does not occur before peanut emergence.

Because the mid-Atlantic and Southeastern peanut production areas frequently receive intermittent spring rains at time of peanut planting, producers may reduce injury by planting peanut and applying flumioxazin PRE before a predicted rain event. Under ideal conditions, peanut can begin to emerge in the field in 7 d for smaller seeded varieties and in 10 d for larger seeded varieties (Jordan 2002). Thus, peanut growers need to anticipate receiving rainfall or applying overhead irrigation on flumioxazin PRE-treated soil within approximately 6 d of application to reduce probability of peanut injury.

Sources of Materials

[1] Pyrex® 500-cm^3 lidded glass container, No. 3250, Corning Inc., One Riverfront Plaza, Corning, NY 14831.

[2] TeeJet® hollow cone spray tips, TeeJet East, 124 A West Harrisburg Street, Dillsburg, PA 17019.

[3] [phenyl-^{14}C] flumioxazin, Valent® USA Corporation, P.O. Box 8025, Walnut Creek, CA 94596-8025.

[4] Induce® nonionic low foam wetter/spreader adjuvant contains 90% nonionic surfactant (alkylarylpolyoxyalkane ether and isopropanol), free fatty acids, and 10% water, Helena Chemical Co., Suite 500, 6075 Poplar Avenue, Memphis, TN 38137.

[5] ScintiVerse® SX18-4 Universal Liquid Scintillation Cocktail, Fisher Scientific, 200 Park Lane, Pittsburgh, PA 15275.

[6] Packard® TRI-CARB 2100TR Liquid Scintillation Spectrometer, Packard Instrument Company, 2200 Warrensville Road Downers Grove, IL 60515.

[7] Coffee Mill®, Mr. Coffee, 24700 Miles Road, Bedford Heights, OH 44146-1399.

[8] Harvey® biological oxidizer, J. Harvey Instrument Corporation, 123 Patterson Street, Hillsdale, NJ 07642.

[9] Pyrex® Tissue Homoginizer No. 7727-40, Corning Inc., One Riverfront Plaza, Corning, NY 14831.

[10] Whatman® K6F Silica Gel 60A Thin Layer Chromatography Plates, Whatman Inc, 9 Bridewell Place, Clifton, NJ 07013.

[11] Bioscan System 200 Imaging Scanner, Bioscan, 4590 MacArthur Boulevard NW, Washington, DC 20007.

[12] Lablogic Win-Scan Radio TLC Version 2.2 (5) 32-bit, distributed by BioScan, 4590 MacArthur Boulevard NW, Washington, DC 20007.

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