Appendix D
AgDRIFT Modeling Approach and Results

The AgDRIFT model (Version 2.01) was used to refine the spray drift exposure estimate for terrestrial plants. Downwind spray drift buffers were developed for possible use in mitigating risks for endangered terrestrial plants that grow in close proximity to agricultural and non-agricultural fields that may be treated with liquid spray applications of simazine. The model was used to estimate spray buffer distances for ground and aerial application to reach the NOAEC and EC_{25} doses for the most sensitive monocot and dicot species in the seedling emergence and the vegetative vigor studies. The standard toxicity level EFED uses for calculating risk quotients for non-endangered terrestrial plants is the EC_{25}. For endangered plants, the NOAEC (or EC_{05} if a NOAEC value is not available) is used. Seedling emergence endpoints are representative of exposure through soil to germinating plants, while vegetative vigor endpoints are representative of foliar exposure. The terrestrial plant measurement endpoints used in the model are specified in Table D- 1.

Table D-1. Agdrift Input Parameters for Terrestrial Plant Measurement Endpoints

Test Type/ Crop	Most Sensitive Study Species	NOAEC (lb ai/A) /Fraction Applied[1]	EC_{25} (g ai/ha) / Fraction Applied[1]	Most sensitive parameter
Seedling Emergence: Monocot	Onion	0.0017 / 0.00018	0.02 / 0.002	Shoot Height
Seedling Emergence: Dicot	Lettuce	0.0018 / 0.00019	0.009 / 0.0009	Shoot Weight
Vegetative Vigor: Monocot	Oat	0.016 / 0.0017	0.033 / 0.0034	Shoot Weight
Vegetative Vigor: Dicot	Lettuce	0.016 / 0.0017	0.033 / 0.0034	Shoot Weight

[1] The fraction of the application rate = NOAEC or the EC_{25}/maximum application rate of simazine (9.6 lb ai/A).

A summary of the results of the AgDRIFT modeling for ground and aerial application of simazine is presented in Table D-2. Downwind spray drift buffers or distances required to dissipate spray drift to NOAEC levels are estimated for both monocot and dicot terrestrial plant species and for ground and aerial applications of simazine. Dissipation to the no effect level was modeled in order to provide potential buffer distances that are protective of endangered terrestrial plant species. Dissipation distances to the EC_{25} level were also modeled in order to provide potential buffer distances required to protect non-endangered terrestrial plant species. The range of dissipation distances is dependant on a number of input variables including droplet size, release height, etc., which are discussed in further detail for ground and aerial applications below.

Drift dissipation distances for endangered species, based on ground boom applications, are expected to exceed the 1,000 foot limit of the AgDRIFT ground model. Modeled dissipation distances for endangered monocots and dicots, based on aerial application of simazine at a 5 foot release in wind speeds ≤ 5 mph, are expected to range from approximately 3,150 to 4,700 feet depending on the spray droplet size. The predicted dissipation distances, based on aerial and ground application, are uncertain because they exceed the 1,000 foot limit of the model. Given the large predicted spray drift buffers and associated uncertainties for ground and aerial application of simazine, it is not possible to predict accurate spray drift buffers for use as a mitigation technique to protect endangered plants. However, label language that requires spray drift mitigation measures (i.e., lower release heights, wind speed restrictions, and specification of medium to coarse spray droplet sizes) is recommended.

Table D-2. Summary of AgDRIFT Modeling Results for Endangered Plant Species

Crop	Dissipation Distance for Ground Application (feet)	Dissipation Distance for Aerial Application (feet)
Monocots	>1,000	3,150 - 4,700
Dicots	>1,000	3,050 - 4,600

Ground Application

The most important factors affecting drift from ground boom applications are spray quality (droplet size), release height, and wind speed. The ground boom part of AgDRIFT is based on field trial data from bare ground applications. The results of the model reflect the quality and conditions of the data on which it was based. The data from the field trials were grouped into categories by spray quality (droplet size) and release height. Results from field trials conducted with different wind speeds were averaged. The average wind speed over all trials was approximately 10 mph, therefore 10 mph should be specified in the label as the maximum allowable wind speed for ground applications of simazine. AgDRIFT outputs for ground boom applications estimate the 50th and 90th percentile of data collected from field trials. For this analysis, the 90th percentile was used to provide protective dissipation distances.

Because the label for simazine does not specify release height or droplet size for ground applications, the AgDRIFT model was run for all four scenarios (high boom and fine spray, low boom and fine spray, high boom and medium/coarse spray, and low boom and medium/coarse spray) to provide a range of possible buffer distances. All drop size descriptions are based on ASAE S-572 standard definitions. High and low boom heights are representative of 4 and 2 foot release heights, respectively. The output of the AgDRIFT model provides distances (in feet) required to dissipate spray drift to the NOAEC and EC_{25} levels. Buffer distances are provided for both types of tests (i.e., seedling emergence (SE) and vegetative vigor (VV)) using the most sensitive monocot and dicot species (Table D-1). The results of the AgDRIFT model for ground application of simazine are provided in Table D- 3. Although spray drift distances are modeled for both SE and VV tests, only buffers associated with the SE emergence test are discussed. Available toxicity data indicate that the terrestrial plants are most sensitive to simazine via soil uptake rather than application of the herbicide directly to post-emergent foilage. Therefore, downwind spray drift buffers based on NOAEC and EC_{25} values derived from SE toxicity tests are believed to be protective of endangered and non-endangered terrestrial plants, respectively.

Table D-3. Results of AgDRIFT Modeling for Ground Application of Simazine

Species	Test Type	Distance Required to Dissipate Spray Drift to NOAEC/EC_{25} Levels (feet)			
		High boom; fine spray (NOAEC/EC_{25})	Low boom; fine spray (NOAEC/EC_{25})	High boom; med/coarse spray (NOAEC/EC_{25})	Low boom; med/coarse spray (NOAEC/ EC_{25})
Onion (Monocot)	SE	>1,000* / 797	>1,000* / 522	>1,000* / 423	>1,000* / 282
Lettuce (Dicot)	SE	>1,000* / >1,000*	>1,000* / >1,000*	>1,000* / 879	>1,000* / 686
Oat & Lettuce (Monocot and Dicot)	VV	886 / 554	607 / 312	495 / 243	344 / 144

* The maximum dissipation distance from the edge of the field in the Tier I ground model is 1,000 feet.

The results of the AgDRIFT modeling for ground application of simazine show that buffer distances of greater than 1,000 feet would be required to dissipate spray drift to NOAEC levels (under even the least conservative conditions of low boom and medium/coarse spray) for seedling emergence, which is the most sensitive endpoint for terrestrial plants. NOAEC values for monocots and dicots indicate roughly equal sensitivity to simazine, based on the seedling emergence endpoint. Although it is not possible to derive an exact buffer distance that would be protective of endangered terrestrial plants, spray drift can be reduced by lowering the release height and/or increasing the spray droplet size. Resulting label language should specify that all ground applications be performed using a low boom height of 2 feet and ASAE S-572 as the droplet sizing standard. The range of spray drift buffers that would be protective of non-endangered species is dependent on the boom height and droplet size. For monocots, the range of protective spray drift buffers is 300 to 800 feet; for dicots, the buffer range is 700 to >1,000 feet.

Aerial Application

The most important factors affecting drift from aerial applications are spray droplet size, release height, and wind speed. The aerial part of the AgDRIFT model predicts mean dissipation distances based on the inputs provided. When wind speed and/or release height is lower than the modeled values, the spray drift levels would expected to be lower. Conversely, in instances where applications may be made in higher wind speeds or at a higher release height, these inputs may not be adequately conservative and higher tier modeling may be necessary.

Although the label does not specify a droplet size for aerial application of simazine, fixed winged applications (applications made by airplanes) are limited in the coarsest droplet size that can be sprayed. Typical fixed wing aerial application speeds exceed 120 mph. At these speeds, coarse droplets shatter and produce medium or finer sprays. Thus, it is generally inappropriate to model coarse sprays for fixed wing applications without some restriction on flight speed.

For aerial applications, the model contains three tiers of increasing complexity.

Tier I Aerial Modeling

The AgDRIFT Tier I model for aerial application limits the input parameters to droplet size only. The output of the Tier I AgDRIFT model provides distances required to dissipate spray drift to the NOAEC and EC_{25} levels. Based on a medium to coarse spray, which is considered the least conservative scenario, dissipation distances from the edge of the field that are protective of both non-endangered and endangered species are expected to exceed beyond the 1,000 foot limit of the model.

Tier II Aerial Modeling

Tier II aerial spray drift estimates were also derived for simazine because this level of modeling allows for greater control over input and output options. With the exception of droplet size, wind speed, and release height, AgDRIFT default parameters were used for all other variables in the Tier II model. Dissipation distances in the Tier II model, based on medium to coarse spray, a release height of 10 feet, and wind speeds limited to 10 mph or less, exceed the 1,000 foot limit of the model for the seedling emergence NOAEC and EC_{25} endpoints. Therefore, the Tier II model was re-run using a release height of 5 feet and a wind speed of 5 mph or less. Dissipation distances for vegetative vigor endpoints were not modeled because it is assumed that buffer distances based on soil uptake would also be protective of foliar exposure (i.e., soil uptake is the more toxic exposure route). The results of the AgDRIFT Tier II model for aerial application of simazine, based on a 5 foot release height and wind speed of $\leq$ 5 mph, are provided in Table D-4.

Table D-4. Results of AgDRIFT Tier II Modeling for Aerial Application of Simazine				
Species	**Test Type**	**Distance Required to Dissipate Spray Drift to NOAEC/EC_{25} Levels (feet) Assuming a 5 Foot Release Height in ≤ 5 mph Winds**		
		Fine to Medium Spray (NOAEC/EC_{25})	**Medium Spray (NOAEC/EC_{25})**	**Medium to Coarse Spray (NOAEC/EC_{25})**
Onion (Monocot)	SE	>1,000* / >1,000*	>1,000* / 950	>1,000* / 600
Lettuce (Dicot)	SE	>1,000* / >1,000*	>1,000* / >1,000*	>1,000* / >1,000*

* The maximum dissipation distance from the edge of the field in the Tier II ground model is 1,000 feet.

Based on a medium to coarse droplet size, downwind spray drift buffers (or distances required to dissipate spray drift to NOAEC levels based on seedling emergence) exceed the limit model of 1,000 feet for release heights of 5 feet and wind speeds ≤ 5 mph. In addition, the limits of the model are also exceeded for non-endangered dicots, based on application of medium and medium/coarse spray droplet sizes, and non-endangered monocots and dicots based on fine to medium sprays. The results of the Tier II model suggest that buffer distances ranging from approximately 600 to 950 feet, for respective use of medium/coarse and medium sprays, are likely to be protective of non-endangered monocot plants.

Tier III Aerial Modeling

Tier III aerial spray drift estimates were modeled for no effect levels (based on seedling emergence) because the dissipation distance can be extended beyond the 1,000 foot limit seen in the Tier I and Tier II models. All input parameters for the Tier III model, including a 5 foot release height and wind speeds of ≤ 5 mph, were identical to those entered into the Tier II model. Based on these inputs, **the distance required to dissipate aerial spray drift to NOAEC levels for monocots and dicots is 4,700 feet.** It should be noted that there is a high degree of uncertainty in spray drift dissipation distances greater than 1,000 feet because the reliable limits of the AgDRIFT model are exceeded.

Table D-5. Results of AgDRIFT Tier III Modeling for Aerial Application of Simazine				
Species	**Test Type**	**Distance Required to Dissipate Spray Drift to NOAEC/EC_{25} Levels (feet) Assuming a 5 Foot Release Height in ≤ 5 mph Winds**		
		Fine to Medium Spray (NOAEC/EC_{25})	**Medium Spray (NOAEC/EC_{25})**	**Medium to Coarse Spray (NOAEC/EC_{25})**
Onion (Monocot)	SE	4,700 / 1,250	4,100 / 950**	3,150 / 600**
Lettuce (Dicot)	SE	4,600 / 2,150	4,000 / 1,750	3,050 / 1,250

** Spray dissipation distances derived from the Tier II modeling (see Table D-4).

Phytotoxicity and Downwind Distance

Distances downwind from application areas at which a particular tested plant species would exhibit a toxic effect level were estimated using the AgDRIFT model and registrant-submitted phytotoxicity data (426346-03 and 426346-04, Chetram, 1993) for simazine. EC_{25} values (for seedling emergence and vegetative vigor shoot weight) of the tested species were used with the slope of the dose-response relationship for each species to calculate EC_{10} to EC_{90} effect levels. Plant species with high (steep) slopes show large increases in toxicity from small increases in exposure, whereas species with low (shallow) slopes show small increases in toxicity from relatively large increases in exposure. A log normal toxicity distribution is assumed. Effects values were entered into an Excel spreadsheet assuming Tier I AgDRIFT (Version 2.01) deposition distance results and a maximum simazine application rate of 9.6 lb ai/A.
The effect levels (EC_{10} to EC_{90}) for all 10 test terrestrial plant species were compared to estimated environmental concentrations resulting from spray drift to display the distances to which a particular effect level is expected to occur. For example, the height of the bar associated with an effect of 10% is the downwind distance at which spray deposition is expected to be equal to the EC_{10} toxicity level. The height of the bar associated with an effect of 90% is the downwind distance at which spray deposition is expected to be equal to the EC_{90} toxicity level. The downwind distance from the application site is shown on the vertical axis, and plant species and percent effects values are shown on the horizontal axes.

Ground Application

The ground application model conditions assume a 10 mph wind. Figures D-1 and D-2 illustrate the potential seedling germination effects to nontarget plants downwind from a single ground application (9.6 lb ai/A) of simazine, based on upper-bound (high boom, fine spray) and lower bound (low boom, medium/coarse spray) deposition distances, respectively. Figures D-3 and D-4 illustrate the potential vegetative vigor effects to nontarget plants downwind from a single application of 9.6 lb ai/A simazine, based on upper-bound (high boom, fine spray) and lower bound (low boom, medium/coarse spray) deposition distances, respectively. Although Figures D-1 through D-4 show effects levels, they do not show distances at which plants are likely to be killed outright. When plants are tested by pesticide companies for efficacy, a 70% effect level is generally considered to be a threshold for lethal effects to a healthy weed (Pallett, 2003). Therefore, the EC_{70} effect level is used to provide an estimate of when non-target plants are expected to have a high likelihood of rapid death, similar to the desired effect for weed species. In general, ground applications using high boom and fine sprays are expected to produce higher drift levels than low boom and medium/coarse sprays, resulting in greater phytotoxicity at greater downwind distances.

The results of the seedling emergence toxicity test show that nine out of the ten plants tested exhibit adverse effects when exposed to simazine at application rates of 4.0 lb ai/A. Reduction in dry weight was observed in all six dicots (radish, soybean, lettuce, tomato, cucumber, cabbage) and two monocots (oats and ryegrass). Shoot height reduction was observed in the monocot, onion. The only plant that exhibited no adverse effects following simazine exposure at 4.0 lb ai/A was the monocot, corn. Under the highest ground boom drift conditions (4 foot boom and fine spray; Figure D-1), all the tested plant species, with the exception of corn and radish, would be expected to be killed in the area that stretches from approximately 50 to 400 feet downwind of the treated field. Under the same conditions of high boom and fine spray, plant species are expected to be affected at the EC_{10} level at distances ranging from 500 to 700 feet for oats, cabbage, tomatoes, ryegrass, cucumbers, and soybeans and >1,000 feet for lettuce, onion, and radish. Under the lowest ground boom drift conditions (2 foot boom and medium/coarse spray; Figure D-2), onion, oats, cabbage, tomatoes, ryegrass, cucumber, and soybean would be expected to be killed in the area that stretches approximately 10 to 35 feet downwind of the treated field. In addition, lettuce would be expected to be killed at downwind distances of approximately 60 feet. Tested species, under similar low boom and medium/coarse spray, would be expected to be affected at the EC_{10} level at 70 - 200 feet (cabbage, oats, tomatoes, ryegrass, cucumbers, and soybeans) and 650 to >1000 feet (lettuce, onion, and radish).

The results of the vegetative vigor toxicity test show that only one out of the ten plants tested, corn, show no adverse effects when exposed to simazine application rates of 4.0 lb ai/A. For nine of the affected plant species, the most sensitive endpoint for the vegetative vigor test is dry weight. Reduction in shoot height was observed as the most sensitive endpoint in only one monocot (ryegrass). Under the highest ground boom drift conditions (4 foot boom and fine spray; Figure D-3), four plant species (radish, soybean, cucumbers, and ryegrass) would be expected to be killed in the area that stretches from 40 to 100 feet downwind of the treated field. In addition, two species (onion and cabbage) and three species (oats, tomatoes, and lettuce) would be expected to be killed in areas that stretch from 100-200 feet and from 200-300 downwind of the treated field, respectively. Under the same conditions of high boom and fine spray, 3 species (radish, soybean, and ryegrass) are expected to be affected at the EC_{10} level at distances of 100 to 450 feet. In addition, test species including lettuce, oats, cucumber, tomato,

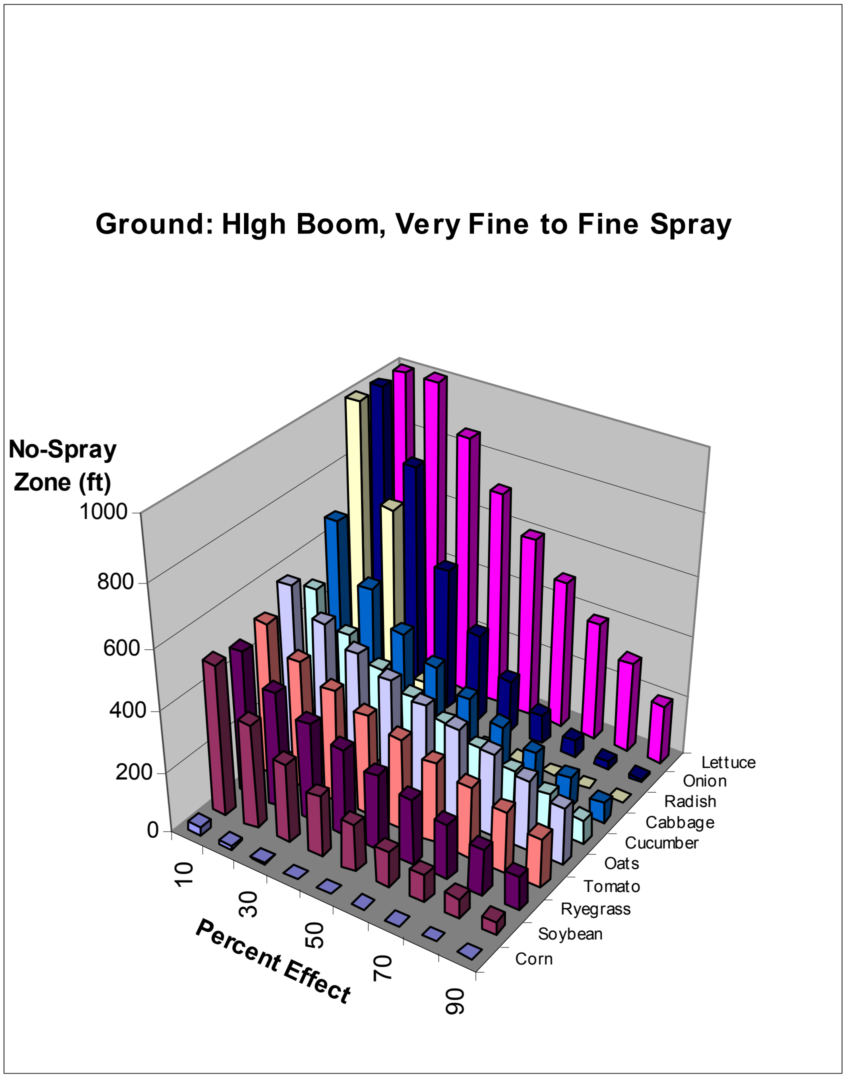

Figure D-1. Predicted **seedling emergence phytotoxicity** levels and associated downwind distances from a **ground boom** application conducted with a **fine spray** in an approximate 10 mph wind with a **4 foot release height** at an application rate of 9.6 lbs ai simazine per acre.

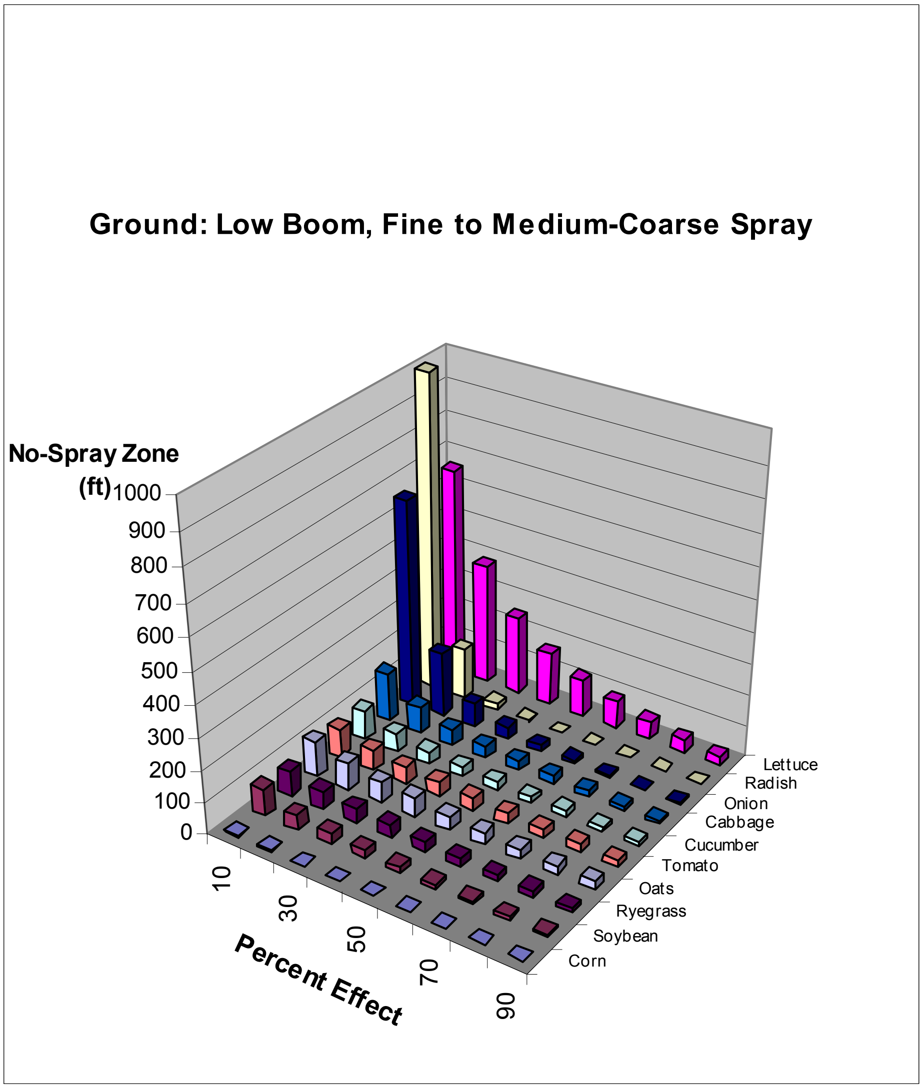

Figure D-2. Predicted **seedling emergence phytotoxicity** levels and associated downwind distances from a **ground boom** application conducted with a **medium/coarse spray** in an approximate 10 mph wind with a **2 foot release height** at an application rate of 9.6 lbs ai simazine per acre.

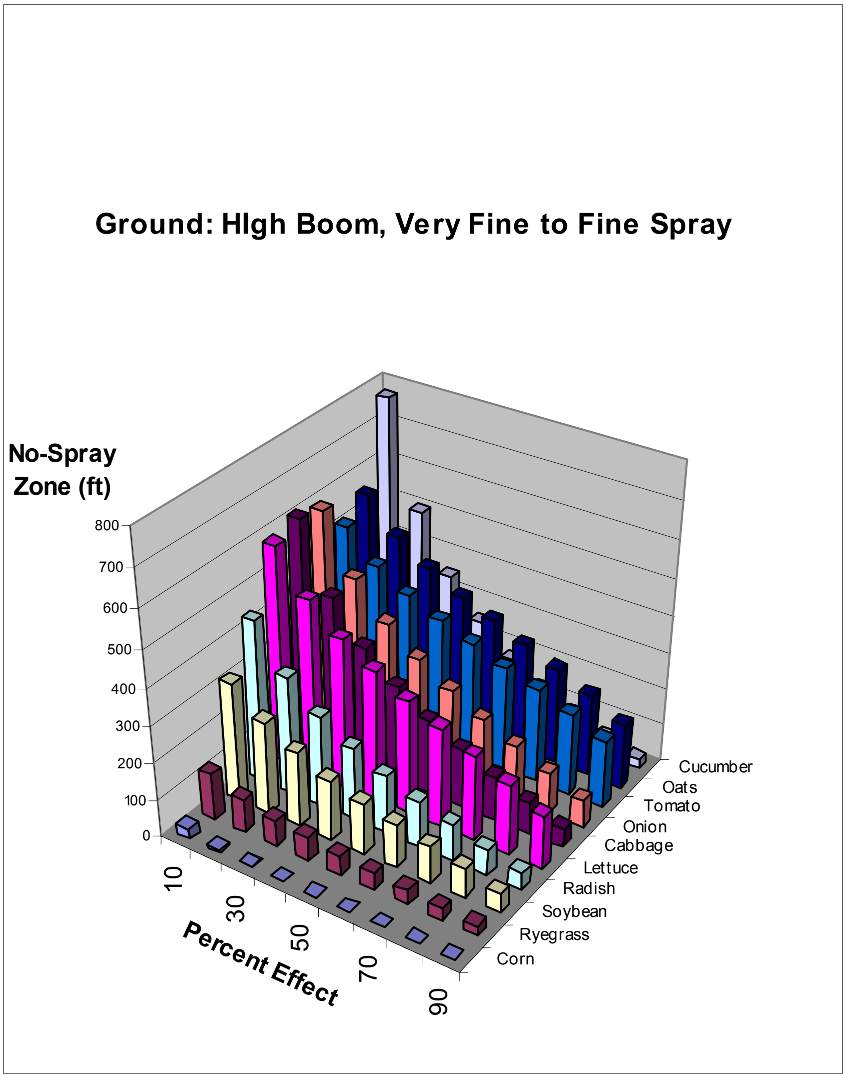

Figure D-3. Predicted **vegetative vigor phytotoxicity** levels and associated downwind distances from a **ground boom** application conducted with a **fine spray** in an approximate 10 mph wind with a **4 foot release height** at an application rate of 9.6 lbs ai simazine per acre.

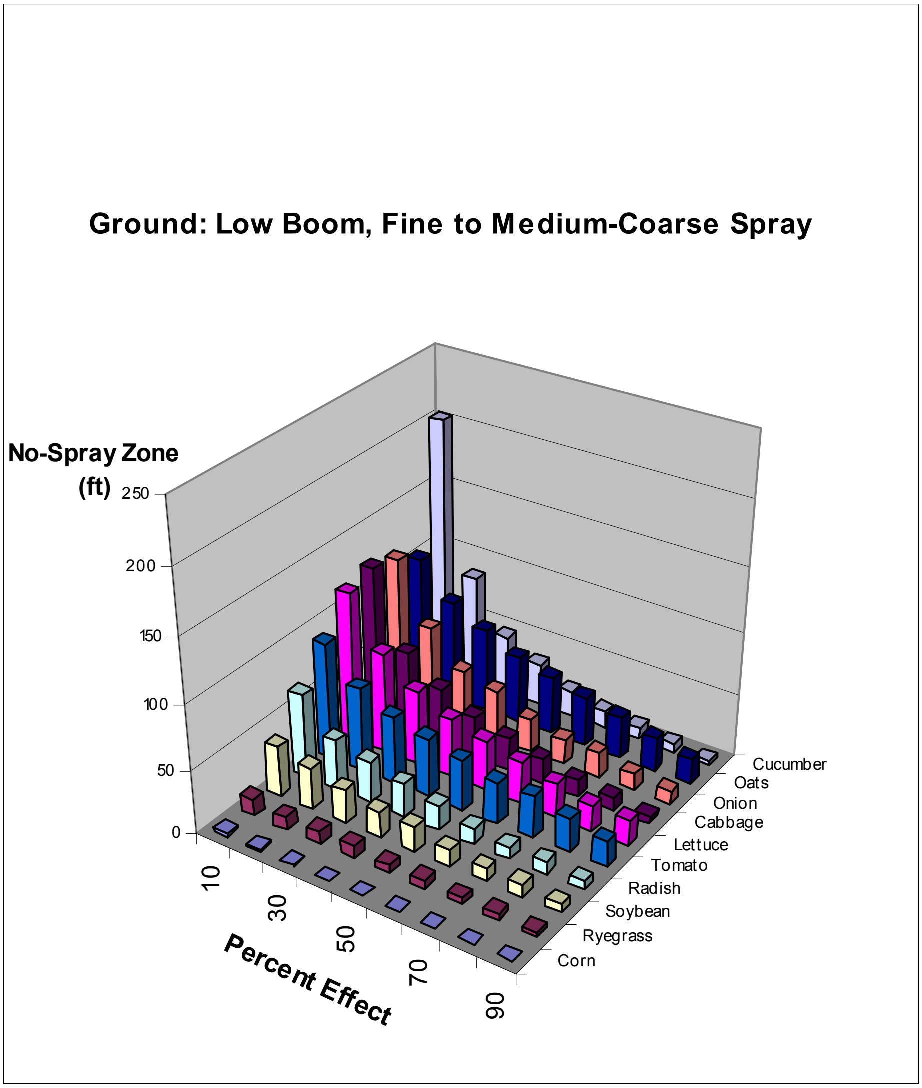

Figure D-4. Predicted **vegetative vigor phytotoxicity** levels and associated downwind distances from a **ground boom** application conducted with a **medium/coarse spray** in an approximate 10 mph wind with a **2 foot release height** at an application rate of 9.6 lbs ai simazine per acre.

onion, and cabbage would also be affected at the EC_{10} level at distances ranging from 500 to 800 feet. Under the lowest ground boom drift conditions (2 foot boom and medium/coarse spray; Figure D-4), the nine affected plant species would be expected to be killed in the area that stretches ≤ 35 feet downwind of the treated field. Tested species, under similar low boom and medium/coarse spray, would be expected to be affected at the EC_{10} level at approximate distances of ≤ 100 feet for tomatoes, radish, soybean and ryegrass, and >100 to 200 feet for oats, lettuce, cucumber, onion, and cabbage.

Aerial Application

For aerial application of simazine, Tier I aerial AgDRIFT modeling input parameters (i.e., 10 mph wind and a 10 foot release height) were assumed. Figures D-5 and D-6 illustrate the potential seedling emergence effects to nontarget plants downwind from a single aerial application (9.6 lb ai/A) of simazine, based on upper-bound (fine to medium spray) and lower bound (medium to coarse spray) deposition distances, respectively. Figures D-7 and D-8 illustrate the potential vegetative vigor effects to nontarget plants downwind from a single aerial application of simazine, based on upper-bound (fine to medium spray) and lower bound (medium to coarse spray) deposition distances, respectively. In general, fine to medium sprays are expected to produce higher drift levels than medium to coarse sprays, resulting in greater phytotoxicity at greater downwind distances.

Under the highest drift conditions (fine to medium spray; Figure D-5), all tested plant species, with the exception of corn and radish, would be expected to be killed from seedling emergence effects (i.e., EC_{70}) in the area that stretches >900 feet downwind of the treated field. Species expected to be affected at the seedling emergence EC_{10} level at distances of >1,000 feet include all tested species, with the exception of corn. Under the lowest aerial drift conditions (medium to coarse spray; Figure D-6), ryegrass, cucumber, cabbage, soybean, and onion would be expected to be killed in the area that stretches approximately 130 to 400 feet downwind of the treated field. In addition, tomatoes and oats would be expected to be killed in areas approximately 570 to 760 feet downwind of the treated field, and lettuce at distances >1000 feet. All tested species, except corn, would be expected to be affected at the EC_{10} level at approximate distances of >1,000 feet, under aerial application of medium to coarse spray.

Under the highest aerial drift conditions (fine to medium spray; Figure D-7), all plant species, with the exception of corn and ryegrass, would be expected to be killed via foliar exposure in the area that stretches > 1,000 feet downwind of the treated field. Ryegrass would be expected to be killed in areas approximately 600 feet downwind of the treated field. Under the same conditions of fine to medium spray, all tested species, with the exception of corn, are expected to be affected at the EC_{10} level at distances of >1,000 feet. Under the lowest aerial drift conditions (medium to coarse spray; Figure D-8), all tested species, with the exception of corn and radish, would be expected to be killed in the area that stretches approximately 200 to 70 feet downwind of the treated field. All tested species, except corn, would be expected to be affected at the EC_{10} level at approximate distances of >1,000 feet, under aerial application of medium to coarse spray.

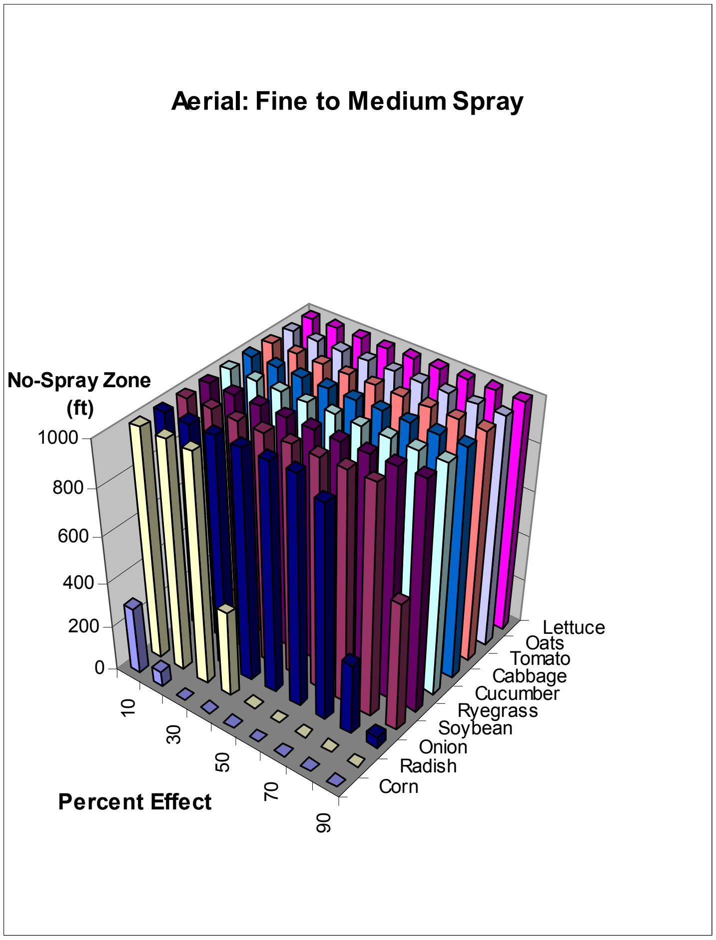

Figure D-5. Predicted **seedling emergence phytotoxicity** levels and associated downwind distances from an **aerial** application conducted with a **fine to medium spray** in an approximate 10 mph wind with a 10 foot release height at an application rate of 9.6 lbs ai simazine per acre.

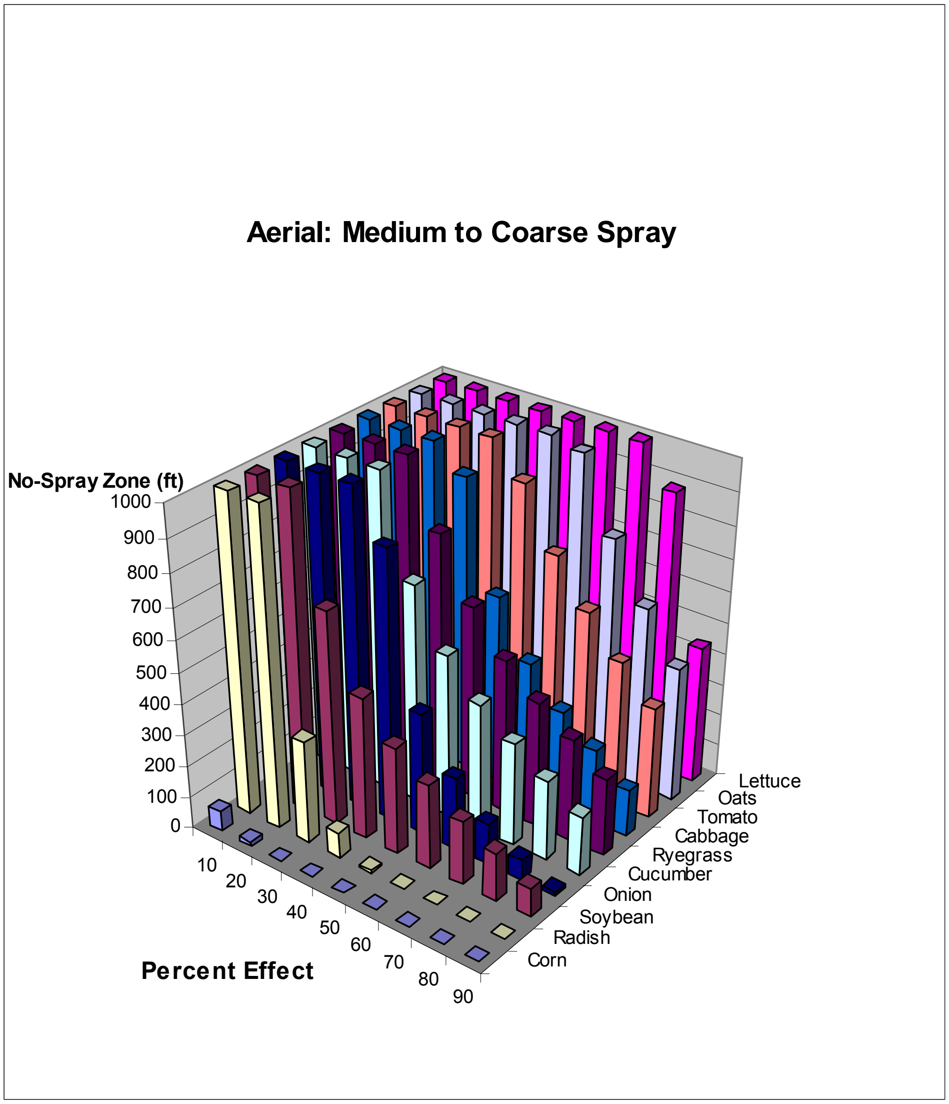

Figure D-6. Predicted **seedling emergence phytotoxicity** levels and associated downwind distances from an **aerial** application conducted with a **medium to coarse spray** in an approximate 10 mph wind with a 10 foot release height at an application rate of 9.6 lbs ai simazine per acre.

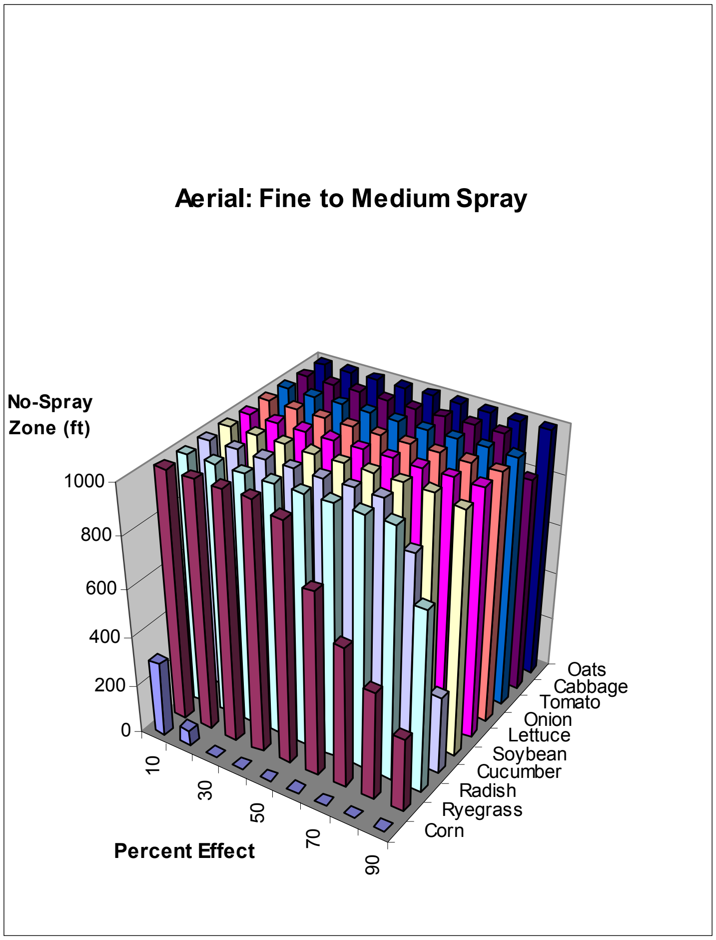

Figure D-7. Predicted **vegetative vigor phytotoxicity** levels and associated downwind distances from an **aerial** application conducted with a **fine to medium spray** in an approximate 10 mph wind with a 10 foot release height at an application rate of 9.6 lbs ai simazine per acre.

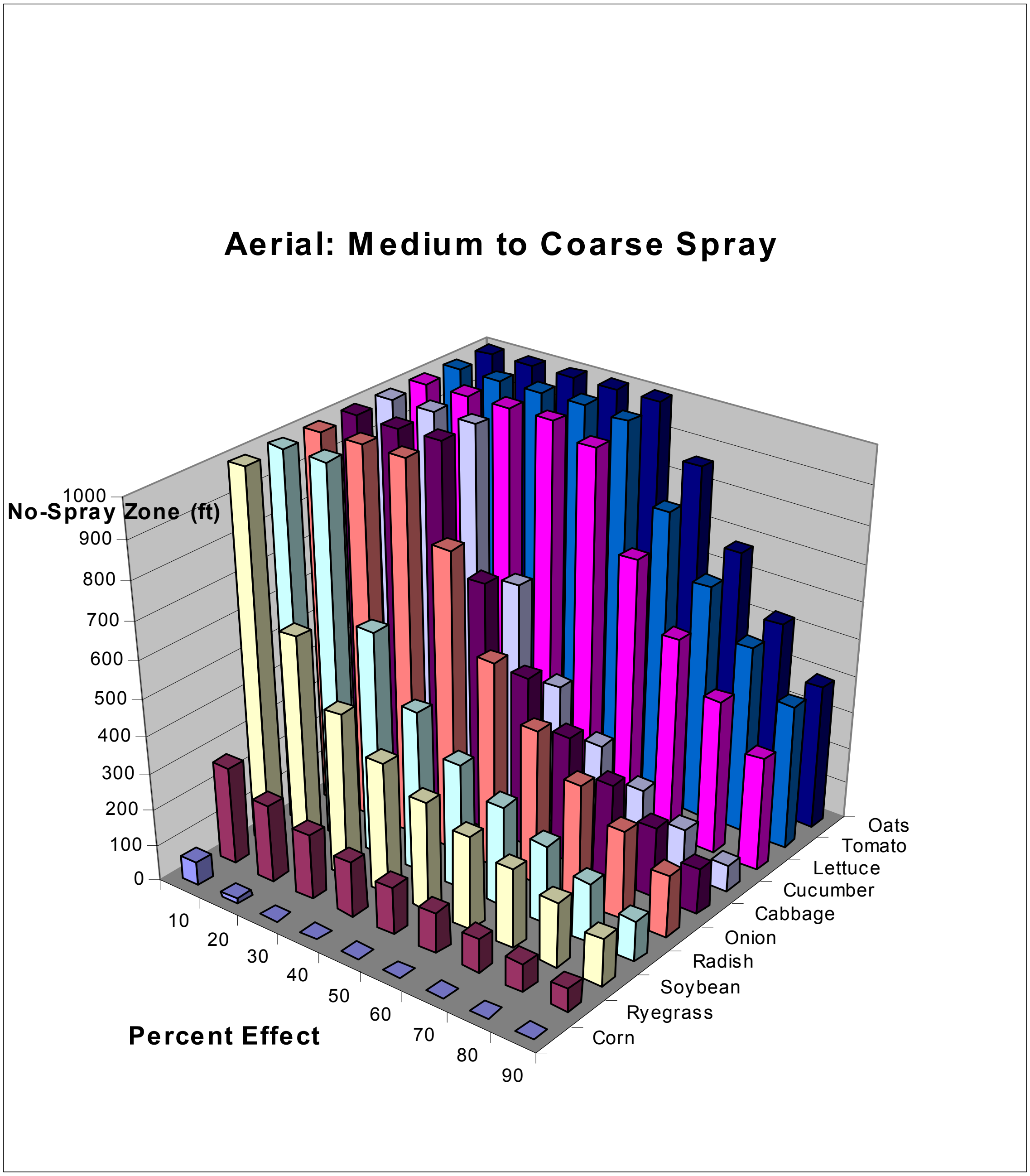

Figure D-8. Predicted **vegetative vigor phytotoxicity** levels and associated downwind distances from an **aerial** application conducted with a **medium to coarse spray** in an approximate 10 mph wind with a 10 foot release height at an application rate of 9.6 lbs ai simazine per acre.

Labeling

The results of this analysis suggest that mandatory product labeling that places restrictions on droplet size, release height, wind speed and potentially flight speed for aerial applications and droplet size and boom height for ground boom application may reduce risks associated with simazine applications. Any resulting label language should identify ASAE S-572 as the droplet sizing standard.

Uncertainties

There are a number of uncertainties associated with the assessment of potential effects of simazine spray drift to plants. It may be possible to further refine this assessment with additional information addressing the following uncertainties:

- **The representativeness of tested species for non-target plant species in simazine use areas**. It is possible that woody and other perennial plant species may be exposed to spray drift in simazine use areas; however, their sensitivity to simazine is unknown. Toxicity data on a wider range of plants could be used to reduce uncertainty related to the potential effects of simazine on perennial and woody species at field edges and downwind of treated fields.

- **The adequacy of laboratory spraying treatments in representing spray drift far from field boundaries**. Plants in laboratory studies are exposed to herbicide in volumes of carrier that are adequate to cover the test plants and/or soil. Plants exposed to spray drift downwind of field boundaries would contact the same amount of herbicides tested in the laboratory, but in much lower volumes of carrier. Plants are exposed to spray drift far away from the field edge in discrete spots where droplets impact the plant foliage, whereas plants are covered with a diffuse coating in lab studies. Off-site spray drift onto the soil surface and foliage is unlikely to be uniform due to many factors including structural interception, wind speed, wind velocity, particle size, soil topography, etc. The effect of small concentrated exposures relative to diffuse exposure is uncertain. Data on the effect of exposure volume on phytotoxicity could be used to refine effect level estimates.

References

Chetram, R.S. 1993. Simazine: Tier 2 Seedling Emergence Nontarget Phytotoxcity Study Using Simazine: Lab Project Number: 92058. Unpublished study prepared by Ciba-Geigy Corp. 218 p. (MRID # 456346-03).

Chetram, R.S. 1993. Simazine: Tier 2 Vegetative Vigor Nontarget Phytotoxcity Study Using Simazine: Lab Project Number: 92059. Unpublished study prepared by Ciba-Geigy Corp. 238 p. (MRID # 456346-04).

Pallett, K. Efficacy testing processes n Industry: relevance for NTTP assessment. Efficacy Data Workshop. August 20, 2003. Office of Pesticide Programs, Crystal City, Arlington, VA.