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Field Study Using Fluorescent Blank Furadan® 15G Granules and a John Deere 7000 MaxEmerge Planter for the Reduction of Granule Exposure

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Abstract: Avian exposure to granular insecticides can be reduced by using novel planter technologies in conjunction with traditional methods of incorporating the granules during application. This study describes a field-based investigation that compares T-band and in-furrow application methods with and without a granular cut-off device. Fluorescent blank Furadan 15G granules were used throughout the study to allow a photographic (and therefore a quantitative) record of exposed granules at the mid-field, lift, post-lift, turn-row, and post-drop positions. These data clearly indicate that in-furrow application significantly reduced exposed granules when compared to T-band application. The cut-off device also significantly reduced exposed granules in the turn-rows, when used in conjunction with T-band or in-furrow application. Of the four treatment regimens, the in-furrow application with the cut-off device resulted in the greatest reduction of exposed granules.

Intended Audience: This research is intended for those individuals working in the areas of pesticide applications, safety, and education.

1. Introduction and Objective

The use of Furadan® (active ingredient: carbofuran) and other granular insecticides have contributed substantially to greater agricultural yields (Gallagher, 1983); however, potential impacts of these agrochemicals to avian species are of concern to the U.S. Environmental Protection Agency (EPA) (Urban and Cook, 1986; USEPA, 1985; USEPA, 1989), because of the acute oral toxicity to birds (Balcomb, Stevens, and Bowen, 1984; Hill and Camardese, 1984). One possible way to reduce bird exposure and potential risk from granular insecticides is to reduce granule leakage and exposed granules due to these application methods.

The cut-off device was developed by FMC Corporation as a means to reduce leakage of insecticide granules during corn planting. The cut-off device is activated through the corn planter's hydraulic system whenever the planter is raised, and is designed to close the granule metering orifice automatically, thus reducing granule leakage during turn-row operations. Technologies, such as the cut-off device, and modification of agricultural practices, such as requiring T-band or in-furrow rather than standard band application of Furadan®, to reduce avian exposure to insecticide granules, have not been evaluated in replicated studies using a John Deere 7000 MaxEmerge planter. Accordingly, the objective of this study was to determine the reduction and distribution of exposed fluorescent blank Furadan® 15G granules when comparing in-furrow application with T-band application, both with and without the use of the cut-off device.

2. Materials and Methods

2.1 Location and Length of Study

A single agricultural field in Champaign, Illinois was divided into eight blocks and each block was divided into four study plots (Fig. 1). The planter was calibrated on 9 July 1990 and the granules were applied and photographs taken on 19-20 July 1990.

Experimental Design and Randomization Procedures

The following four treatment combinations were monitored:

1) In-furrow application with use of the cut-off device;
2) In-furrow application without use of the cut-off device;
3) T-band application with use of the cut-off device; and
4) T-band application without use of the cut-off device

Treatments were randomly assigned to the study plots (Fig. 1). Each of the eight blocks received all four treatment combinations.

2.2 Field Chemical Methods

2.2.1 Chemicals used in the study

Six 50 lb bags of blank (i.e., no carbofuran present) granules were treated by FMC (Lot Nos. PL90-123, PL90-214) with Calcofluor® fluorescent dye (BASF Co., Parsipanny, NJ; 1 g dye/100 ml methyl alcohol) and shipped to Champaign for use in measuring granule exposure

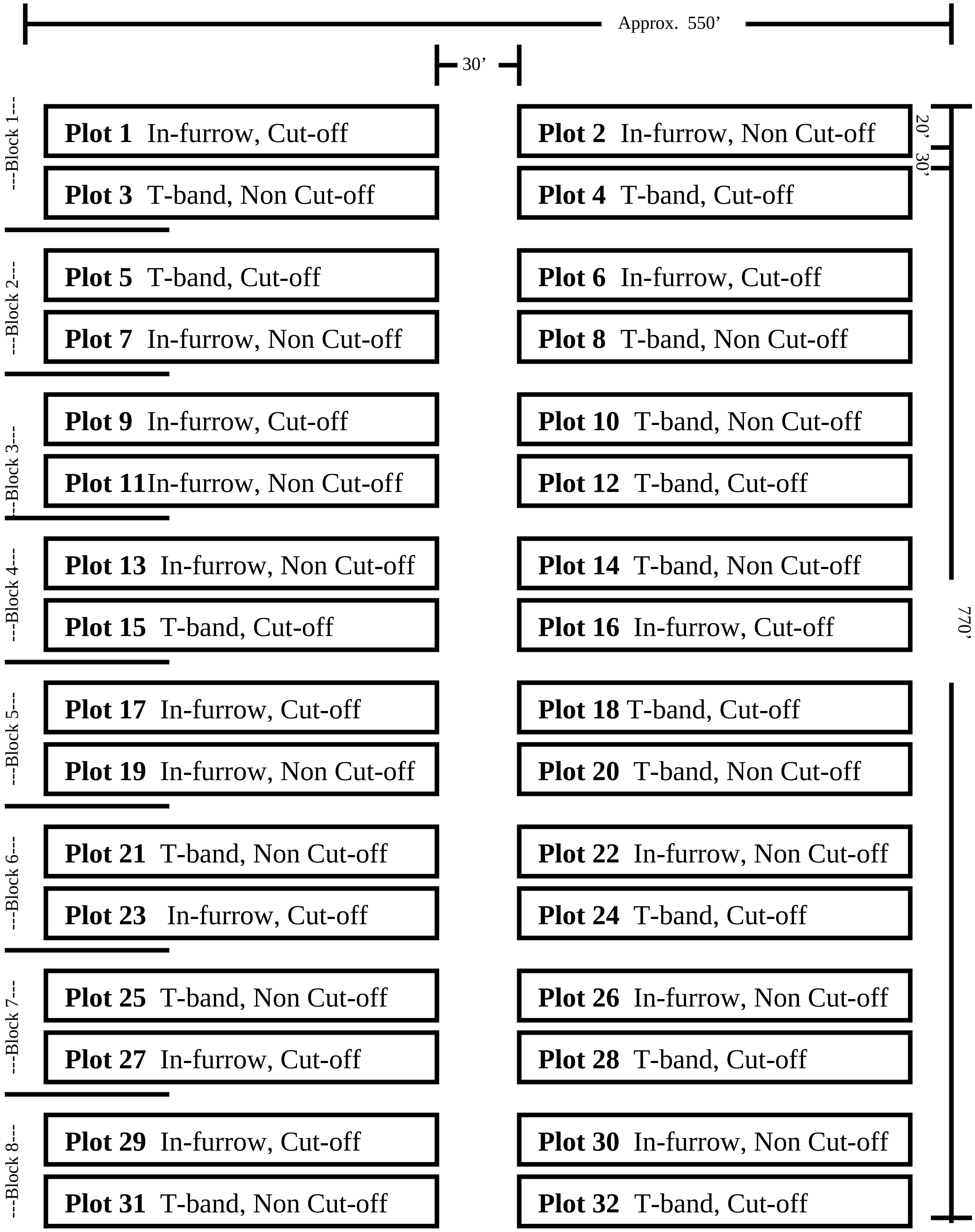

Figure 1. Schematic diagram of study plots showing the statistical design and treatment assignment to the four plots within each block.

and density on the soil surface. All bags of fluorescent granules were stored in dry locations. The blank fluorescent granules were delivered by Environmental Labs Inc (ELI) personnel to the study pots at the time of application. The purity and stability of the test material (blank fluorescent sand core granules) is not applicable, since this study was strictly a granule count investigation.

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2.2.2 Planter

A 4-row John Deere 7000 MaxEmerge planter equipped with a cut-off device and both in-furrow and T-band applicators was used to apply the blank fluorescent granules to the study plots. The cut-off device could be engaged or disengaged by a single switch located on the planter. The planter was changed to either T-band or in-furrow application by simply switching a section of polypropylene tubing.

2.2.3 Calibration procedures

Prior to planter calibration, the triple-beam balance used to weigh granules was calibrated for accuracy using standard weights. For planter calibration purposes, each of the four insecticide hoppers on the planter was partially filled with fluorescent granules and fitted with a calibration tube. A 91.44 m (300 ft) section of the field was marked off using a tape measure. Each planter was operated under normal planting conditions throughout the measured distance of 91.44 m (300 ft) required for calibration, and weights of the granules released were recorded for each calibration tube as grams per tube (g/tube). The planter speed was approximately 8.1 km/h (5 mph).

Calibration runs were repeated until g/tube was within ± 10% of the expected 69.6 g/tube for each insecticide hopper. Three verification runs were performed and the mean g/tube for each hopper was calculated (Table 1). A value of 69.6 g/tube (278 g total for all four hoppers) was equivalent to 1.33 lb a.i. per acre (ac), or 8.9 lbs Furadan® 15G/ac. This was equivalent to a 1.0 lb a.i./ac application rate based on a 40-inch row spacing.

Table 1. Deere 7000 MaxEmerge four-row Corn Planter used in Champaign, Illinois. Calibration units are mean g/tube; FMC Fluorescent Blank Furadan® 15G Study, Champaign, Illinois, 1990.

	Planter 2
Mean g/tube from verification runs	
Tube No.	
1	72.3 g
2	68.1 g
3	62.3 g
4	73.4 g
Mean (g/tube) observed	69.0 g
Standard deviation	±5.0 g
g/tube expected	69.6 g
% Difference†	-0.9 g
% RSD‡	7.3%
Km/h (mph)	~8.1 km/h (~5.0 mph)
Planter width in meters (ft)	3.1 m (10.0 ft)
Calib. dist. in meters (ft)	91.5 m (300 ft)
Square meters (feet)	283.7 m (3000 ft)
Linear feet/ac§	17424 ft
Lbs. formulation/ac	8.8 lbs

† % Difference = $\frac{\text{(mean g/tube observed – g/tube expected)} \times 100}{\text{g/tube expected}}$

‡ % RSD = % Relative Standard Deviation = (s.d./mean) × 100.

§ Linear feet/acre is based on 40-inch row spacing where: 43,560 ft/2.5 ft = 17,424 linear feet/acre.

2.3 Application of fluorescent granules

All planting procedures conformed to standard agricultural practices normally observed within the study area. All plots were planted with the same planter, and every attempt was made to maintain planting consistency between paired plots. Planting of field corn was done at a seeding rate of approximately 22,000-29,000 seeds/ac. End-rows were planted first in all plots. The number of end-rows planted was kept constant at 12. Each plot consisted of 8 rows (Fig 2).

The fluorescent granules were applied at a rate of 1.33 lb a.i./ac, which is equivalent to 1.0 lb a.i./ac with a 40-inch row spacing. All possible care was taken to avoid spillage while loading granules into insecticide hoppers in accordance with label instructions. If accidental spills occurred during granule loading, spill areas were covered or incorporated according to Furadan® 15G label directions.

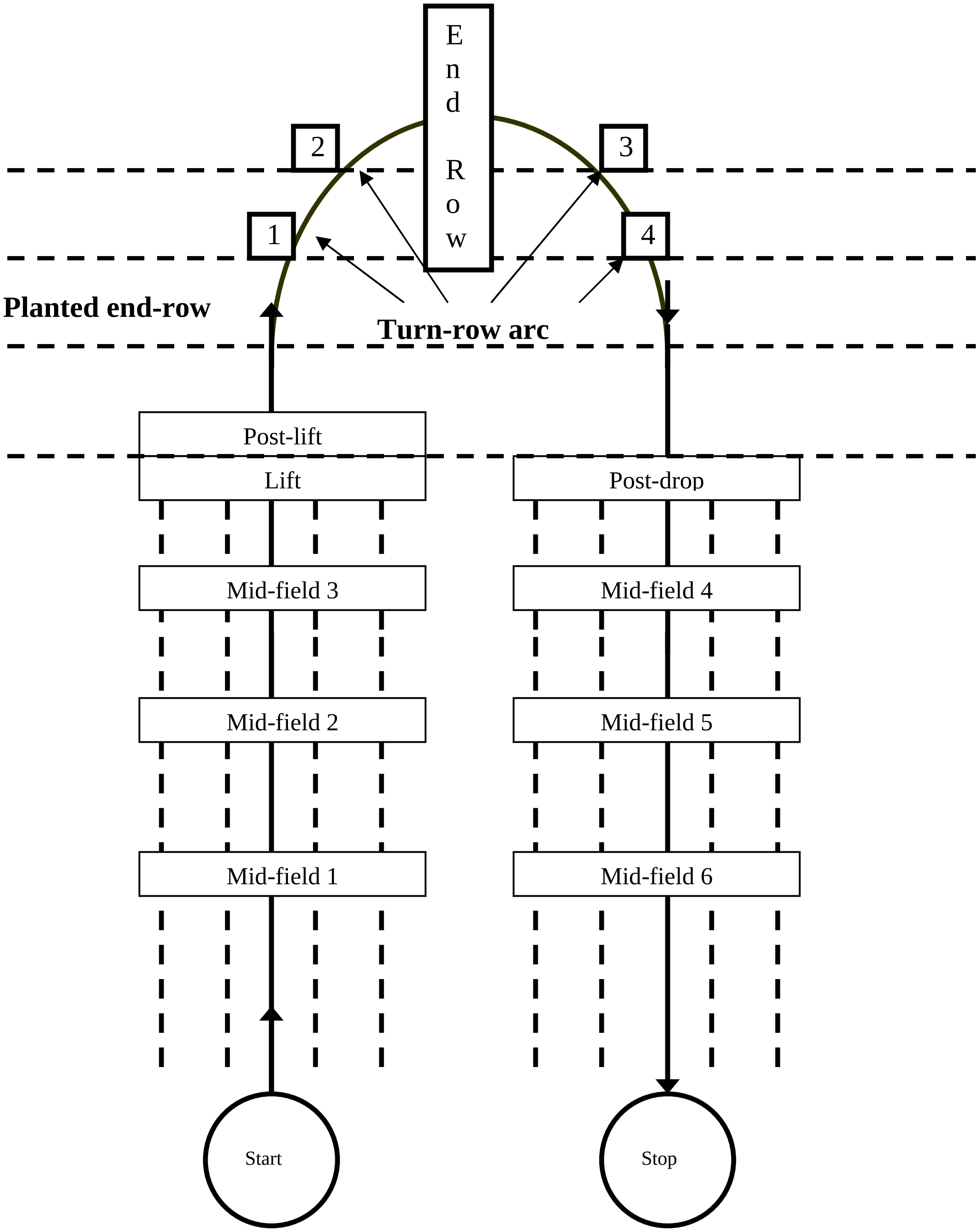

Figure 2. Schematic diagram of sampling locations (blocked areas) for photographing fluorescent granules in the planted field. Each rectangle represents a site where 4 photographs were taken. Each square represents a site where a photograph was taken.

2.4 Fluorescent granule counts

Proficiency of the method for detecting and counting fluorescent granules was determined by photographing a known number of fluorescent granules with a Nikon MF-12 35mm camera and making three independent granule counts of each slide. Color slides for detection proficiency purposes were taken on May 8, 1990, in freshly planted corn fields (not the study plots, but the soil appeared similar) in Carrollton, Illinois. Fluorescent granules were added to the soil substrate by scattering them from a small weighing vessel. The granules were placed onto the soil in seven different sample sizes by adding the granules into the samples 10 at a time (i.e., 10, 20, 30,…70) and photographed after each completed sample. Slides were presented independently to each of three granule counters in a random sequence. After the granules were counted, results were graphed as the number observed versus the actual known number, and regression analysis was performed on the data.

2.5 Field Photographic Methods

Distribution and density of Furadan® 15G granules on the soil surface of planted fields was determined by ultraviolet photography of fluorescent blank Furadan® 15G granules. Rectangular ultraviolet fluorescence analysis cabinets (Spectroline® CL-150 Ultraviolet Viewing System; Spectronics Corp., Westbury, NY 11590), designed for use with Polaroid CU-5 and standard 35mm cameras, were modified for use in the field. Polaroid CU-5 cameras were used for instant photographic print documentation of granule distribution. In addition, Minolta XG1 and XG7 cameras equipped with a Minolta data back G, and a Nikon MF-12 camera equipped with a Nikon MF-12 data back were used for 35mm photographic slide documentation.

Photography personnel placed flags in fields at locations where photographs were to be taken. Care was taken not to disturb areas being photographed. Four photographs were taken at each of the following positions: lift, post-lift, turn-row arc, end-row, post-drop, and six mid-field locations (Fig. 2). The terms lift, post-lift, turn-row arc, end-row, and post-drop describe the planter position as it makes the turn at the end of the field. End-row photographic positions were selected to maximize the number of exposed granules photographed. This maximum exposure of granules occurred where the paths of the four insecticide hoppers during lift around the turn-row crossed the end-row furrows. A single photograph was taken at each of the four turn-row locations as marked by a square (Fig. 2). A rectangular ultraviolet fluorescence analysis cabinet was placed lengthwise at designated end-row positions. Therefore, granules that leaked from the insecticide hoppers while in the raised position, and exposed granules due to end-row planting could be photographed simultaneously.

An ultraviolet fluorescence analysis cabinet was also placed lengthwise over the seed row to photograph fluorescent granules at these designated locations. At least one Polaroid photograph (B&W Type 107C) and at least one 35mm color slide (Fujichrome ASA 400) were taken at each flagged location. Field and photograph location were recorded directly on each slide using a data back with the 35mm cameras, and by writing the appropriate information on the back of each Polaroid photograph with waterproof ink. Each Polaroid photograph represented an area 24.94 cm x 21.59 cm (538.5 cm^2) or 11 in. x 8.5 in. (.065 ft^2) and each 35mm slide represented an area of 41.76 cm x 25.55 cm (1067 cm^2) or 16.44 in. x 10.06 in. (1.15 ft^2).

Granules visible in Polaroid photographs were counted by placing each photograph separately in a clear plastic cover and marking each granule on the cover with an overhead projection pen. A magnifying glass was used when necessary to count granules located close together. However, these Polaroid photographs were not used in the final analysis. Granules visible in 35mm slides were counted by projecting each slide onto a clean white sheet of plastic and marking each visible granule on the plastic using a permanent pen. Two individuals independently counted the visible granules on each photograph or slide.

Using the Poisson distribution as a model, the standard deviation was estimated as the square root of the mean of the two replicate counts. Granule counts further than the three standard deviations from the mean of the two replicate counts were defined as outliers. When outliers occurred, the slide was recounted independently by two individuals and the results tested again for outliers. If the recount showed no outliers, the recount results replaced the original counts in the data set for analysis. If outliers still occurred, the counts from that slide were not included in the granule density analysis.

2.6 Statistical Analysis

Granule count data were analyzed in two separate groups. The first group consisted of photographic observations in mid-field. The second group consisted of photographic observations made at the lift, post-lift, turn-row, end-row, and post-drop positions. Each group was analyzed by a weighted general linear model analysis of variance where, using the Poisson assumption, the weight was1/mean. The Poisson assumption was used primarily as a “quality control” unit in the model (Kotz and Johnson, 1986); however, the model was slightly different for each group.

For the mid-field group, the appropriate model was:

$Y_{ijk} = \mu + B_i + T_j + BT_{ij} + e_{ijk}$

where:

Y_{ijk} = mean granule density of the k^{th} mid-field location in the plot with treatment in block i,

μ = overall mean granule density,

B_i = effect of the i^{th} block, i = 1, 2, …, 8,

T_j = effect of the j^{th} treatment, j = 1, 2, 3, 4

BT_{ij} = block by treatment interaction effect

e_{ijk} = residual error term.

Because there was no complete replicate for the lift, post-lift, end-row, and post-drop locations the models for each location were:

$Y_{ij} = \mu + B_i + T_j + e_{ij}$

where:

Y_{ij} = mean granule density of the location with treatment j in block i,
μ = overall mean granule density of position,
B_i = effect of the i^{th} block, i = 1, 2, …, 8,
T_j = effect of the j^{th} treatment, j = 1, 2 ,3, 4
e_{ij} = residual error term.

The model for the turn-row arc position was:

$$Y_{ijk} = \mu + B_i + T_j + BT_{ij} + P_k + PT_{jk} + e_{ijk}$$

where:
Y_{ijk} = the mean granule density from the k^{th} arc position in the plot from block i with treatment j.
μ = overall mean granule density
B_i = effect of the i^{th} block, i = 1, 2, …, 8,
T_j = effect of the j^{th} treatment, j = 1, 2 ,3, 4,
BT_{ij} = block by treatment interaction effect
P_k = effect of the k^{th} position of the arc, k = 1, 2, 3, 4,
PT_{jk} = treatment by position interaction effect
e_{ij} = residual error term.

2.7 Quality Assurance Procedures

The Quality Assurance Unit (QAU) consisted of a QA director and assistant QA directors. The QAU monitored data collection in the field, reviewed raw data for compliance with the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) GLP Standards, made site visits to monitor the conduct of the study, inspected field activities (i.e. calibration of the corn planter, planting of the study plots, ultraviolet fluorescence photography), verified data entered into computer files, and made duplicate files of raw data.

3. Results and Discussion

3.1 Calibration

The planter was calibrated on July 7-9, 1990, at the FMC Research Farm in Champaign. Mean tractor speed for calibration was approximately 8.1 km/h (5.0 mph). A weight of 69.6 g of blank fluorescent granules per calibration tube was the goal for each tube (from each insecticide hopper) which is equivalent to 8.9 lbs Furadan® 15G/ac, calculated in the following manner:

$$\frac{8.9\ \text{lbs}}{43560\ \text{ft}^2} \times \frac{454\text{g}}{1\ \text{lb}} \times 3000\ \text{ft}^2 \times \frac{1}{4} = 69.62\ \text{g/tube}$$

Calibration results indicated that the planter delivered an average of 4.0 kg (8.8 lbs) of blank fluorescent granules/ac with an average precision (% relative standard deviation) of 7.3% (Table 1). The 35mm color slides were used to obtain counts of fluorescent granules. Results of a regression analysis (R^2=0.99) performed on granule count efficiency data indicate that fluorescent granules on the soil surface can be counted accurately using ultraviolet photography.

3.2 Application of Fluorescent Granules

Fluorescent blank Furadan® 15G granules were applied (in-furrow or T-band, with or without use of the cut-off device) to all plots within a the two-day period of July 19 and July 20, 1990 (Fig. 1).

3.3 Granule Counts

The 35mm color slides were used to obtain counts of fluorescent granules. In-furrow application, when compared to T-band applications, significantly reduced exposed granules in the mid-field, lift, and post-drop positions, but not in the post-lift and end-row positions (Fig. 3a-3e). The cut-off device significantly reduced the number of exposed granules in the post-lift, end-row, and post-drop positions but not in the mid-field or lift positions. Since the cut-off device was not activated in mid-field, significant granule count differences would not be expected. However, significant differences in granule counts at lift should be more evident since the cut-off device was activated. This may be partially due to drainage of granules already in the tube, past the cut-off device, at lift. Significant post-drop differences associated with the cut-off device were surprising since the cut-off device was not activated at that position. Note, however, that the differences were small.

P-values for the interaction term showed a significant effect only at post-drop. This means that the differences in T-band application and in-furrow application outside the turn-row area were not affected by the cut-off device and vice versa, except at the post-drop position.

A mean of 45.54 granules/ft^2 from T-band applications and a mean of 3.55 granules/ft^2 from in-furrow applications were observed by averaging the mid-field granule counts (Figure 3a). Thus, in-furrow application reduced the number of exposed granules when compared to T-band application by 92%. In addition, 3.55 exposed granules/ft^2 resulting from in-furrow application represented at 95% reduction when compared to 74 exposed granules/ft^2 with standard band application observed in a study (unpublished data) in Carrollton, Illinois using an International Harvester Cyclo 400 planter. All of these data are consistent with other reports (Erbach and Tollefson, 1983; Hummel, 1983) which also showed that band applications leave more exposed granules than in-furrow applications.

Averaging the results of the post-lift and end-row granule counts across both in-furrow and T-band, a mean of 117.75 exposed granules/ft^2 was observed when the cut-off device was used, and 292.45 exposed granules/ft^2 were observed when the cut-off device was not used. Furthermore, adjusting for granules placed previously during end-row planting (i.e., subtracting the mean of

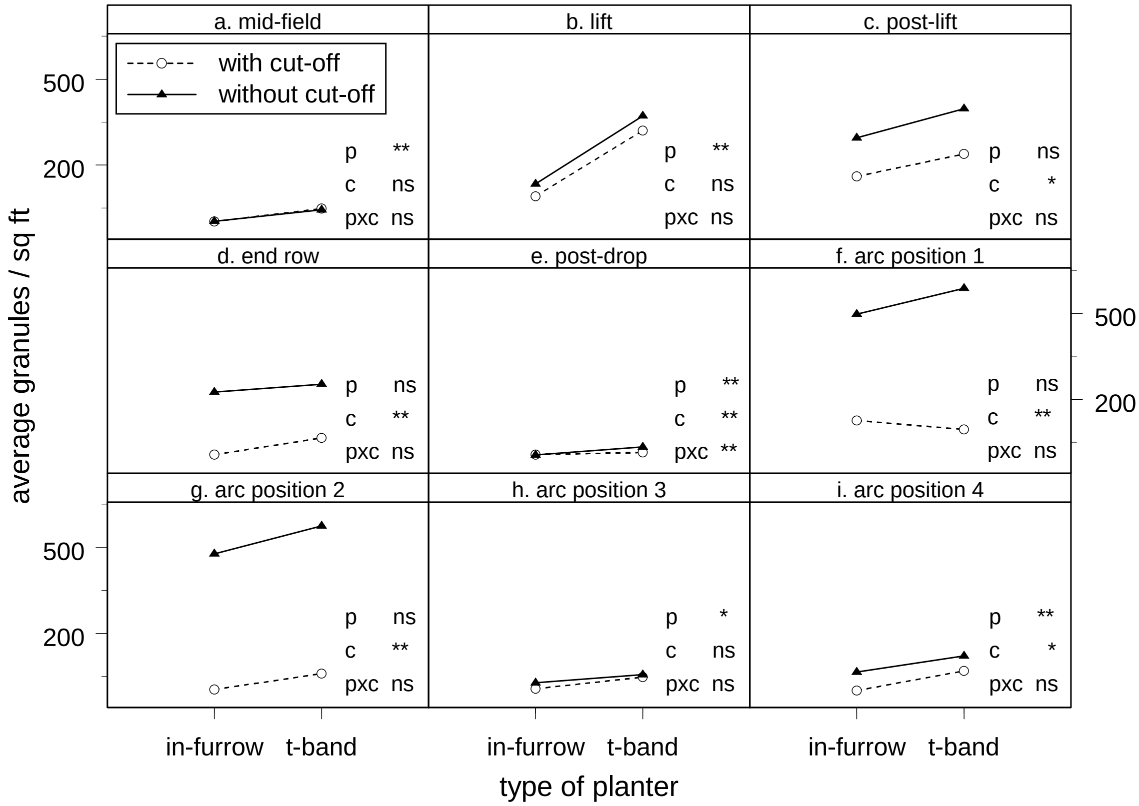

Figure 3. Average Fluorescent blank Furadan® granule counts / ft^2 from 9 sampling locations in study plots. Plots were planted with a John Deere 7000 MaxEmerge applicator equipped with two types of planters (in-furrow vs. T-band) combined with presence/absence of a cut-off device. The median standard error was 22% of the average count. Significance levels of the type of planter (p), cut-off device (c) and the interaction (pxc) effects for each sampling location are indicated as ns (p>.05), * (.01<p<.05), or ** (p<.01).

mid-field and post-drop counts, 117.75 less 17.86), 99.89 granules/ft^2 is the estimated additional exposed granule count resulting during the use of the cut-off device as compared to 270.97 granules/ft^2 (292.45 less 21.48) without the use of the cut-off device. This represents a 63% reduction in exposed granules with the cut-off device in the turn-row area, as measured by a combination of post-lift and end-row granule counts.

Figures 3f through 3i summarize granule counts by treatment and arc positions (1, 2, 3, or 4) in the turn-row area. Compared to non-cut-off, the cut-off treatment significantly reduced granules exposed in every arc position except position 3. Granule reductions ranged from 75% to 99%. Exposed granule counts were significantly higher in T-band application than in-furrow application in arc positions 3 and 4, but not in arc positions 1 and 2.

Overall, these data show that the cut-off device significantly reduced granules in all arc positions (except for position 3) for both in-furrow and T-band planting regimes. Reducing granular exposure in these turn row areas is of particular importance since the edge habitats are significant foraging areas for a variety of birds (Best, Whitmore and Booth, 1990). The planter modifications described in our paper are consistent with what has been recommended in the literature in improving pesticide application methods (Best and Fisher, 1991; Hart, Lewis, and Brown, 2003) as one of several ways to reduce avian exposure to granular insecticides.

Losses of songbirds that forage in agroecosystems will continue to be a concern until there is a complete understanding of the risk assessment process, including better application methods. Recent data (Pimentel, 2005) have suggested that bird losses from pesticides in the U.S. could approach $2.2 billion. Furthermore, granular formations could account for 10 to 52 million dead songbirds annually in the American corn belt. In Western Ontario, songbird mortalities were estimated at 244,000 to 1.3 million per acre from a granular pesticide (Environment Canada, 2002). However, other investigators (Knapton and Mineau 1995) have shown in a controlled field study that some granular applications resulted in no significant impact on adult song sparrows or on reproductive success. The latter study demonstrates that not ingesting granules in lethal doses or in amounts sufficient to affect reproductive success may significantly reduce bird mortalities.

In addition, some research shows that the relationship between avian risk and granules availability in asymptotic, not linear (Stafford and Best, 1999). This suggests that estimates of bird mortalities in literature could be overestimated. It seems reasonable that risk assessment models take into consideration both the availability of granules as well as the likelihood of consumption. Risk assessment models must also consider other factors such as the type of grit consumed by both graniverous and non-graniverous birds (Luttik and deSnoo 2004).

Since the EPA is particularly interested in the ecological risk assessment process for all agrochemicals, results from our paper should be useful in improving our understanding of the overall environmental risk assessment of pesticides to birds.

Conclusions

1. The in-furrow application method significantly reduced exposed granules when compared to the T-band method of application.
2. The cut-off device significantly reduced exposed granules in the turn-row portions of the study plots when used in conjunction with T-band application or the in-furrow application method.
3. The greatest reduction on exposed granules occurred when using in-furrow application with the cut-off device.
4. Still further reductions in exposed granules, beyond those reductions observed in this study, could be achieved by modifying the granule delivery tube system to allow for more rapid

discharge of granules at the time of lift. This could effectively reduce or eliminate further granule "dribble" from the delivery tube and thereby reduce wildlife risk in the turn-row areas of an agricultural field.

5. It is clear from these experiments show that future planter-modifications and/or novel incorporation methods…and field data collected from such modifications…could significantly improve our understanding of the ecological risk assessment process associated with granular insecticides and potentially reduce further avian mortalities.

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