MEASUREMENT OF SURFACE PESTICIDE RESIDUE IN SEEDING OPERATIONS

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R.C. Maze, JR. MEMBER ASAE
R.P. Atkins, ASSOC. MEMBER ASAE
P. Mineau,
B. T. Collins

ABSTRACT

The percentage of total seed or granules on the soil surface following seeding operations was evaluated. Implements seeding cereal and rapeseed crops were evaluated under different soil conditions. Overall percentages of seed or granules remaining on the soil surface varied from 0.077% to 6.960% of applied. Recommendations were made for decreasing the hazards to wildlife of chemically treated seeds or granules left on the soil surface. KEYWORDS. Seeders, Pesticides, Residue, Wildlife.

INTRODUCTION

The objective of this study was to determine how much coated seed and insecticide granules remained on the soil surface following typical prairie seeding and soil finishing operations. At present, most cereal seeds are treated with a pesticide and most oilseeds have pesticide granules added before seeding. Insecticide granules and pesticide-coated seeds, if not properly placed into the seedbed, present a readily available, highly concentrated source of chemical exposure to wildlife. Consumption of pesticide-coated seed and granules has caused numerous bird kills which have been documented in North America and elsewhere (Mineau, 1988; Greig-Smith, 1988). This study evaluates seed and granule placement efficiencies of four types of seeding equipment under ideal and adverse soil conditions using wheat and canola.

EQUIPMENT AND PROCEDURE

Using two seed types, the field performance of seeding implements was evaluated under summerfallow, stubble, single and double or cross-seeding conditions. Placement efficiencies were evaluated for the following implements*:

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Reference to a proprietary product or company is for specific information only and does not imply approval or recommendation of the product by the Alberta Farm Machinery Research Centre or the Canadian Wildlife Service at the exclusion of others which may be suitable.

The authors are **R. C. Maze**, Project Engineer, and **R. P. Atkins** Manager, Alberta Farm Machinery Research Centre, Alberta Agriculture Lethbridge, Alberta, Canada; **P. Mineau**, Head, Pesticide Evaluation Section, and **B. T. Collins**, Biostatistician, Wildlife Toxicology and Surveys Branch, Canadian Wildlife Service, Hull, Qu6bec, Canada.

1) International Harvester Model 100 double disk press drill; 2) Cereal Implements Model 2300 hoe drill; 3) Cereal Implements Model 1150 pneumatic seed application system.

Tobin Rapeseed (Certified No. 1) was combined with a substitute for granular Furadan CR-10 Systemic Insecticide (active ingredient Carbofuran 10%). The rapeseed and granular substitute were used to evaluate the seeding placement of the press drill, hoe drill, air seeder with harrow packer operation, and the air seeder surface broadcasting with a harrow packer application. Neepawa Wheat (Certified No. 1) was used in evaluating the seed placement of the press drill, hoe drill, air seeder with one harrow packer operation, and air seeder with a packer operation. All implements were representative of current production models.

A fluorescent dye was used to determine the amount of wheat seed and Carbofuran granules remaining on the surface. The dye, Fluorescien (1, 3-dihydroxybenzene phthalein), was applied to the wheat seeds and a non-soluble Carbofuran granular substitute as outlined in Atkins et al. (1989). Since Fluorescien had to be in a distilled water solution to exhibit fluorescence, it could not be applied to the soluble Carbofuran granules. Therefore, a ground wheat substitute (granule) for the Carbofuran was used. To ensure the suitability of the granule, a 100 g sample of Carbofuran was run through four sieves. The Carbofuran remaining on each sieve and passing through all the sieves was weighed. The granule was mixed in the same size proportions as the Carbofuran. The use of the granule was qualified using a mass density analysis. A difference in density of 0.36% was found between the Carbofuran and the granule.

Photographs using longwave ultraviolet light were taken of the soil surface. The dye-coated seed and granule remaining on the surface could easily be seen and seed placement determined. The photographic technique used to measure surface seed placement is discussed further by Atkins et al. (1989).

CALIBRATION

All seeding implements were calibrated to ensure proper seeding rates using either standard Alberta Farm Machinery Research Centre calibration test procedures or field calibration. Seeding rates were set, based on the calibration results, to 78.5 kg/ha for the wheat and 9.53 kg/ha for the canola/granule mixture. The standard rate of 2.8 kg/ha for Carbofuran was used. To ensure proper application rates, the amount of wheat and canola/granule used in each trial was determined in the field.

TEST PROCEDURE

Approximately 3.2 ha of land, 1.6 ha in wheat stubble and 1.6 ha in summerfallow, was used for the test. The minimum surface trash on stubble was 2000 kg/ha. Maximum trash cover was 7660 kg/ha. The average soil surface trash cover was 4020 kg/ha, corresponding to approximately a 2.7 tonnes/ha wheat crop.

The land, located 40 km north of Lethbridge, Alberta, Canada, was divided into 45 m by 9 m strips. Each strip constituted one test trial. Summerfallow strips were worked before testing with a cultivator with tine harrows to ensure an ideal seeding soil condition.

Moisture and stubble samples were taken to monitor surface soil conditions. Before each replication was made, three soil samples were taken randomly from the top 7 cm of the trial strip about to be seeded. To determine residue levels for stubble conditions three random 1 m² samples were also taken from each strip. The amount of seed put into the implement was also recorded. Wheat was seeded into moist soil at a depth of 5cm and canola at a depth of 2 cm. The same two-wheel-drive tractor was used for all trials at a speed of 8 km/h. Three replicates were made for each implement, soil condition and seed type. Double seeding for both summerfallow and stubble was accomplished by reseeding strips at a 45° angle to the initial seeding direction.

After the implement seeded the trial strip, a truck pulling a photographic box moved up the length of the strip. Ten random photographs of the soil surface were taken using the technique discussed by Atkins et al. (1989). After the completion of the test run, the amount of seed remaining in the implement was recorded and the seeding rate for the test determined. If any deviation from the required seeding rate occurred, alterations in the seed meter setting were made. To determine if there were any changes in soil moisture, three additional samples were taken from each trial strip. Soil samples were analyzed for moisture content and particle distribution.

ANALYSIS PROCEDURE

The percentage of seed or simulated insecticide granules remaining on the soil surface was found using photography. From inspection of the photographs of the soil surface, the number of seeds in each 0.5 m² photographed area was determined. A corrected value for the number of seeds per 0.5 m² was found by dividing the number of seeds in each photograph by a correction factor. This factor was used since it was not possible to ensure all seed and granule were coated with dye. The correction factors for wheat and the granule were 0.885 and 0.875, respectively. Details of the photograph calibration procedure, including use of the correction factor, is discussed by Atkins et al. (1989).

In 5 g of Carbofuran granules, 2219 granules were counted. The wheat was found to have 25 seeds/g. Using the number of seeds or granules/g, the mass of seeds and granules in each photograph was found. The total weight of granules or seeds/ha remaining on the soil surface was calculated for each test trial. The percentage of total granules or seeds that remained on the surface was calculated using the seeding rates.

A statistical analysis was carried out on the data. Numerous zeroes and ones were present in the photographic results, causing an 85.7% coefficient of variation in the data. Due to the high coefficient of variation, a square root transformation was carried out on the photographic data to normalize the distribution (Steel et al., 1980).

TABLE 1. Anova factors and levels

Factor	Level
Seeds (2)	Wheat
	Canola/granule
Soil conditions (2)	Summerfallow (ideal)
	Stubble (adverse)
Implements (4)	Air seeder harrow/packer application
	Air seeder packer application (wheat)
	Air seeder broadcast application (canola)
	Hoe drill
	Press drill
No. of seedlings (2)	Single
	Double

An analysis of variance (ANOVA) and multiple range test were performed on the normalized distribution (Welsch, 1977). A full factorial model and two random factors were used. The analysis consisted of four implements, two soil conditions and two seedings, a single and a double, as fixed factors (Table 1). The two random factors, nested within the cells of the fixed effect factors, were replicate trials and measurements within trials. Levels of each main effect were compared using the Ryan-Elinot-Gabriel-Welsh multiple range test (SAS Institute, 1988). ANOVA tables for both the wheat and canola/granule showed a significant among trial variance. Thus, the mean square error among trims was used as the error term for all F-tests and comparisons among fixed effects.

RESULTS AND DISCUSSION

SOIL TYPE AND MOISTURE CONTENT

Results of a Bouyoucos method of particle analysis indicated 17% sand content, 41% clay content, and 42% silt content. The textural class of the soil was a silty clay to silty clay 10am.

Soil moisture before seeding ranged from 2.0% (dry weight) to 38.3%. Average soil moisture before seeding was 17.0%. Soil moisture after seeding ranged from 2.1% to 32.9%, with an average value of 16.8%. Soft moisture conditions were considered typical for the Lethbridge area.

SEED AND GRANULE INCORPORATION DATA

Seed or granule mass remaining on the soil surface varied from 0.077 to 6.96% of total applied. For wheat seeding operations, an average of 0.660% of the total seed remained on the surface. Canola/granule seeding resulted in an average of 2.18% of the total granule remaining on the surface. Tables 2 and 3 contain overall surface seed placements for specific implements and soil conditions. Figures 1 and 2 graph the percentages of total seed and granule on the surface. Details of the factorial analysis (ANOVA) are provided in Tables 4 and 5.

SOIL CONDITION

The summerfallow and stubble represented ideal and adverse seeding conditions, respectively. Soil conditions provided no statistically significant difference among the means of the test results (Tables 4 and 5). Therefore, a procedure outlined by Sokal and Rohlf (1981) was used. The procedure, which made the soil condition significant at

TABLE 2. Surface seed placement results for wheat

Implement* (Regwq Grouping)	Soil Condition	Average Seed Count (0.5m²)	Average Seed Count (ha)	Average kg Seed (ha)	Percentage Total Seed On Surface
Air seeder har/pack (B)	Summer fallow,	0.23	4520	0.181	0.230
	S. fall. double	1.39	27870	1.115	0.710
	Stubble	0.41	8290	0.332	0.422
	Stubble double	0.45	9040	0.362	0.230
Air.seeder packer (B)	Summer fallow	0.34	6780	0.271	0.346
	S. fall. double	0.72	14310	0.573	0.365
	Stubble	0.23	4520	0.181	0.230
	Stubble double	0.30	6030	0.241	0.153
Press drill (A)	Summer fallow	2.75	54990	2.201	2.803
	S. fall. double	3.31	66290	2.653	1.690
	Stubble	0.41	8290	0.332	0.422
	Stubble double	2.07	41430	1.658	1.056
Hoe drill (B)	Summer fallow	1.32	26370	1.055	1.344
	S. fall. double	0.60	12050	0.482	0.307
	Stubble	0.08	1510	0.060	0.077
	Stubble double	0.26	5270	0.211	0.134

* Different letters indicate statistically significant difference among sample means (0.05% confidence level).

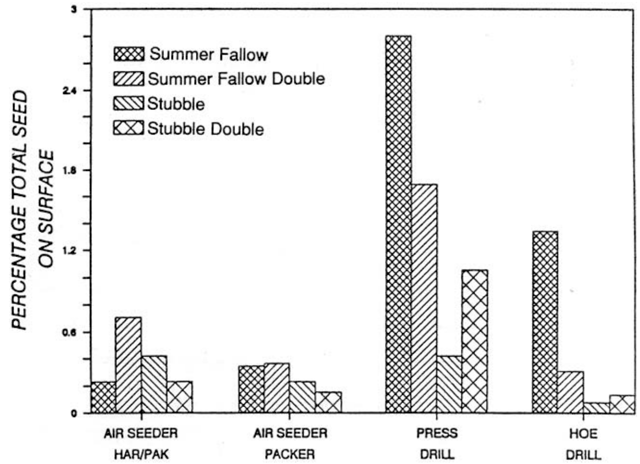

Figure 1-Percentage of surface wheat seed placement.

TABLE 3. Surface granule placement results for Canola/granule

Implement* (Regwq Grouping)	Soil Condition	Avg. Granule Count/ (0.5m²)	Avg. Granule Count/ (ha)	Avg. kg Granule/ (ha)	Percentage Total Granule On Surface
Air seeder har/pack (C)	Summer fallow	0.19	3810	0.009	0.307
	S. fall. double	0.50	9900	0.022	0.398
	Stubble	0.57	11430	0.026	0.920
	Stubble double	0.16	3150	0.007	0.127
Airseeder broadcast (B)	Summer fallow	2.59	51810	0.117	4.169
	S. fall. double	2.90	57900	0.130	2.330
	Stubble	1.37	27430	0.062	2.207
	Stubble double	2.06	41140	0.093	1.655
Press drill (A)	Summer fallow	3.31	66290	0.149	5.334
	S, fall. double	8.65	172950	0.390	6.959
	Stubble	2.93	58670	0.132	4.721
	Stubble double	4.42	88380	0.199	3.556
Hoe drill (C)	Summer fallow	0.45	9140	0.020	0.736
	S. fall. double	0.72	14480	0.033	0.582
	Stubble	0.23	4570	0.010	0.368
	Stubble double	0.57	11430	0.026	0.460

* Different letters indicate statistically significant difference among sample means (0.05% confidence level).

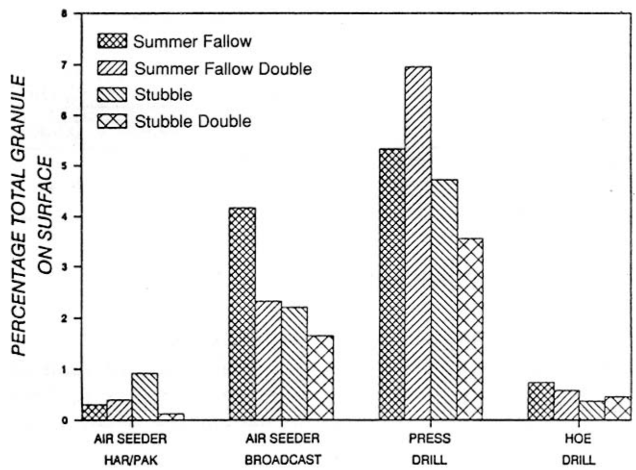

Figure 2-Percentage of surface granule placement.

the 5% level, combined the results of the wheat and canola/granule analysis. Thedifferences in the soil condition counts were at the 0.052 level of statistical significance for wheat. Soil condition count differences were significant at the 0.080 level for canola/granule. Overall, seed counts were higher in summerfallow than those in stubble. Higher counts in the ideal seeding conditions were attributed to less seed and granule being covered by surface residues.

IMPLEMENTS AND INTERACTIONS

For both wheat and canola/granule, the press drill had statistically significanthigher surface counts than all other implements (Tables 2 and 3). The air seeder broadcast operation gave statistically significant higher surface counts than the air seeder harrow packer and the hoe drill when seeding canola/granule.

AIR SEEDER HARROW PACKER OPERATION

Tests on the air seeder with a harrow packer application indicated an increase in surface seed counts when summerfallow was double seeded, compared to single seeded trials. This is in contrast with other seeding implements, which showed a decrease or little change in surface seed or granular placement when double seeding. The increase was attributed to the pitch angle of the cultivator shovels. The pitch angle caused the point of the sweep to operate slightly lower than the sweep wing. As a result, any later operations with the air seeder resulted in displacing previously sown seeds. Some of the previously sown seeds were displaced by the sweeps and exposed on the soil surface.

In stubble, going from single to double seeding resulted in a decrease in the surface seed placement for both the wheat and canola/granule mixture. This was mainly due to the action of the harrows. On the first operation into stubble, the harrows dragged along the surface trash, exposing the seedbed. Later operations resulted in better harrow action and less seeds being exposed.

AIR SEEDER PACKER OPERATION

Wheat was seeded with an air seeder followed by a single packer operation. Results were similar to those for the air seeder harrow packer operation. Under stubble conditions there was a slight advantage to using packers only, rather than a harrow packer operation. A single packer operation was also favorable in double seeding conditions. As mentioned before, the harrows tended to plug and disturb the seedbed.

TABLE 4. Analysis of variance for wheat

Source	DF	Type III SS	Mean Square	F Value	PRF
Implement, IM	3	22.76	7.59	5.07	0.0055
Soil conditions, SC	1	6.09	6.09	4.07	0.0520
Num. seedings, NUM	1	6.53	6.53	4.37	0.0447
IM * SC	3	4.23	1.41	0.94	0.4310
IM * NUM	3	1.95	0.65	0.43	0.7301
SC * NUM	1	0.11	0.11	0.08	0.7885
IM * SC * NUM	3	4.19	1.40	0.94	0.4348
TR (IM * SC * NUM)	32	47.85	1.50	3.14	0.0001
Error	432	205.81	0.48		
Corrected error	479	299.54			

TABLE 5. Analysis of variance for canola/granule

Source	DF	Type III SS	Mean Square	F Value	PRF
Implement, IM	3	173.82	57.94	49.33	0.0001
Soil conditions, SC	1	3.80	3.80	3.23	0.0816
Num. seedings, NUM	1	8.46	8.46	7.20	0.0114
IM * SC	3	2.33	0.78	0.66	0.5815
IM * NUM	3	7.40	2.47	2.10	0.1197
SC * NUM	I	1.00	1.00	0.85	0.3627
IM * SC * NUM	3	3.14	1.05	0.69	0.4561
TR (IM * SC * NUM)	32	37.59	1.17	2.43	0.0001
Error	432	209.22	0.48		
Corrected error	479	446.77			

Air Seeder Broadcast Operation

An air seeder harrow packer operation was used to broadcast canola/granule. The broadcasting operation had a statistically significant higher surface count than the conventional air seeder harrow packer or hoe drill. There was a reduction in granules on the surface when double seeding compared to single seeding on summerfallow. The decrease was due to the ability of the harrows to incorporate granules into the soil. Although twice the number of granules were applied to the surface, the extra pass with the harrow packer resulted in more granules being incorporated. A similar decrease occurred in stubble. Again, the amount of surface trash determined how wel! the harrows operated.

There was a decrease in the relative amount of surface seeds when stubble was seeded compared to seeding summerfallow. The amount of seed covered by surface trash increased when stubble was seeded compared to summerfallow.

All trials using a broadcast application resulted in higher surface granule counts than air seeder and hoe drill treatments.

Hoe Drill Operation

The hoe drill provided a statistically lower amount of exposed surface seed than the press drill and the air seeder broadcast operation. In the wheat and canola/granule seeding operations, double seeding on summerfallow decreased the amount of exposed seed or granule. For double seeding stubble, the opposite occurred, with an increase in exposed seed or granule. The amount of seed or granule covered by surface trash increased in stubble.

Press Drill Operation

In all trials, the press drill provided the maximum amount of exposed seeds. The maximum percentage, 6.97%, occurred when double seeding wheat on summerfallow. As expected, the press drill had less soil disturbance compared to the other implements used. This resulted in more seed being exposed even after packing or double seeding.

Press drills are typically known for their accurate seed placement under ideal seedbed conditions. If environmental concerns warrant, manufacturers may consider design modifications to ensure that seeds and granules are covered by soil. A simple solution would be the reintroduction of drag chains or furrow closing packers behind each opener. When requiring more positive placement under adverse soil conditions, a more aggressive opener design is required. Under such conditions, hoe openers or shanks used on cultivators are suitable.

Conclusions

Air seeder harrow packer operations were examined with a constant harrow aggressiveness setting used in all tests. Since harrow aggressiveness determined the depth and penetration at which the harrow worked, a different harrow setting may have resulted in different seedbed disturbance and seed incorporation.

Using typical conditions, numerous factors were set for the study. Soil type, travel speed, seeding depth, stubble height, trash levels, and seeding rates were unchanged throughout all trials. Variations of these factors could affect the overall surface seed placement results.

A greater hazard to wildlife may actually be caused by seed spillage during filling operations in the field. Future studies should take spillage into consideration.

Surface counts were obtained by a single overhead photograph. Stubble or soil contours may have hidden seed or granule from the camera's view. Observation of the soil surface from a few centimeters above the soil with variable angles of view (like foraging wildlife) may result in higher counts than those reported.

The total seed or granule remaining on the soil surface ranged from a minimum of 0.077% to a maximum of 6.96%. The average seed or granule remaining on the surface was 0.660% for wheat and 2.18% for canola/ granule. The average percentage of the total wheat seed remaining on the surface was 0.398% for the air seeder harrow packer, 0.274% for the air seeder packer, 1.49% for the press drill, and 0.466% for the hoe drill. For the canola/granule operations, the average percentage of total granule remaining on the soil surface was 0.438% for the air seeder harrow packer, 2.59% for broadcasting with the air seeder, 5.14% for the press drill, and 0.537% for the hoe drill.

When stubble was seeded, the trash covered the soil surface seeds and decreased the percentage of total seed visible on the surface. The press drill had statistically significant higher seed and granule surface counts than all other implements tested. Steps should be taken to ensure better seed coverage before packing if seeds are shown to be a hazard to wildlife.

The hoe drill, the air seeder with harrow packers, and the air seeder with packers were the most effective seeding devices in terms of least amount of exposed surface seed. The difference between the packer operation and the harrow packer operation was not significant for the air seeder. However, results indicate a packer operation, rather than a harrow packer operation, should be used to minimize surface seed placement.

If levelling is required, further work is necessary to determine optimum harrow settings.

When seeding equipment is taken out of the ground when turning at headlands, some seeA may be deposited on the soil surface. To determine if double seeding could benefit in such cases, further testing is required. However, double seeding inevitably increases the number of available seeds which may be placed on the soil surface. Therefore, double seeding should be minimized unless further research indicates that double seeding lowers overall surface residue by covering spills.

Design of seeding equipment is concerned with seed placement, trash clearance, soil moisture loss, erosion control, and other typical seeding problems. Any approach to redesigning seeding equipment to reduce wildlife pesticide exposure must be based on all factors involved in the design of agricultural machinery.

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