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SEED-SPECIFIC PLACEMENT OF IN-FURROW CROP PROTECTANTS

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Abstract

Recent trends in planting, toward lower seeding rates with more distance between seeds, have generated opportunities for improved application efficiency of in-furrow chemicals. Focusing the chemical application at the seed, and minimizing the chemical applied between seeds could reduce in-furrow inputs significantly. A seed-specific applicator was developed to apply discrete pulses of liquid chemical to individual seeds at planting. The applicator was prototyped in the UT Sensors and Controls Laboratory and field-tested in Spring 2002. Testing evaluated (1) the concept of seed-specific treatment and (2) the accuracy of the prototype applicator. In cotton plots inoculated with seedling disease, seed-specific fungicide application produced plant stands statistically identical to those produced by conventional fungicide application, while reducing fungicide inputs by 50%. In the accuracy tests, seed coverage varied from 55 to 98% depending on planter speed (2, 4, 6 mph) and spray band length (1 to 2.6 in.). A conceptual design for a multi-row seed-specific applicator has been developed, and additional field tests are planned for 2003.

Introduction

Recent technological advances in the electronics, defense, and automotive industries have provided new tools to maximize production efficiency. Tools such as Global Positioning Systems (GPS), variable rate controllers, and real-time sensors are allowing producers to address variability within fields and to focus chemical applications where the material will be the most beneficial. For example, producers can divide large fields into smaller areas for unique treatments, or treat individual clusters of weeds while ignoring the adjacent bare soil. Technological advances will likely improve the resolution of treatment area even further, until individual plants and seeds receive specialized treatments.

At the seed level, significant opportunities for improved application efficiency exist for in-furrow application of cotton fungicides. Cotton producers currently apply a continuous band of fungicide along the length of the furrow, as shown in Figure 1. However, Newman (1998) and Uniroyal (2001) suggest that fungicide applied between cottonseeds is wasted. Some experts believe that fungicide is only required in a localized (1- to 1.5-in.) zone around the seed. Assuming this is true, substantial savings could be realized by minimizing or eliminating the wasted material.

Current trends in planting are increasing the potential for such savings. Before the advent of transgenic seeds, producers typically planted at high seeding rates (five to eight seeds per row foot) because seed costs were low. Planting costs increased with the introduction of transgenic seeds. In addition to the basic seed cost, producers who plant these seeds must also pay a technology fee. To offset cost increases, producers are cutting seeding rates dramatically – down to two seeds per foot, in some cases. This increases the distance between seeds, which increases the amount of chemical wasted by a continuous application system. Applying fungicides seed-specifically would result in material savings of 75% at the two-seed/ft rate, assuming each seed received a chemical-band 1.5-in. long.

The advantages of seed-specific chemical application are numerous. From an economic standpoint, eliminating the wasted chemical between seeds should reduce in-furrow chemical costs by 50% or more. Although not easily quantifiable, environmental benefits associated with reduced chemical usage also exist. Furthermore, this technology could facilitate the labeling of new chemical products, which were previously cost-prohibitive to produce or unable to obtain regulatory approval. Clearly, seed-specific application could redefine in-furrow chemical usage by reducing costs, decreasing environmental impacts, and opening the market to new products.

While the above discussion of seed-specific application focused on in-furrow fungicides, this technology could be beneficial with other in-furrow chemicals, as well. Roberts et al. (1998) investigated the precision placement of in-furrow insecticides for controlling early season thrips. They concluded that precisely placing the insecticide at the seed provided comparable protection to the conventional method; however, they noted that no device currently exists to apply chemicals in this fashion. Precisely placing in-furrow starter fertilizer at the seed could provide similar benefits, although no reported research has evaluated this concept.

Materials and Methods

A prototype seed-specific applicator was developed to individually treat seeds with in-furrow liquid chemicals at planting. The conceptual design for the seed-specific applicator was as follows: (1) detect each seed as it passes through the seed tube; (2) track each seed from the point of detection to the point of chemical application; and (3) apply a discrete pulse of chemical spray to each seed and the surrounding soil, as the seed lands in the furrow. Design challenges and the prototype applicator are described below.

Design Challenges

The conceptual design of the seed-specific applicator is quite simple. However, several challenges complicate implementation. First, a sensor is required to detect each seed as it falls from the seed meter to the furrow. Since the seeds do not fall uniformly in time, a mechanical-timing method synchronized to the revolution of the seed meter is not adequate. Fortunately, most modern planters are already equipped with a seed sensor on each row unit. However, these seed sensors are typically located 8 to 12 inches above the seed tube outlet. With the seed sensor located so far from the point of chemical application, variability in planter speed or in the seed's travel path through the seed tube could adversely affect spray band placement. Additionally, multiple seeds will be present between the sensor and application point during normal planter operation. This dictates that the seed-specific applicator incorporate a seed tracking system capable of tracking multiple seeds. Finally, an on/off fluid valve capable of high frequency operation is required. At a 6-seed/ft seeding rate and 6-mph speed, approximately 50 seeds are planted each second. Assuming a spray-band length of 1.5-in. is desired, the valve would need to cycle at 50 Hz, with an ON time of 15 ms and an OFF time of 5 ms.

Prototype Seed-Specific Applicator Design

A block diagram of the prototype system is shown in Figure 2. It consisted of the following major subsystems: (1) a seed detection sensor; (2) a seed-tracking circuit; (3) a fluid delivery subsystem; and (4) a text-based user interface. Seed detection was accomplished using a commercially-available seed sensor, as factory-installed on a planter seeding tube. A micro-controller-based (MCU) algorithm, capable of tracking a plurality of irregularly-spaced seeds and providing a digital actuation signal for the high-speed valve, was used for seed-tracking. The fluid delivery subsystem was connected to the seed-tracking device and included components necessary to produce spray band lengths of 0.5 to 6 inches at planting speeds up to 6 mph. Seed delay time (time between seed detection and the point of chemical application) and spray pulse width (time to generate a spray band length of XX-in.) were adjusted using the user interface.

Testing and Results

Field evaluation of the prototype seed-specific applicator involved two phases. First, the biological concept of seed-specific fungicide application was evaluated, focusing on whether fungicides applied seed-specifically provided equivalent protection to those applied in a continuous band. The second stage of testing focused on the seed-specific applicator itself. Applicator accuracy was evaluated over a range of planting conditions to determine the effects of speed, seeding rate, and spray band length on applicator performance. Both tests and their results are described below.

Evaluation of Seed-Specific Fungicide Application

This test was designed to either prove or disprove the seed-specific concept using side-by-side, field comparisons of conventionally-applied fungicides and fungicides applied seed-specifically at the same rate. Cotton (DP451 BRR with Gaucho) was planted on 18 April 2002 in a field with a history of seedling disease pressure. Eight fungicide treatments were evaluated including an untreated check, two rates of Terraclor Super X (TSX) 2.5EC applied conventionally (48 and 64 oz/ac), TSX 2.5EC applied seed-specifically (same rates as conventional), and three hopper box treatments (Table 1). The seed-specific treatments consisted of chemical spray bands 2-inches in length applied about each seed using the prototype applicator described above. Additionally, both inoculated and uninoculated rows were planted for each chemical treatment, generating 16 treatments. The inoculum consisted of millet seed inoculated with *Pythium spp.* and *Rhizoctonia spp.*, and it was applied at a rate of 15 mL per 30 row-ft.

Cotton was planted at three seeds per row foot (41,000 seeds/ac) at a speed of 3 mph using a one-row planter constructed in the UT Biosystems Engineering Department. Stand counts were collected on May 9 (21 days after planting, DAP), May 29 (41 DAP), and June 13 (56 DAP). This information was used to evaluate the effectiveness of each treatment in protecting against seedling diseases.

Stand counts from this experiment are shown in Table 1. No statistical differences were detected in the uninoculated treatments, suggesting that there was no seedling disease pressure in the uninoculated plots. Since there was no disease pressure, the results of the eight uninoculated treatments were useless for comparing fungicidal performance; however, they did provide a baseline to which the inoculated treatments were compared.

In inoculated treatments, statistical differences were detected ($p<0.01$) at all three observation periods, and mean separation was performed using Least Significant Differences (alpha = 0.05). Lower-case letters that follow stand count averages indicate the statistical groupings for each observation period (21, 41, & 56 DAP). Severe disease pressure was present in these plots, with stands averaging less than one plant per five row-feet in the untreated check. Statistically, there were no differences in any of the in-furrow liquid fungicide treatments, regardless of application method or rate. All four TSX treatments provided protection against seedling disease, as evidenced by the fact that these treatments were statistically grouped with the uninoculated treatments in which there was no disease pressure. These results support the concept of seed-specific fungicide application, suggesting that fungicide applied between seeds can be eliminated without negatively impacting efficacy.

Evaluation of Seed-Specific Applicator Accuracy

This test was designed to determine how the applicator might perform in a production environment. Accuracy was evaluated at three planter speeds (2, 4, and 6 mph) and five spray-band lengths (1.0, 1.3, 1.5, 2.0, and 2.6 in.). For each treatment, a 200-ft row was planted. To aid in evaluation, the furrow-closing wheels were removed, and the seed-specific applicator sprayed purple dye instead of chemical. Five, 10-ft segments along each row were randomly selected for evaluation. Within each segment, accuracy was evaluated by visual inspection. Each seed was classified as a hit or miss, depending upon whether it landed completely within a sprayed band of soil.

The results of the accuracy tests are shown in Table 2. The applicator performed best at two and four mph, with accuracies ranging from 70 to 98% at these speeds, depending on the length of the spray band. Accuracy decreased at 6 mph, particularly when shorter spray band were used (1 to 1.5 in.). Still, 80% to 90% of seeds were sprayed at all speeds when the spray band length was at least 2 in. As expected, accuracy increased with spray band length at all speeds.

Figures 3, 4, and 5 visually illustrate the performance of the seed-specific applicator. For these photos, the applicator was set to deliver a spray band length of 2 inches. As shown in Figure 3, the applicator delivered an acceptable spray band, thoroughly covering the sidewalls and upper edges of the furrow with liquid chemical. Additionally, the applicator functioned as designed, lengthening the spray band when double or triple seed drops occurred (Figure 3) and omitting the spray band when the seed meter skipped a seed (Figure 4). A spray pulse was delivered for each seed, although the seed did not always land in the band of sprayed soil. Most misses resulted from seed bounce in the furrow or variability in seed drop times (time between seed detection and chemical application). Figure 6 illustrates the applicator in action.

Conclusions

Seed-specific placement of in-furrow fungicides (placing the chemical in a small zone around the seed) reduced chemical inputs by 50%, while providing seedling disease protection equivalent to the conventional, continuous application method. Additionally, the prototype seed-specific applicator developed for this study was accurate across a range of cotton planting conditions, adequately spraying over 80% of seeds at 2, 4, and 6 mph when the spray band length was at least 2 inches. Seed-specific application has the potential to reduce in-furrow chemical inputs significantly. Additional tests are needed with other in-furrow inputs (fungicides, insecticides, etc.) to determine the potential benefits of seed-specific application in other areas.

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References

Newman, M. A. 1998. Personal interview. The University of Tennessee Agricultural Extension Service. 605 Airways Boulevard, Jackson, TN: 8 June.

Roberts, P. M., J. N. All, G. A. Herzog, and P. Guillebeau. 1998. Precision placement of in-furrow insecticide for early season thrips control. In *Proc. of the 1998 Beltwide Cotton Conferences*, eds. P. Dugger and D. Richer, 1269-1270. Memphis, TN: National Cotton Council.

Uniroyal Chemical Company, Inc. 2001. Terraclor Super X In-furrow Fungicide: Technical Information Sheet. Uniroyal Doc. UNI-21297. Middlebury, CT.

Table 1. Stand count results from the evaluation of the seed-specific concept.

	Rate	**Plant Stand per 10 ft**					
Treatment	**(fl. oz./ac)**	**21 DAP**		**41 DAP**		**56 DAP**	
Uninoculated Plots							
Untreated Control		16.0	a	12.7	a	14.7	a
TSX, Continuous	48.0	15.8	a	12.1	a	14.9	a
TSX, Seed-Specific	24.0[**]	15.6	a	12.9	a	14.2	a
TSX, Continuous	64.0	14.8	a	11.7	a	14.2	a
TSX, Seed-Specific	32.0[**]	15.6	a	11.7	a	14.1	a
Delta Coat	11.75 fl. oz./cwt	13.8	a	11.8	a	13.1	a
Protege XT	0.6 oz. wt./cwt	13.6	a	12.0	a	12.8	a
System 3	12 oz. wt./cwt	14.4	a	12.0	a	12.8	a
Inoculated Plots							
Untreated Control		2.0	c	1.3	b	1.5	c
TSX, Continuous	48.0	14.7	a	13.0	a	13.6	a
TSX, Seed-Specific	24.0[**]	12.5	a	10.7	a	11.3	a
TSX, Continuous	64.0	14.1	a	10.2	a	11.9	a
TSX, Seed-Specific	32.0[**]	15.2	a	13.4	a	13.9	a
Delta Coat	11.75 fl. oz./cwt	6.9	b	4.7	b	5.6	b
Protege XT	0.6 oz. wt./cwt	4.9	bc	3.7	b	4.2	bc
System 3	12 oz. wt./cwt	5.0	bc	4.1	b	4.5	bc
LSD (alpha=0.05)		***3.04***		***3.30***		***3.02***	

[**] Seed-specific treatments were applied as 2-in. long spray bands, with 2 inches (on average) of bare soil between the bands. Seed-specific application resulted in one-half the continuous rates because 50% less volume of identical formulation was applied.

Table 2. Sprayer accuracy results (% coverage), based on in-field calibration.

Spray Band	**% Seeds Adequately Sprayed**		
Length (in.)	**2-mph**	**4-mph**	**6-mph**
1.00	71.2	70.2	55.2
1.30	79.4	76.5	63.6
1.50	85.5	89.9	78.6
2.00	93.1	90.1	83.8
2.60	98.2	95.7	89.0

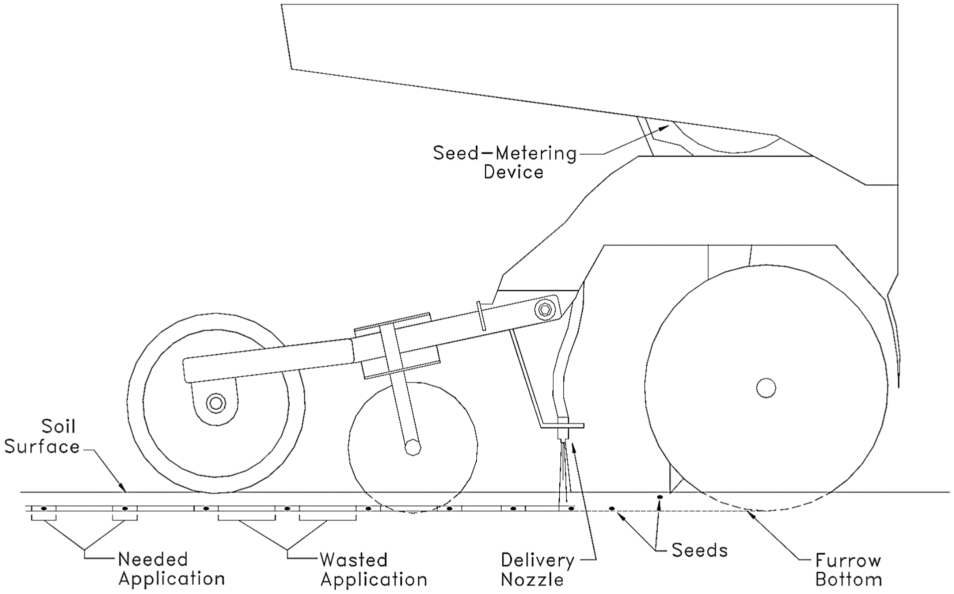

Figure 1. Conventional method of in-furrow chemical application and the potential for reduced waste.

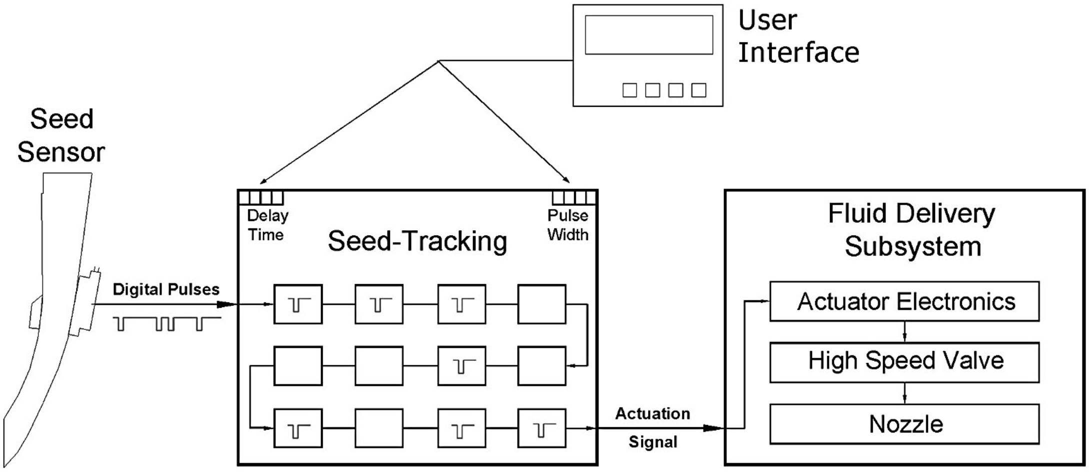

Figure 2. Block diagram of prototype seed-specific applicator components.

Figure 3. When multiple seeds were dropped by the seed meter, the seed-specific applicator adjusted the length of the spray band accordingly to ensure all seeds were sprayed.

Figure 4. When the seed meter failed to deliver a seed (notice skip in photo), no spray was delivered.

Figure 5. Example of seed-specific applicator performance (2-in. spray band length).

Figure 6. Photos of seed-specific applicator spraying a seed and a furrow closeup.