Arizona Iceberg Lettuce Research Council
Final Report
Project Cycle 2010-2011

Project Title:

Improving Lettuce Production through Utilization of Spike Wheel Liquid Injection Technology – A First Look

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***Abstract*.** Spike wheel liquid injection systems were developed in the late 1980's as an improved method for applying fertilizer post emergence. Although studies have shown that use of the system provides measurable yield benefits in a variety of crops, limited studies have been conducted in lettuce production systems. This study addresses this shortcoming. The objectives of the project were to determine if spike wheel injection technology can be used in lettuce to 1) improve plant growth, nutrient uptake efficiency and crop yield and 2) determine if the system can be used to deliver soil applied pesticides post emergence. Replicated field trials were conducted in Yuma, Arizona in 2010 to achieve the stated objectives. Use of the spike wheel injector significantly improved mid-season lettuce plant weight and nitrogen uptake levels as compared to conventional knife blade fertilizer application systems. Despite these early advantages, crop yield was not significantly affected by fertilizer applicator method. Use of the system for controlling Sclerotinia lettuce drop through injection of the fungicide Endura into the soil for was not effective for the one year study. The data showed that Coragen, a soil applied systemic insecticide, can be effectively delivered post emergence using the point injection system. These data were very promising in that it implies that the system could also be used successfully to deliver other soil applied pesticide chemistries post emergence in lettuce crops. This would benefit the industry by greatly increasing the control options growers have for managing pests. Additional study is needed to confirm/validate the results of this one year study.

Keywords. lettuce, point injection, sidedress, fertilizer, pesticide, insecticide, fungicide, crop production, yield

Introduction

Spike wheel liquid injection systems were developed in the late 1980's as an improved method for applying fertilizer post emergence. These systems utilize spikes attached to a rotatable wheel to inject liquid fertilizer into the root zone at precise intervals and depths with minimal root damage and soil disturbance (Fig. 1). Research studies have shown that as compared to conventional application methods, use of the system provided yield increases of 9% and 6% in ridge-till and no-till corn, respectively (Blaylock and Cruse , 1992; Timmons and Baker, 1992), 8% in dryland winter wheat (Schlegel et al., 2003) and 6% in sugar beets (Van Tassel et al., 1998; Stevens et al.,2007). Significant yield increases have also been reported with use of spike wheel injection systems in first harvest of bell peppers (Bracy, 2000) and direct seeded broccoli (O'Dell, 2000). Yield increases were attributed to reduced root pruning and better placement and utilization of fertilizer and as compared to conventional broadcast and knife blade applicator methods. Because knife blade applicators are commonly used for side-dressing fertilizer in Arizona iceberg lettuce production, we hypothesize that use of the device may also provide similar benefits in lettuce production.

The system also has potential to improve the efficacy and usefulness of soil applied pesticides since it can be used to apply pesticides to mature plants without damaging plant roots or causing crop injury. One promising use is for making timely, post emergence applications of the fungicide Endura. Such applications would more uniformly distribute the fungicide throughout the soil profile and place the relatively immobile fungicide close to plants roots thereby improving protection against infection. Research studies conducted over a 3 year period have shown that better distribution of Endura through soil incorporation to a depth of one inch improved control of Sclerotinia drop by 6% in iceberg lettuce (M. Matheron, unpublished data, 2010. Yuma, Ariz.: University of Arizona). Another potential use would be for delivering highly immobile, soil applied pesticides post emergence. An example of such a pesticide used in lettuce production is the insecticide Coragen. Typically, the full label rate is applied at planting directly beneath the seed where it is absorbed by lettuce seedling roots as the plant grows. Toxic levels of the insecticide are found in the plant for only about 28 days thereafter. During certain periods of the growing season, pest pressure of the targeted species commences 3-4 weeks after seeding. An application of Coragen cannot be made at this time because the compound is highly immobile and in conventional, furrow irrigated lettuce production, there is no way to apply the insecticide close enough to plant roots for it to be absorbed without causing plant injury. A spike wheel injection system could be used to inject the insecticide into the root zone 25 days after sowing and expand the utility of the compound. Favorable study results would imply that similar benefits could be realized with other systemic, soil applied pesticides.

Figure 1. Spike wheel fertilizer applicator side-dressing winter wheat.

Objectives

The main objective of this project is to determine whether spike wheel injection technology can be used to improve iceberg lettuce production. The specific project objectives are to:

1) Determine if improvements in iceberg lettuce crop growth, nutrient uptake and yield can be achieved using the spike wheel fertilizer applicator system as compared to conventional, knife-blade application methods

2) Determine if improvements in control of Sclerotinia drop in iceberg lettuce can be achieved by making timely, post emergence soil applications of the fungicide Endura with the spike wheel applicator

3) Determine if the spike wheel applicator can be used to successfully deliver liquid, soil applied pesticides post emergence.

Methods

The two bed spike wheel fertilizer applicator used in this study was fabricated using four spike wheel injector units obtained from LiquiJect Inc. (Helix, OR). One spike wheel injector was utilized for each plant row and positioned so that the wheel operated on the bed side wall. To facilitate wheel rotation, the wheels were mounted at an angle so that wheel orientation was perpendicular to the bed side wall (Fig. 2). Each of the spike wheels utilized was comprised of twelve, ½ inch diameter spikes that are designed to inject liquid fertilizer and/or pesticides at a depth of 3 inches below the soil surface. Spike spacing and wheel geometry is such that a spike enters the soil and injects liquid product every six inches during operation. In lettuce thinned to 6 inch or greater spacing, the maximum distance between a plant and an injection point is 3 inches with this design. Each wheel contains a metering sleeve that allows liquid products to be released only when the spike is in the soil.

In October of 2010, fertilizer applicator efficacy/performance trials in iceberg lettuce crops were initiated at the Yuma Agricultural Center in Yuma, AZ. Experimental design was a randomized complete block design with 5 treatments and 5 replications. Experimental unit plot size was 55 feet long by 4 beds wide. Treatments included: 1) Conventional: liquid fertilizer applied using knife-blade applicator, 2) Conventional Modified I: slow release fertilizer applied pre-plant (no post-emergence application), 3) Conventional Modified II: slow release fertilizer applied pre-plant, knife-blade applicator used to impose tillage, but no fertilizer applied during operation, 4) Spike Wheel: liquid fertilizer applied using spike wheel applicator and 5): Spike Wheel Modified I: liquid fertilizer applied using spike wheel applicator, knife-blade applicator used to impose tillage, but no fertilizer applied during operation. Two side dressing applications were made in accordance with conventional practices. Regardless of application method, all treatments received at total 200 lbs of N during the growing period.

Figure 2. Spike wheel fertilizer applicator configured to inject liquid chemicals into sidewalls of lettuce beds.

Crop yield potential for each treatment was assessed by measuring plant growth (dry matter) and nutrient uptake (midrib NO_3-N) at four times during the growing period - the 8 leaf stage of growth, two weeks after the 1st side dressing, 15 days after the 2nd side dressing and at maturity. Marketable yield and quality (head size) was also measured. With this experimental design, one can determine whether the spike wheel injector applicator improves crop productivity as compared to conventional technology by comparing treatment 1 with 5. By comparing treatment 2, 3 and 4, one can also ascertain the affect of tillage on lettuce plant growth and crop yield.

In the fall of 2010, a second field trial was established to determine if spike wheel injection technology can be used to apply the fungicide Endura to improve control of Sclerotinia drop caused by *Sclerotinia minor* (*S. minor*) and *Sclerotinia sclerotiorum* (*S. sclerotiorum*) in iceberg lettuce. The spike wheel injection system was configured to apply liquid product into the bed sidewalls and bed top (Fig. 3). Sclerotia of *S. minor* and *S. sclerotiorum* was produced in the laboratory and then incorporated into plots to initiate the disease. Experimental design for each species of fungus was a randomized complete block design with 6 treatments and 5 replications. Each replicate consisted of two beds of lettuce, 25 ft in length, each containing two rows of lettuce. The six treatments examined were: 1) Conventional: ½ rate of Endura sprayed onto bed surface after thinning, ½ rate of Endure sprayed onto bed surface two weeks after first application, 2) Conventional Mod I: ½ rate of Endura sprayed onto bed surface and incorporated into the soil after thinning, ½ rate of Endura sprayed onto bed surface and incorporated into the soil wo weeks after first application, 3) Conventional Mod II: full rate of Endura sprayed onto bed surface after thinning, 4) Conventional Mod III: full rate of Endura sprayed onto bed surface and incorporated into the soil surface after thinning, 5) Spike Wheel: conventional application of Endura as per treatment 1 and use of spike wheel to inject Endura into the bed side walls and bed top after thinning and two weeks after first application and 6) Control: No Endura applied. The total amount of product applied, 0.69 pounds a.i. per acre, was the same for all treatments. Level of disease control for each treatment was assessed at plant maturity by recording the number diseased plants in each plot and comparing the results to those of the untreated control.

The third field trial established in the fall of 2010 was conducted to determine whether the spike wheel applicator can be used to successfully deliver the insecticide Coragen. Lettuce beds were established and planted in mid October under four treatment regimes. These included: 1) Conventional (A): 7.0 oz of Coragen applied pre-plant beneath the seed row, 2) Conventional (B): 3.5 oz of Coragen applied pre-plant beneath the seed row, 3) Split Application/Spike Wheel: 3.5 oz of Coragen applied pre-plant beneath the seed row and 3.5 oz of Coragen applied to bed side walls using the spike wheel applicator 26 days after seeding (DAS), and 4) Control: No Coragen applied. Experimental design was a randomized complete block design with 5 replications. Each replicate was two beds wide by 60 ft long. Leaf samples were collected every 5 days beginning at 10 DAS and ending at 50 DAS. Coragen uptake levels in the plant tissues collected were assessed using high performance liquid chromatography (HPLC) analysis techniques.

Figure 3. Spike wheel fertilizer applicator configured to inject liquid chemicals into sidewalls and top of lettuce beds.

Results

The results of the fertilizer applicator efficacy trial showed that use of the spike wheel applicator significantly (P=0.05) improved mid-season plant growth in terms of plant weight as compared to conventional knife blade application (Fig. 4). Plant nutrient uptake as measured by midrib NO3-N was also significantly (P=0.10) higher after the second side dress when the spike wheel applicator was used (Fig. 5). These early plant growth advantages potential did not translate into significant increases in crop quality or yield (Table 1). Tillage imposed by knife blade or spike wheel applicators did not significantly affect lettuce plant growth, nutrient uptake or yield (data not shown). These data indicate that nutrient placement has a larger affect than tillage induced soil disturbance/root pruning on lettuce plant growth for the two fertilizer applicators examined.

Although the conventional, split application of Endura generally provided the best control of lettuce drop, there were no conclusive, statistically significant differences between the five application methods examined (Table 2). This result is inconsistent with previous results that showed improved lettuce drop control with soil incorporation (M. Matheron, unpublished data, 2010. Yuma, Ariz.: University of Arizona). An explanation for this may be that growing conditions during the crop year were unusually wet and cool which promoted high levels of lettuce drop incidence and may have inhibited "normal" levels of control with fungicidal products like Endura.

Coragen concentration levels in the 2nd true leaf increased for all Coragen treatments until about 18 DAS and then decreased to values near that of the control treatment (0.0 oz of Coragen applied) at 25 DAS (Fig. 6). After using the spike wheel applicator to make the second, split application of Coragen 26 DAS, Coragen concentration levels in the treated plants increased to over 600 parts per million (ppm) while levels in plants from the Conventional (A) (7.0 oz at sowing) and Conventional (B) (3.5 oz at sowing) treatments remained near that of the control treatment (0.0 oz of Coragen applied) at 10 ppm. Especially encouraging was that after delivering Coragen using the spike wheel applicator, high levels of the insecticide were found in the new plant tissue. This is evidenced by the data shown in figure 7 where Coragen

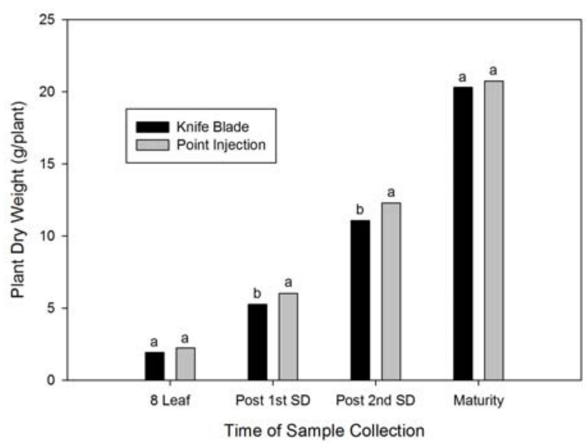

Figure 4. Effect of fertilizer applicator type on iceberg lettuce plant weight at four sampling times – 8 leaf stage of plant growth (8 leaf), before the second side dress application (Post 1st SD), 15 days after the second side dress application (Post 2nd SD) and at harvest (Maturity). Within sampling periods, means followed by the same letter are not significantly different by Fisher's Least Significant Difference Test (P=0.05).

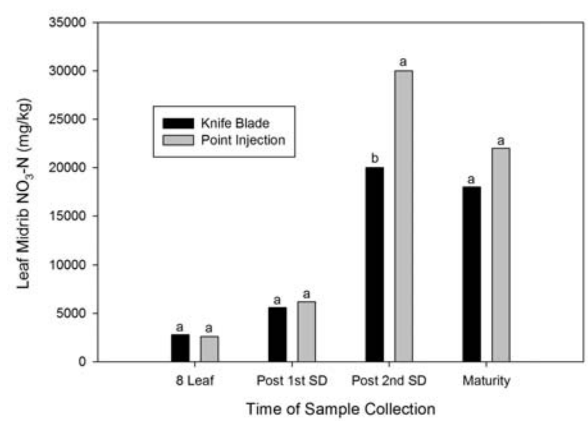

Figure 5. Effect of fertilizer applicator type on iceberg lettuce midrib nitrogen content at four sampling times – 8 leaf stage of plant growth (8 leaf), before the second side dress application (Post 1st SD), 15 days after the second side dress application (Post 2nd SD) and at harvest (Maturity). Within sampling periods, means followed by the same letter are not significantly different by Fisher's Least Significant Difference Test (P=0.10).

Table 1. Effect of fertilizer applicator type on iceberg lettuce yield parameters in 2010, Yuma, AZ.

Applicator Type	Crop Yield (lb acre^{-1})	Head Weight (lb head^{-1})	Marketable Heads (% of total)
Spike wheel	19,197 a[1]	1.2 A	55.4 a
Knife blade	18,941 a	1.1 a	52.6 a

[1] Within columns, means followed by the same letter are not significantly different by Fisher's Least Significant Difference Test (P=0.10).

Table 2. Effect of Endura application method on control of lettuce drop in Yuma, AZ in fall of 2010.

Application Method	Application Frequency*	*S. minor* control	*S. sclerotorium* control
		(percent)	(percent)
Spray	Split	46.3 a**	47.0 a
Spray + Cultivate	Split	38.0 a	37.2 ab
Spray + Cultivate	Single	32.2 a	30.1 b
Spray	Single	47.1 a	30.1 b
Spray + Inject	Split	39.7 a	23.0 b

* Total amount of Endura applied for each treatment was 0.69 pounds.

** Within columns, means followed by the same letter are not significantly different by Fischer's LSD test (P = 0.05).

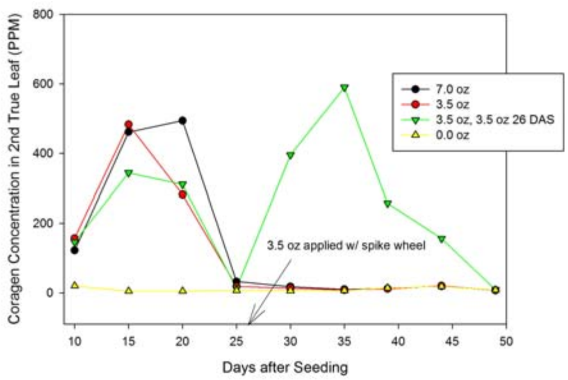

Figure 6. Effect of rate, placement and timing on Coragen uptake in iceberg lettuce as measured by Coragen concentration in the 2nd true leaf of iceberg lettuce plants. Treatments include applying 7 oz below the seed at sowing (7.0 oz), 3.5 oz below the seed at sowing (3.5 oz), 3.5 oz below the seed at sowing and 3.5 oz with the spike wheel applicator 26 days after seeding (3.5 oz, 3.5 oz 26 DAS) and no Coragen (0.0 oz).

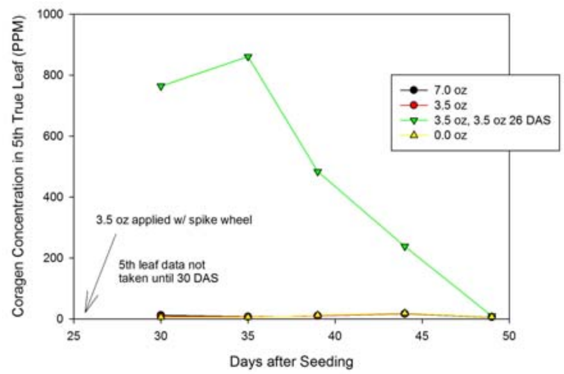

Figure 7. Effect of rate, placement and timing on Coragen uptake in iceberg lettuce as measured by Coragen concentration in the 5th true leaf of iceberg lettuce plants. Treatments include applying 7 oz below the seed at sowing (7.0 oz), 3.5 oz below the seed at sowing (3.5 oz), 3.5 oz below the seed at sowing and 3.5 oz with the spike wheel applicator 26 days after seeding (3.5 oz, 3.5 oz 26 DAS) and no Coragen (0.0 oz).

concentration levels in the 5th true leaf were approximately 800 ppm for the treatment where the spike wheel applicator was used. Coragen concentration levels for all other Coragen treatments were 20 ppm and essentially no different than the control treatment where no Coragen was applied. DuPont, the manufacturer of Coragen, stated that the data were very promising and that additional study is warranted (D. Tamayo, personal communication, 12 November 2010).

Conclusions

Use of the spike wheel injector system to side dress fertilizer was found to significantly (P=0.10) improve mid season lettuce plant growth and nitrogen uptake levels as compared to conventional knife blade fertilizer applicator system. These results are thought to be due to more optimal placement of the fertilizer in the root zone; however data necessary to confirm such a hypothesis were not measured. In this study, improved early plant growth did not translate into significant increases in crop yield. Because plant tissue nitrogen levels were higher when the spike wheel injector system was used, additional study is warranted to confirm that nitrogen uptake is improved through better fertilizer placement with the system.

In this one year study, the spike wheel applicator was found to be effective for delivering the soil applied insecticide Coragen to lettuce plants post emergence. These preliminary results are encouraging in that they imply that the system could also be used to successfully deliver other soil applied pesticide chemistries post emergence in lettuce and other vegetable crops. This would benefit the industry by greatly increasing the control options growers have for managing pests post emergence. Based on these results, the authors conclude additional study is merited.

Outreach Program

An extensive outreach program was conducted to inform the vegetable industry about spike wheel injection technology and the results of these research studies. The following is a listing of the outreach activities performed during the project year.

Invited Presentations

2011 *Innovations for Improved Application of Crop Protection Chemistry.* Dupont Crop Protection Meeting, Brawley, Calif., June 15. 30 minutes. Attendance - 35.

2011 *Innovations for Improved Application of Crop Protection Chemistry.* Dupont Crop Protection Meeting, Yuma, Ariz., June 14. 30 minutes. Attendance - 45.

2011 *New Technologies for Pesticide Application.* 2011 Desert Ag Conference, Casa Grande, Ariz., May 5. 50 minutes. Attendance - 28.

Volunteered Presentations

2011 *Improving Lettuce Production through Utilization of Spike Wheel Liquid Injection Systems.* 2011 ASABE Annual International Meeting, Louisville, Ky., August 8. 15 minutes. Attendance - 21.

Field Days

2011 *New Technologies for Applying Pesticides Post Emergence.* 2011 Southwest Ag Summit Field Demonstration, Yuma, Ariz., Mar. 9. 4 hours. Attendance - 150.

Publications

Siemens, M.C., K.D. Nolte and R.R. Gayler. 2011. Improving lettuce production through utilization of spike wheel liquid injection systems. ASABE paper No. 1111245, pp. 11. St. Joseph, Mich: ASABE.

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