RESEARCH PROJECT TITLE: Development of Residue Manipulation Systems for Direct-Seeding Drills to Improve Seed Opener Performance

INVESTIGATORS:

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REPORT STATUS: Interim

OBJECTIVES:

1. To form an advisory board of local farmers, industry representatives, and university personnel to guide the research effort.
2. Study direct-seeding opener designs to develop a system to eliminate hair pinning and improve emergence.
3. To construct a prototype opener for testing under controlled conditions.
4. To construct a prototype direct seeding drill and to test the system in a range of residue conditions.
5. Based on the research findings, make recommendations for improved direct-seeding drill design.

KEY WORDS: direct-seeding openers, maintaining crop residue, erosion control, powered row cleaner

STATEMENT OF PROBLEM: To limit soil erosion in the Palouse region, growers have been encouraged to adopt conservation practices that involve maintaining crop residues and using direct-seeding drills. Surface residue is an established method to reduce erosion and can provide long-term benefits to soil fertility (Baker et al, 1996). Surface residues from wheat in high precipitation zones can range from 3,000 to 11,000 lbs per acre (Veseth et al, 1995). However, these high residue levels can interfere with the performance of direct-seeding drills. For example, the disk openers will press residue into the furrow, called hairpinning or tucking. The presence of residue in the furrow prevents good soil-to-seed contact and results in poor germination. There are also lesser problems with residue bunching, accumulating, and plugging equipment. In high residue conditions growers are very concerned about poor germination which leads to reduced yields. All these concerns about seeding a crop in high residue conditions may limit the adoption and continued use of direct-seeding by growers.

The Palouse offers the unique conditions of steep hills, high yields, and wet winters. The rolling hills with their loessial soils may have slopes of greater than 50% (McCool and Busacca, 1999).
The hills are also a productive growing region with high cereal yields and even higher residue yields. The amount (mass) of straw produced can be as much as twice the amount of the harvested grain (Wysocki, 1989). Residue is critical in preventing erosion in the winter when the Palouse region receives the majority of its precipitation. McCool et al. (1995) presents results showing a dramatic decrease in water erosion with increasing residue. Erosion is reduced by more than 95% with residues of 2000 lbs per acre. In spring, the moist residue creates seeding problems for direct-seeding drills and creates traction problems on the steep hills for the tractor and the drill.

For use in the unique conditions found in the Palouse, we propose to develop a drill attachment to move residue from in front of the opener so that direct-seeding drills can work effectively in a wide range of residue conditions. Many direct-seeding drills have been developed for use in other regions, e.g., the relatively flat Northern Great Plain—and do not function as well as needed in the Palouse. Growers need a reliable and effective drill for seeding in difficult conditions, for example for seeding a spring crop into winter wheat residue, in order to adopt continuous direct-seeding cropping systems. If growers are not confident in achieving effective seeding and germination they will take steps to reduce or remove the erosion-preventing residue. With conventional tillage for winter wheat, erosion rates can average from 10 to 20 tons of soil per acre and can be as high as 50 to 100 tons of soil per acre on slopes (Papendick et al, 1995).

One approach to improving opener performance is to cut or clear the residue directly in front of the opener by using ground-driven devices. A wide range of coulters and row cleaners are commercially available (e.g., Yetter, 1998). These devices are generally rigid wheels with wavy, scalloped, or toothed edges. With sufficient downforce (drill weight) these devices work well to cut through thick corn stalks. However, corn stalks are not easily hairpinned like moist, thin, flexible, tough winter wheat straw. To cut through wheat residue, Siemens et al (2000) used a toothed rubber wheel to press and hold the residue for a hoe-type opener to pass through. The rubber wheel improved the cutting action of the opener but did not clear away the residue. To clear away residue, aggressive, toothed row cleaners are available, but these can cause excessive soil disturbance and can move the residue into the adjacent seed rows. In the high rainfall zones of the Palouse, a narrow row spacing only 7 ½ inches is used for cereals which leaves much less room for moving residues than the wide 30 inches spacing commonly used for corn. Growers in the Palouse have tried many types of ground driven—i.e., passively powered—devices. However, no widely accepted solution has emerged.

An approach that has not been well explored is the use of powered devices to move the residue. Powered devices have been tried with some success as furrow openers but they are power intensive. For example, the eight foot wide John Deere 1500 Powr-Till Seeder with rotating disk openers used as much as 90 hp of PTO power (PAMI, 1978). Townsend and Bethge (1984) tested a prototype rotating disk opener which required 3.5 hp for a single disk when traveling at 3 mph, i.e., 161 hp for a 28 ft. wide, 46 opener drill. Baker et al (1996) discusses powered devices as furrow openers. These openers include strip tillers that destroy soil structure, stimulate weed germination and require high power. Powered soil engaging tools also experience high wear. A promising alternative that should require much less power is powered residue moving devices. A powered horizontal disk row cleaner was successfully used in corn and soybean residue by Kaspar and Erbach (1998) but power requirements were not measured. A lawn mower can be
used as a crude measure of power to move residues. A 4 hp mower cutting a 20 inch strip corresponds to only 0.4 hp per opener—i.e., a 2 inch wide strip. Powered residue manipulating devices also offer flexibility in design alternatives. They could be designed to skim above the ground to avoid soil disturbance and are not limited in speed to the drill travel speed. With speed and control over the direction of rotation a variety of residue cutting, chopping and pushing devices can be considered. Furthermore, a powered device can be adjusted to direct residue where desired.

We propose to develop powered residue manipulating devices to clear a narrow strip (e.g., 2 inches wide) in front of the opener, commonly a single-disk, or offset, double-disk opener in high production zones. The moved residue would need to be placed somewhere and we propose to develop a device to which would move the residue to the side of the furrow.

AGRONOMIC ZONE OF INTEREST: Primarily higher precipitation production zones, but with potential applications to medium and low precipitation production zones as well. The production system involves annual cropping of winter and spring cereals using direct-seeding systems.

ABSTRACT OF RESEARCH FINDINGS: A hydraulically powered residue management tool has been developed and is in process of test. The unit has performed well in low to medium high residue. The very high stubble conditions resulted in plugging. However, staggering the openers on several ranks from front to back will likely solve this problem in all but the heaviest residue conditions.

RESULTS AND INTERPRETATION: Managing residue is one of the predominant and major problems of direct-seeding today. High crop yield and unusual weather often leave hard-to-handle crop residue conditions, the thick layer of residue affects the penetration of the furrow opener and the coverage of the seed after it has been placed inside the furrow, eventually this will affect the germination of the seed and the crop yield.

This report will describe the research that has been done so far and the design of a special furrow opener that has the advantage of clearing the residue from the top of the furrow will be presented. To evaluate the design, tests are being conducted under different field conditions to determine the advantages and associated problems and to suggest modifications required of the prototype to overcome the disadvantages.

To start the project, information was gathered about existing residue clearing and row cleaning tools. Many types of commercially available coulters and row cleaners are passively powered. These devices are generally rigid wheels with wavy, scalloped, or toothed edges. There is an obvious lack of information about powered driven tools especially using hydraulics as the power source.

One of the main factors in this study is residue (determination of the characteristics of wheat residue and stubble to see how much can the developed furrow opener will manage), the information needed for that factor was quantity of stubble and residue and to answer a simple
question like: how much is residue is too much? A common classification has been used to
determine the quantity of residue as follows:

- Class I (0 to 500 lbs/acre)
- Class II (500 to 1000 lbs/acre)
- Class III (1000 to 2000 lbs/acre)
- Class IV (2000 to 3000 lbs/acre)
- Class V (greater than 3000 lbs/acre)

Another question about residue was how much residue is needed? It is known that residue
controls soil erosion and enhances water infiltration; whereas the negatives are that excessive
residue makes tillage and seeding difficult. We found that 1000 lb. per acre of residue will cover
50% of the soil surface. Surface cover, has been found to reduce the erosion by 92% (McCool
1994) and (Unger 1994).

This project sought to develop a new approach for design of direct-seeding openers. The main
concern was to find an ideal tool to put the seed in the opened furrow without any hairpinning or
tucking (as recommended by STEEP, basic goal: seeding method that can place the seed and
fertilizer in the ground with least soil disturbance or less aggressive openers).

**Advisory Board**

One of the approaches to this problem was the formation of an advisory board. As listed
elsewhere in this report, an advisory board was formed. It met only once formally during the
past year, unfortunately due to a number of factors the attendance was low. The progress of the
project was described and a demonstration was provided. While the powered planting
mechanism works successfully in low to medium high stubble conditions, during the advisory
board meeting the demonstration was held in a field with a very high level of residue where a
straw spreader had not been used. Unfortunately, in the very heavy stubble conditions the
opener did not perform well during the demonstration. We believe subsequent refinements and
adjustments have continued to improve the opener and that it does, in fact, show promise.

**Preliminary Tests**

To test the idea of rotary cutting, a field test was conducted with the DR Field and Brush Mower
to evaluate the cutting action of a rotating blade on heavy moist winter wheat residue (plant
science farm, field No. 12). The test included steep sloped areas of the field and both moist and
dry standing stubble. The results showed that the cutting was clean and sharp and the cut
materials were placed in one row.

**Prototype 1**

In February 2002, the design and building of the first prototype of the powered residue
management tool was started. The idea was to place a rotary mower blade in front of a standard
double disc opener. The main function of the blade was to cut the stubble and windrow the
residue to the side of the opener. A single opener, mounted on a square, three point hitch tool
bar, was used. The 5 inch mower blade was welded to a hub which hooked to the hydraulic
motor shaft. The hydraulic motor rotated at 794 rpm (loaded) with a flow rate of 3 gpm. The
prototype blade was designed to be adjusted horizontally, vertically and at an angle. The design
is shown in Figure 1.
The field testing of this design was conducted in a bare field, a bale of wheat straw was spread to simulate the wheat residue as there was no actual wheat stubble and residue available at the time of the field test. The first observations were as follows:

- The cutting (chopping) of the residue was good.
- There was still a lot of hairpinning by the opener.
- Windrowing of the chopped residue was observed and easy to manage.
- There was no significance for the direction of blade rotation.

Many parameters were estimated from the first field test, the speed and the angle of rotation of the blade were important and crucial to control the cutting action. The blade was too short and had to be adjusted frequently. The guard over the rotary blade was also too narrow to move all the cut materials through. These observations led to modifications of the first prototype to match the new findings.

The revised Prototype 1 had these main features:

- Wider guard
- Longer blade 9 inch (diameter)
- The blade had a bent section on each of the two ends (with a bent length of 1.5 inch each end)

The second field test showed an increase in cut materials and more residue handling. The hairpinning was still accruing and the direction of rotation had significance. With a counter-clockwise rotation cutting was improved and clearing and windrowing of the cut material at the side of the furrow was much better than from clockwise blade rotation. The speed of the edge of the blade relative to the stubble will be higher when the blade is rotating counter-clockwise, due to the forward motion of the machine, thus the performance of the blade would be expected to improve. The cut materials forced by the counter-clockwise rotation were dragged to the back of the blade and the front of the opener and that is what caused hairpinning. Adjustments and the angling of the blade did not improve the process.
Test Configurations
Over 25 configurations of new blade designs with different features were fabricated and tested in the shop, among these designs were various configurations of the following:

- 9 inch blade with 1.5 inch bent edge.
- 9 inch blade with 3 inch bent edge.
- 9 inch blade with 3 inch bent edge and toothed edge.
- 9 inch blade with 3 inch bent edge and sharpened to the inside of the blade.
- 9 inch blade with 3 inch bent edge and sharpened to the outside of the blade.
- 3 inch long flails type blades (L shape).
- 3 inch long flails type blades (Y shape).
- 3 inch long flails type blades (? shape).

All of these designs were field tested and showed no improvement for the elimination of hairpinning, the same problem with cut residue lying down in front of the opener continued. To cope with this problem, two designs were tested that dealt with revisions to the back of the guard over the rotating blade, one of them was a deflector with a V shape to divide the flow of the materials to the right and left sides of the opener. This method didn't work and the hairpinning was still prevalent. Another method to overcome this problem was investigated, by using a 3 inch diameter metal hose that was welded to the back of the guard, the function of the hose was to direct the materials to one of the sides of the opener. This method also didn't work as the material plugged the hose from the first run.

Prototype 2

The approach that did show good results was using a shovel type soil engaging tool in the back of the rotating blade. The shovel was directly in front of the disk opener and will work the same furrow that the opener is seeding into. Thus it was not affecting any other area and it will maintain the direct-seeding principles. This device we call the Powered Residue Management Tool (PRMT). This design is illustrated in figure 2 and shown in photos at the end of this report.

![Prototype 2 powered residue management tool (PRMT). This design with some modification of shovel design and location the powered rotary blade is the final configuration used in these tests.](image-url)
The shovel will remove all the cut materials that have been placed behind the rotating blade, the rotating blade prevents residue from accumulating on the shovel, and the shovel prevents residue from being forced into the furrow by the opener. The field test of this design showed a clean furrow, less hairpinning, and improved action.

Prototype Drill Design

A Tye manufacturing company Pasture Pleaser drill model 104-3004 was used to test the concept of the powered residue management tool. The drill has 8 double disk openers with 10 inch spacing; each opener has a 17 inch coulter. The three right side openers were equipped with the PRMT, the center two coulters were left unused, and the three left openers were left in a standard configuration. Thus when using the drill, the three right openers are the test openers, a 20-inch test strip is left by the unused two center openers, and the three left openers are used for a control.

The hydraulic motors used to power the rotating blade have the following specifications:

- rotational speed 2500 rpm
- flow rate 7.1 gpm
- displacement 0.66 cu inch
- Small dimension to fit in the drill spacing.
- Can work in a series, i.e., can accept back pressure

For the PRMT as used on the test drill the shovel was modified as shown in Figure 3. The design of the shovel was developed to perform a lifting action. The lifting action is important so that the residue is raised from the ground so that the rotating blade does not have to cut into the soil, and so that the rotating blade can cut the stubble close to the shovel preventing it from hanging up and becoming plugged. For this configuration it was found that a counter-clockwise rotation worked best.

![Figure 3. Prototype drill shovel design used with the PRMT and showing the adjusting bracket for changing the depth of operation.](image-url)
The field test of the new design was conducted on August 13, on a field managed by the University dairy farm. The straw was dry and the field was a steep hill. The test showed clean furrows and no plugging and no hairpinning. A down hill passes showed different penetration between the two sides of the drill. A high forward speed for the tractor was chosen to test the PRMT at production speeds. A 5 mile per hour speed was setup and tool performance was actually improved because the time allowed for materials to go back to the opener area was shortened. The drill was further tested at the U of I Plant Science Farm and judged to be successful in all but the heaviest residue conditions.

**Emergence Study:**

The next step was to test the benefits of the drill in an emergence study with winter wheat. The objective of the emergence study field test was to test the PRMT drill in comparison with the standard coulter and disk configuration.

The factor to be used for evaluation as measured in this experiment is the emergence of plants following direct seeding.

The response studied is to the effect of using the PMRT to clear the path of the opener and to place the seed in a seed bed and cleanly and firmly close the seed bed without residue and stubble incorporated inside.

Three residue levels were selected to test the residue management tool: high, medium and low

The experimental design consists of 4 blocks, each block consists of 4 replicates; each replicate is a plot which measures 7 ft (drill width) by 50 ft.

The sample units will be randomly selected from the replicates. Each replicate will have six sample units (two sides of the drill the treatment and the control). The sample unit will be 20 by 30 inch. Fig 6 illustrates the sampling process.

Seed rate was setup at 141 lb per acre, and the seeding operation took place on October 8, 2002. No data were collected from the sites because of the dry fall. Also, a second test which was to be performed in moist stubble has not been possible because of the extremely low rainfall during the planting season.

**INTERACTION (COOPERATION) WITH OTHER SCIENTISTS CONDUCTING RELATED ACTIVITY:**

Stephen Guy - Extension Crop Management Specialist, University of Idaho, Moscow, Idaho 83843. Dr. Guy was consulted early on in this process but was overlooked at our advisory board meeting. We will ask him to be included in future planning.

Advisory Group:
Roger Veseth - Extension Conservation Specialist, UI/WSU.
Russell Zenner - President-PNW Direct Seed Assoc., Grower, Genesee, ID
Michael Stubbs - Research Chairman-PNW Direct Seed Assoc., Grower, Lacrosse, WA
David Mosman - Board Member-PNW Direct Seed Assoc., Grower, Craigmont, ID
John Whitcraft - Engineering Technician, University of Idaho, Retired

PUBLICATIONS AND PRESENTATIONS:

Publications: none
Presentations: Meeting and demonstration with advisory board.

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Side view of Prototype 2 of the powered residue management tool.
Front view of Prototype 2 of the powered residue management tool