Injecting Swine Manure with Minimum Disturbance

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1. Summary

Liquid swine manure is a very dilute fertilizer that contains most of the essential nutrients required for crop growth and seed yield. Due to high transport and application costs, hog operations typically apply very high application rates in the range of 9,000 to 12,000 Imperial gallons per acre, repeated every 4th year. These rates are intended to supply crop nutrients over a three-year period and current research is investigating the agronomic effects and sustainability of these high rates. Swine manure is typically surface broadcast, broadcast and incorporated or high disturbance injected into the soil. Broadcast without incorporation results in high nitrogen losses and severe odour problems. Broadcast and incorporated and high disturbance injection is unacceptable for zero till farmers and for pasture or forage crops. To address the problems of low disturbance manure injection PAMI evaluated openers for low disturbance injection of swine manure into zero till and a system for injection into pasture or forage land. All openers were field tested to assess their capability to inject large volumes of liquid with minimum soil disturbance. The Yetter Avenger provided excellent injection efficiency and low soil disturbance at injection rates as high as 14,000 Imperial gallons per acre (GPA). The modified Bourgault mid-row bander provided good injection efficiency and acceptable soil disturbance up to 9,000 GPA. The wide blade and HarvestTechnologies hollow wing both provided excellent injection efficiency but had high levels of soil disturbance. The Dutch coulter had good injection efficiency at 3,000 GPA and fair efficiency at 6,000 GPA with acceptable soil disturbance. In pasture, the Greentrac's soil disturbance was very low at all ground speeds and it had good injection performance at 3,300 GPA but poor injection performance at 6,600 and 13,300 GPA.

The results of this evaluation indicate that some openers have the potential to provide acceptable swine manure injection capability under zero till or pasture conditions.

2. Background

Saskatchewan produces about 7% of the total Canadian hog production with about 41% of the cultivated and pasture acreage. With Saskatchewan's large land base, sparse rural population and low cost feed grains it should have a natural advantage for hog production. Consequently, there will likely be a huge increase in Saskatchewan hog production over the next decade.

Traditionally hog manure was not seen as a valuable fertilizer but was considered a waste product that was often disposed of without thought to crop response. Currently farmers and hog producers are recognising that swine manure is an excellent source of crop nutrients and producers are now beginning to treat the slurry as a fertilizer.

Liquid swine manure application methods include surface broadcast, broadcast and incorporated and high disturbance injection. Currently there is a trend towards injection for odour control and nutrient efficiency. About 25% of seeded acres in Saskatchewan are now low disturbance seeded and this trend is continuing. Unfortunately, current application technology does not permit the efficient application of swine manure to zero till and pasture land. As a result, PAMI began testing equipment for low disturbance swine manure injection.

2.1 About Liquid Swine Manure

Liquid swine manure is an excellent crop nutrient source that contains nutrients in approximately the correct balance for good crop response. In the fall of 1996, 72 earthen manure storages were sampled for nutrient analysis (Table 1).

Table 1. Average nutrient quantities in selected hog lagoons (Bayne 1996).

Nutrient	Unit	Range in LBS/1000 Gallons	Average
Nitrogen N	Wet %	27 – 33.8 lbs.	30.4
Ammonium NH4-N	Wet %	17.5 – 20.6 lbs.	19.1
Phosphorus P	Wet %	7.4 – 11.6 lbs.	9.5
Potassium K	Wet %	11.8 – 13.8 lbs.	12.8
Sulphur S	Wet %	2 – 3 lbs.	2.5

The total nitrogen (N) is **not** the amount of N that is plant available in the first year of application as about 60 percent is plant available and the balance is tied up in the form of organic N. The organic N is slowly released over time and will be plant available primarily in year 2 and 3. The ammonium form of N is the approximate amount of plant available N in year 1.

Example #1: Annual Application

If a crop requires 80 lb/ac N it would require 80 lb/ac N ÷ 19.1 lb/1000 gallons = 4,200 GPA of slurry to meet crop requirements in year 1. Note that if the application was repeated in year 2, the application volume would be decreased to allow for the slow release of organic N from the previous year.

Example #2: Three Year Application

If the crop requires an average of 80 lb/ac N each year for three years it would require 80 lb/ac N x 3 years = 240 lb/ac total N ÷ 30.4 lb/1000 gallons = 7,900 GPA. Note that the amount of N/1000 gallons is the total N because most of the N will be converted to plant available N over three years.

As the application volumes are very high and it is expensive to transport and inject the manure (about $50/acre) the three year application rates are used by most hog operations.

3. Objective

The objective of the project was to evaluate equipment for the low disturbance injection of swine manure.

4. Description of Study

4.1 Low Disturbance Openers for Stubble Injection

Seven types of openers were tested in wheat stubble during the fall 1997 and spring 1998 to assess their capability to inject large volumes of liquid with minimum soil disturbance. Injection systems included three types of single disc systems (Bourgault mid-row bander [MRB], Dutch coulter, Yetter Avenger coulter), three types of cultivator shank mount openers (inverted T, diamond point and hollow wing type) and a wide blade sweep. Coulters from Bourgault and Dutch are commercially available units with respective disc diameters of 19" and 18" used for granular fertilizer application. The Dutch system can also be used as a seeding tool. In contrast, the Yetter Avenger is a purpose build liquid swine manure injector with a disc diameter of 25". The Dutch and Yetter systems reduce soil "throw" by using closing wheels on one side of the disc. PAMI fabricated the inverted T and diamond point injectors while the hollow wing type opener is a seeding tool from HarvestTechnologies. The wide blade sweep is a 32" wide V-blade with low lift characteristics manufactured by Haybuster.

Minor modifications were made to most systems to adapt them to fluid delivery. The only major modification was the fabrication of a dual delivery manifold behind the wide blade sweep to facilitate lateral movement of liquid behind the blade.

Testing in the fall of 1997 and spring of 1998 was done under typical wheat stubble conditions. Initial testing was done with water followed by a field demonstration with liquid swine manure. Openers were adjusted for optimum operation and operated at a range of ground speeds from 0.5 to 4.8 mph. Liquid application rates were approximately 3000, 6000, 9000, 13000 and 26,000 GPA. Opener operating depth, soil disturbance and amount of water on the soil surface were recorded for each set of openers and for each operating speed. The field plots were evaluated for injection efficiency, residue retention, soil disturbance, residue clearance and draft.

In the spring of 1998 a field demonstration in the R.M. of Leroy was conducted with the best of the opener systems from the initial test program. All treatments were applied on May 6 and May 7 following seeding of the plots to canola. Three coulter systems and one bolt on opener were evaluated using liquid swine manure. Each system was mounted on PAMI's field scale cultivator/tank system for the tests. In addition, the Greentrac system, a coulter/knife system designed for low disturbance pasture injection of swine manure was added to the project for purposes of comparison. Except for the Greentrac machine, four openers @ 12' row space were attached to the injector system (cultivator frame and manure tank/pump) to conduct the tests. Plot

size was 12 x 100 ft. Swine manure application rates were 3,000, 7,000 and 13,000 GPA. Changing the ground speed of the applicator changed application rates. The field plots were evaluated for injection efficiency, soil disturbance and residue clearance.

4.2 Low Disturbance Injection for Hay and Pasture Land

The Greentrac system from Ireland was used for grassland manure injection. The machine consists of a 1,200 Imperial gallon pressure tank, three point hitch injection unit and manure distribution manifold. The injection unit attaches to the back of the tank and consists of a row of cutting coulters followed by narrow openers which direct the swine manure into the furrow produced by the coulter.

The Greentrac was used to inject manure at 3,300, 6,600 and 13,300 GPA on fields of crested wheatgrass, brome/alfalfa and Russian wild ryegrass.

5. Results and Discussion

5.1 Low Disturbance Openers for Stubble Injection

Initial testing near Humboldt was started in the fall of 1997 and completed in the spring of 1998. The Leroy plots had manure applied following seeding of the field and prior to canola crop emergence.

Wheat stubble field conditions in both fall and spring were moist to wet with typical residue cover. In some of the testing a very high rate of application was applied (+20,000 GPA). This rate is much higher than recommended, however some operations are applying rates in excess of 20,000 GPA, so the high rate was incorporated in some of the testing. The following information is a combination of information from both the initial and field testing.

Residue clearance and trash cutting were not problems with any of the opener systems except the Greentrac coulter. The Greentrac coulter system was included as part of the field testing at Leroy. This system did not have sufficient residue clearance to operate in zero till cereal stubble conditions as residue built up in front of the coulters and plugged the toolbar. Consequently, the Greentrac plots were used only as a demonstration of surface broadcast swine manure.

Although not measured as a part of this project, a minimum of about 400 lb. down force per opener is generally required for disc or coulter penetration to 5” in typical soil conditions. Actual down force requirements are subject to many design factors. Penetration depths deeper than 5” often require heavy springs and much higher down force. In contrast, knife and sweep openers do not require heavy down force for soil penetration.

The following description parameters were developed for injection and disturbance parameters.

Injection performance was rated as follows:

- Excellent: 0% liquid surface pooling and 0-5% visible in furrow
- Good: 0% liquid surface pooling and 6–50% visible in furrow
- Fair: 1-10% liquid surface pooling and 51-100% visible in furrow
- Poor: 11% or greater liquid surface pooling

In these ratings the percentage figure is the percent of total soil area covered by liquid or percent of trench area covered by liquid.

Soil disturbance was rated as follows:

- Excellent: 0-30% loose soil on soil surface
- Good: 31-50% loose soil on soil surface
- Fair: 51-75% loose soil on soil surface
- Poor: 76-100% loose soil on soil surface

In these ratings the percentage is the percent of total soil area covered by loose soil.

5.1.1 Bourgault Mid-Row Bander

The Bourgault MRB is a commercial fertilizer-banding opener that uses a single 19" disc operating at a slight angle to the direction of travel. The disc system was set for maximum soil penetration, however due to insufficient spring tension, the maximum cutting depth was 3¾ to 4 inches with less depth in areas of higher soil density (**Table 1**).

Table 1. Performance of the Bourgault mid-row bander.

Ground Speed mph	Flow Rate GPA[1]	Penetration Depth in.	Net Draft lb./opener	% Fluid Showing[2]	% Outside Pooling[3]	Av. Width Soil Dist.[4]	% Soil Disturbance
1	26000	max 3½	N/A	100	100	5"	42
2	13000	max 3½	N/A	100	83	7"	58
3	9000	max 3½	N/A	100	50	9"	75
1	6000	max 4	N/A	20	0	6"	50
2	3000	max 4	188	10	0	9"	75

[1] Flow rate based on 12" opener row spacing

[2] % fluid showing in the furrow immediately after injection

[3] % of area outside furrow with surface pooling immediately after injection

[4] Average spread width of loose soil

The Bourgault MRB provided good liquid injection performance at 3,000 and 6,000 GPA with 10 and 20% visible liquid showing in the furrow immediately following injection. All visible liquid disappeared within one minute following injection. In contrast, at application volumes of 9,000 GPA, 50% or more of the soil surface was covered with pooled liquid resulting in poor injection performance.

Soil disturbance with the MRB ranged from good at a ground speed of 1 mph to fair at 3 mph. Residue retention was rated good with sufficient standing stubble remaining for good snow trapping.

5.1.2 Modified Bourgault Mid-Row Bander

The Bourgault opener was modified by replacing the standard spring with a spring with 50% greater tension. The heavier springs resulted in improved penetration with a maximum cutting depth of 4¾ to 5 inches (**Table 2**).

Table 2. Performance of the Modified Bourgault mid-row bander.

Ground Speed mph	Flow Rate GPA[1]	Penetration Depth in.	% Fluid Showing[2]	% Outside Furrow[3]	% Soil Disturbance	Net Draft lb./Opener
1.2	9000	4¾	20	0	N/A	N/A
1.8	6000	4¾	5	0	N/A	N/A
3.7	3000	4¾	0	0	N/A	N/A

[1] Flow rate based on 12" opener row spacing

[2] % fluid showing in the furrow immediately after injection

[3] % of area outside furrow with surface pooling immediately after injection

At all injection rates up to and including 9,000 GPA, no liquid pooling occurred and only between 5 and 22% liquid was visible in the furrow at respective application rates of 6,000 and 9,000 GPA. The injection efficiency of the modified opener was improved compared to the standard MRB with good injection performance at application rates of up to 9,000 GPA.

Soil disturbance and residue retention were similar to the standard MRB.

5.1.3 Dutch Coulter

The Dutch coulter is a commercial seeding or fertilizer banding opener that uses a single 18" disc with a rubber closing wheel that is operated at a slight angle to the direction of travel. In addition to the disc system there is an optional integral packer wheel that firms up the soil following the disc. The packer wheels were not used in this test. The disc system also can be adjusted to tilt laterally from the vertical axis to allow for a wider soil opening. The system was operated at both the vertical and maximum tilt angles. Maximum tilt resulted in maximum volume injection so the data and discussion about the Dutch coulter are based on the disc angle at maximum setting (**Table 3**).

Table 3. Performance of the Dutch Coulter.

Ground Speed mph	Flow Rate GPA[1]	Penetration Depth in.	Net Draft lb./opener	% Fluid Showing[2]	% Outside Pooling[3]	Av. Width Soil Dist.[4]	% Soil Disturbance
1	24000	4	N/A	100	83	5"	42
2	12000	4	N/A	100	50	5"	42
3	9000	4	N/A	100	42	7"	58
1	6000	4	N/A	65	10	5"	42
2	3000	4	225	0	1	7"	58

[1] Flow rate based on 12" opener row spacing

[2] % fluid showing in the furrow immediately after injection

[3] % of area outside furrow with surface pooling immediately after injection

[4] Average spread width of loose soil

The Dutch coulter was set for maximum penetration depth of about 4". The maximum depth was limited by the disc/hub design as the spring trip has sufficient tension to achieve deeper cutting depth.

The opener provided good injection performance at 3,000 GPA with almost no visible liquid in the furrow or on the soil surface. At 6,000 GPA opener performance was fair with 65% liquid visible in the furrow and 10% surface pooling. All application rates above 6,000 GPA resulted in poor injection performance with liquid pooling in excess of 40% of the soil surface.

Soil disturbance with the Dutch coulter ranged from good at a ground speed of 1 mph to fair at 3 mph. Residue retention was rated good with sufficient standing stubble remaining for good snow trapping.

5.1.4 Diamond Point Opener

The diamond point opener is a PAMI fabricated tool that bolts to a standard cultivator shank and uses a diamond shaped opener to form a V shaped slot in the soil. This opener was not run through a complete set of tests due to excessive soil disturbance (**Table 4**).

Table 4. Performance of the Diamond Point Opener.

Ground Speed mph	Flow Rate GPA[1]	Penetration Depth in.	% Fluid Showing[2]	Av. Width Soil Dist.[4]	% Soil Disturbance
2	14000	3	70	10”	83
3	9000	3	15	11”	92

[1] Flow rate based on 12” opener row spacing

[2] % fluid showing in the furrow immediately after injection

[4] Average spread width of loose soil

Diamond point soil disturbance rated poor with over 80% of the soil surface covered with loose soil including large lumps of soil. In addition, the volume of soil within the loose soil was observed to be much higher than with the disc openers. As the purpose of the project was to evaluate low disturbance injectors, testing of this opener was discontinued.

5.1.5 Inverted T Opener

The inverted T opener consists of a shovel type opener with flat (low lift) wings 8” wide in a V configuration. The wings were attached to a Bourgault knife opener that extends 1” below the bottom of the V. Performance of this bolt on opener was superior to the diamond point opener (**Table 5**).

Table 5. Performance of the Inverted T Opener.

Ground Speed mph	Flow Rate GPA[1]	Penetration Depth in.	% Fluid Showing[2]	% Outside Pooling[3]	Av. Width Soil Dist.[4]	% Soil Disturbance
1	24000	5	60	N/A	7”	58
2	12000	4	10	0	8”	67
3	9000	4	0	0	9”	75

[1] Flow rate based on 12” opener row spacing

[2] % fluid showing in the furrow immediately after injection

[3] % of area outside furrow with surface pooling immediately after injection

[4] Average spread width of loose soil

Soil disturbance rated fair with the inverted T opener with increased levels of soil disturbance as ground speed increased. Due to the large volume of loose soil and the number and size of soil lumps, testing was stopped.

5.1.6 Yetter Avenger Coulter

The Yetter Avenger coulter is a purpose built manure injection system. The Yetter uses a large 25" coulter with a rubber closing wheel operating on the side of the coulter. In addition, the Yetter system has optional paired discs that follow behind the coulter system. These discs move the soil back over the trench opened by the coulter and may reduce the escape of odour and fluid to the soil surface. The paired discs were used in preliminary trials and were effective in moving loose soil back into the furrow. As the coulters, without the optional discs, were effective in injecting large volumes of liquid, the discs were not used in the reported data. The Avenger's heavy construction and large diameter coulter allowed working depths of up to 9", although the maximum depth used in this project was 7" (**Table 6**).

Table 6. Performance of the Yetter Avenger Coulter.

Ground Speed mph	Flow Rate GPA[1]	Penetration Depth in.	Net Draft lb./opener	% Fluid Showing[2]	% Outside Pooling[3]	Av. Width Soil Dist.[4]	% Soil Disturbance
1	28000	7	N/A	100	40	5"	42
2	14000	7	562	0	0	5"	42
3	9000	7	N/A	0	0	5"	42
2	6000	4	350	30	0	N/A	N/A
3	3000	4	N/A	0	0	N/A	N/A

[1] Flow rate based on 12" opener row spacing

[2] % fluid showing in the furrow immediately after injection

[3] % of area outside furrow with surface pooling immediately after injection

[4] Average spread width of loose soil

The Yetter Avenger was an early production model and there was a problem with the positioning of the rubber closing wheel with respect to the coulter. The closing wheel had a gap between the wheel and coulter that allowed wet soil to build up between the coulter and the wheel plugging the assembly. The manufacturer provided an upgrade kit to reduce the plugging problem. However, plugging of the closing wheel continued following the installation and adjustment of the modified parts. As closer wheels have successfully been used for many years by seeding equipment manufacturers it is anticipated that the closing wheel problem will be solved.

The Yetter system provided excellent injection efficiency at all application rates up to 14,000 GPA at a depth of 7" and provided good injection efficiency up to 6,000 GPA at a depth of 4". The high rate of application was possible due to the depth capability of this opener system.

Draft at the 7” coulter depth was more than 1.5 times the draft at the shallow 4” depth. Although it was not measured, this system requires high down force on each coulter to achieve 7” penetration depths. To accomplish this it would require either adding weight to the toolbar or transferring the weight from the mounted three-point hitch of a tractor or from an injector tank wagon.

Soil disturbance with the Avenger rated good with about 42% of the soil surface covered with loose soil at ground speeds of 1, 2 and 3 mph. Residue retention was rated good with sufficient standing stubble remaining for good snow trapping.

5.1.7 Wide Blade

The Haybuster 32” wide blade is a low lift V blade similar in design to the Noble blade. A dual delivery manifold was fabricated for the back of the opener to direct the liquid flow along both sides of the blade. The single blade was set to operate at a 4” depth for the test (**Table 7**).

Table 7. Performance of the Haybuster 32” Wide Blade.

Ground Speed mph	Flow Rate GPA[1]	Penetration Depth in.	% Fluid Showing[2]	% Outside Pooling[3]	Av. Width Soil Dist.[4]	% Soil Disturbance
1	12000	4	0	0	8”	25

[1] Flow rate based on 32” opener row spacing

[2] % fluid showing in the furrow immediately after injection

[3] % of area outside furrow with surface pooling immediately after injection

[4] Average spread width of loose soil

The wide blade provided excellent injection efficiency with no visible liquid within the furrow or on the soil surface at an application rate of 12,000 GPA. Field observation indicated that although the amount of loose soil on the soil surface was low, all of the soil above the blade was lifted and settled following passage of the blade. The amount of sub-surface soil disturbance was a concern as it may result in weed germination and disruption of soil pores. As a result, the wide blade was judged as not acceptable to zero till farmers and no further testing was conducted with this opener.

5.1.8 HarvestTechnologies Hollow Wing

The hollow wing is a bolt on seeding opener consisting of a 1" wide vertical section and a hollow, 4" wide shovel attached to the bottom of the opener. The leading edges of the opener have carbide inserts for abrasion protection. Liquid flows from the supply hose through the centre of the vertical section of the opener and discharges through the rear of the hollow wing section.

The hollow wing provided excellent injection efficiency at rates of application up to 13,000 GPA (**Table 8**).

Table 8. Performance of the HarvestTechnologies Hollow Wing.

Ground Speed mph	Flow Rate GPA[1]	Penetration Depth in.	Net Draft lb./opener	% Fluid Showing[2]	% Outside Pooling[3]	Av. Width Soil Dist.[4]	% Soil Disturbance
0.5	12000	4¾	N/A	0	0	N/A	N/A
1	6000	4	N/A	0	0	11"	92
2	3000	3	N/A	0	0	9"	75
1.4	13000	3¾	N/A	5	0	10"	83
2.4	7000	3¾	N/A	0	0	10"	83
4.8	3000	3¾	N/A	5	0	12"	100
2	N/A	4	265	N/A	N/A	N/A	N/A

[1] Flow rate based on 12" opener row spacing

[2] % fluid showing in the furrow immediately after injection

[3] % of area outside furrow with surface pooling immediately after injection

[4] Average spread width of loose soil

Soil disturbance with the hollow wing opener rated poor at all ground speeds and depths except for the 2 mph - 3" depth treatment, where soil disturbance rated fair.

5.2 Low Disturbance Injection for Hay and Pasture Land

In pasture, the Greentrac's soil disturbance was very low at all ground speeds and it had good injection performance at 3,300 GPA but poor injection performance at 6,600 and 13,300 GPA. The poor injection efficiency at higher application rates was due to the relatively narrow slot cut by the coulter and a maximum penetration depth of 3½ to 4½ inches.

6. Conclusions

The Yetter Avenger provided excellent injection efficiency and low soil disturbance at injection rates as high as 14,000 Imperial gallons per acre (GPA). The modified Bourgault mid-row bander provided good injection efficiency and acceptable soil disturbance up to 9,000 GPA. The Haybuster wide blade and HarvestTechnologies hollow wing both provided excellent injection efficiency but had high levels of soil disturbance. The Dutch coulter had good injection efficiency at 3,000 GPA and fair efficiency at 6,000 GPA with acceptable soil disturbance. Its design limits depth of penetration and as such limits application volume. Other tested openers either had high levels of soil disturbance or were not able to inject large volumes of product without excessive amounts of pooling on the soil surface. The results of this testing indicate that some openers have the potential to provide acceptable swine manure injection capability under zero till field conditions. As testing was conducted on relatively few acres, durability of the openers was not evaluated. Prior to commercial application, openers should be tested over large acreage and under various soil conditions and textures including stony land.

6.1 Low Disturbance Injection for Hay and Pasture Land

In pasture, the Greentrac's soil disturbance was very low at all ground speeds and it had good injection performance at 3,300 GPA but poor injection performance at 6,600 and 13,300 GPA. The results of this testing indicate that low disturbance openers designed to work in pasture and hayland have the potential to effectively inject swine manure at low application rates. Further development of the opener systems is required to allow higher manure application rates.

7. Acknowledgements

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Appendix I

Figure 1. Modified Bourgault Mid-Row Bander.

Figure 2. Dutch Coulter.

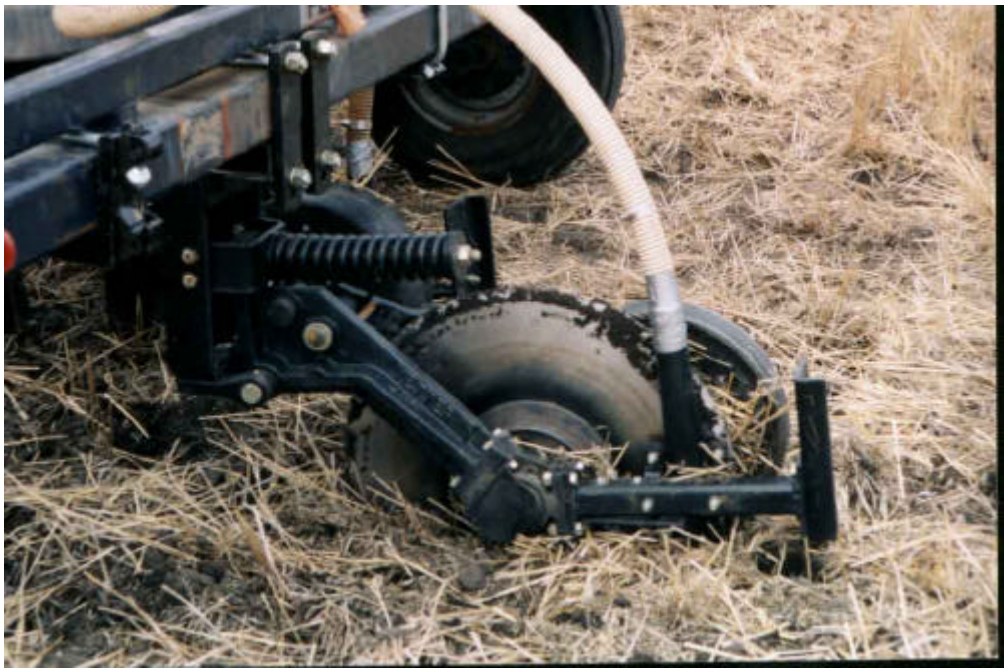

Figure 3. Yetter Avenger Coulter.

Figure 4. Haybuster Wide Blade.

Figure 5. HarvestTechnologies Hollow Wing.

Figure 6. Greentrac Coulter/Boot System.

Figure 7. Greentrac Soil Disturbance in Pasture.