MONTANA STATE UNIVERSITY

Modification of grain drill openers to place fertilizer below the seed

by John Thomas Palmer

A thesis submitted In partial fulfillment of the requirements for the degree of Master of Science I n Agricultural Engineering
Montana State University
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Abstract:
Field experiments were conducted to evaluate the effect of different furrow opener designs on small, grain stand and yield. Modified hoe-type grain drill openers that band fertilizer below the seed at planting time were used on a conventional grain drill under no-till and summer fallow conditions. Two sets of grain drill, openers that band fertilizer below the seed were designed and constructed In the Agricultural Engineering Research shop. Two sets of commercial grain drill openers that band fertllIzer below the seed were purchased from the manufacturers of the openers. The four fertll Izer-band I ng openers were of significantly different design.

RandomIzed complete block experiments were used to evaluate the performance of the openers. Banding fertilizer below the seed using the fertilizer-banding openers was compared to conventional fertilizer placements using standard openers.

Montana test results concur with other test results in that banding fertilizer below the seed with fertilizer-banding hoe-type openers sometimes Increases yields and never reduces yields. Weather and Insects were the major contributing factors to the low yields observed during tests and to the I ack of significant dlfferences In the results. One conclusion that concurs with farmers' observations Is that good stand establishment does not necessarily result In high yIelds.

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A thesis submitted in partial fulfillment
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of

Master of Science

in

Agricultural Engineering

MONTANA STATE UNIVERSITY
Bozeman, Montana

February, 1985

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Feb 8, 1985 — Date

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ACKNOWLEDGMENTS

The assistance provided by the following Montana State University faculty is gratefully acknowledged: Dr. W. E. Larsen and Dr. L. R. Erickson of the Department of Agricultural Engineering, Mr. A. Dubbs of the Central Agricultural Research Center in Moccasin, and Dr. A. J. Jones of the Western Triangle Research Center in Conrad. The shop assistance provided by Al Lien was essential for development of the test devices.

Data analyses for this project utilized MSUSTAT (1983) developed by Dr. Richard E. Lund. The particular programs used were Multi-Factor ANOVA (AVMF) and Pairwise Multiple and Contrast Comparisons (COMPARE).

Financial assistance for this project was provided by the Montana Agricultural Experiment Station and by a grant from the Montana Wheat Research and Marketing Committee.

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ABSTRACT

Field experiments were conducted to evaluate the effect of different furrow opener designs on small grain stand and yield. Modified hoe-type grain drill openers that band fertilizer below the seed at planting time were used on a conventional grain drill under no-till and summer fallow conditions. Two sets of grain drill openers that band fertilizer below the seed were designed and constructed in the Agricultural Engineering Research shop. Two sets of commercial grain drill openers that band fertilizer below the seed were purchased from the manufacturers of the openers. The four fertilizer-banding openers were of significantly different design.

Randomized complete block experiments were used to evaluate the performance of the openers. Banding fertilizer below the seed using the fertilizer-banding openers was compared to conventional fertilizer placements using standard openers.

Montana test results concur with other test results in that banding fertilizer below the seed with fertilizer-banding hoe-type openers sometimes increases yields and never reduces yields. Weather and insects were the major contributing factors to the low yields observed during tests and to the lack of significant differences in the results. One conclusion that concurs with farmers' observations is that good stand establishment does not necessarily result in high yields.

CHAPTER 1

LITERATURE REVIEW

Introduction:

The majority of the research studies on fertilizer placement, grain drills, and drill openers have been conducted with some form of conservation tillage in conjunction with conventional management practices. Tests are being performed of different management practices and equipment for conservation tillage. These tests are broadly classed as no-till and reduced tillage operations. The increased interest in conservation tillage shows the importance of including conservation tillage in research studies on fertilizer placement, fertilizer placement equipment, or other aspects of crop production (Bauder, 1984).

One in four farmers today practice some form of conservation tillage (Bauder, 1984). In 1983, 35 million hectares (87 million acres) representing 31 percent of the 1983 cropland in the United States was in some form of conservation tillage. Approximately nine percent of Montana's farmers use some no-till, which is the same as the national average. Thirty-four percent of Montana's farmers practice some form of reduced tillage, which is more than the national average of 24 percent. It is estimated (Bauder, 1984) that by the year 2000 over 90% of the crop producing areas in the United States will be under some type of conservation tillage.

Conservation tillage is not a new idea. In 1948 the USDA published a brochure entitled Stubble Mulch Tillage (Bauder, 1984). This practice was recommended when people began to realize that soil was one of the nation's most fragile resources and that tons of soil were being washed or blown away each year. However, traditional production economics were of primary importance and the conservation ethic secondary. Recently, with increased production costs, conservation tillage is becoming more economical, with soil conservation an important secondary benefit.

Tests were made in different parts of Montana (Jackson and Krall, 1980) to compare till-plant with no-till techniques. The data were averaged for the Eastern portion of Montana and for the Foothills region (Western Plains). Yield of small grains in Eastern Montana were practically alike with 1621 kg/ha and 1624 kg/ha (1446 and 1449 lb/ac) obtained on tilled and no-till land, respectively. However, in the Foothills region a 20-percent increase in yield was achieved by no-tilling. No-till is probably superior in the Western portion of the plains due to differences in weed species, soil types, moisture, and differing cultural practices.

Conservation tillage usually requires modification of existing equipment or the purchase of new equipment. Tests have been conducted (Payton, et al., 1979) to compare the performance of both new commercially-available and experimental no-till drills under a variety of soil and residue conditions. The drills tested did not have fertilizer banding capability. Results indicated that double disk openers penetrated poorly in heavy straw and tended to "hairpin" the straw down into the soil furrow. Coulters in front of the double disk openers appeared to improve opener performance, especially in heavy straw residue. John Deere HZ openers operated well in all of the residue conditions encountered, but trash clearance was improved somewhat when coulters were used in heavy residue. No significant yield differences between commercial and research drills were observed in the tests.

Fertilizer Placement:

Research studies comparing the effect of fertilizer banded below the seed with broadcast fertilizer applications have resulted in higher grain yields and more efficient use of fertilizer for the banding application. Greenhouse studies (Babowicz and Hyde, 1983) have shown no significant differences in stand establishment and early plant growth when fertilizer was placed 50 mm (2 in) or 75 mm (3 in) below the seed. However, when the fertilizer was placed 25 mm (1 in) below the seed it was found that stand establishment and early growth were significantly reduced.

Canadian scientists (Tomar and Soper, 1981) have found that under varying field trash conditions, wheat yields ranged from 3.76 to 5.40 Mg/ha (55.9 to 80.3 bushels per acre) when fertilizer was banded approximately 50 mm (2 in) below the seed. This compared to yields ranging from 3.26 to 4.53 Mg/ha (48.5 to 67.4 bushels per acre) when the same fertilizer rates were surface broadcast. These yield differences were obtained with banding under different field residue conditions. Soil scientists with the Montana Agricultural Experiment

Station (Skogley, 1984) have obtained similar results in numerous on-farm fertilizer trials throughout Montana.

Additional studies (Smith and Lillard, 1976) showed that fertilizer placement for no-till corn grown on chemically killed vegetative mulch cover gave comparable yields with all treatments if the soil had high fertility and rainfall was adequate and well distributed. However, during years when frequent periods of water deficiency existed, some increase in yield occurred with subsurface banding of all or part of the fertilizer.

Fertilizer placed directly below the seed was advantageous for both spring wheat and winter wheat when grown with a stubble residue mulch (Payton, et al., 1979). When fertilizer was placed below the seed there was also a decrease in wild oat populations. Additional studies showed that placing liquid and anhydrous fertilizer below the seed resulted in increased yields (Hyde, et al., 1982).

Placement of fertilizer too close to the seed can injure seedlings and reduce stands (Klepper, et al., 1983). If seed and fertilizer are separated adequately, fertilizers banded below or below and to one side of the seed can efficiently provide nutrients to the seedling and not damage the roots. Placing fertilizer three to five centimeters (1 to 2 in) below the seed or three centimeters below and up to 5 centimeters to one side is sufficient separation between seed and fertilizer in a silt loam soil (Wilkins, et al., 1982).

Efficiency of fertilizer use is improved with banding because fertilizer remains available to the plant longer into the growing season when it is placed deeper in the soil where there is available moisture (Larsen, 1984). Placing the fertilizer in a narrow band also reduces the tendency of the soil to tie up the fertilizer, allowing more nutrients to be available to the plant. Fertilizers can be banded deep in the soil either prior to planting or at planting time.

The optimum banding distance between the seed and fertilizer will vary with different field conditions. Factors such as soil type, soil moisture, small grain variety, the amount and kind of fertilizer applied, and the initial soil conditions all affect the crop response to fertilizer placement.

It is usually impractical to attempt to band fertilizer 75 mm (3 in) or deeper below the seed with conventional drills because of space limits on the machinery. The longer openers required would not lift high enough for adequate travel clearance.

The proper depth for seed placement will vary with different field conditions. Under dryland conditions it is desirable to place the seed in contact with firm, moist soil.

Fertilizer Banding and Planting Equipment:

Farmers and equipment manufacturers realize the benefits to be gained from banding fertilizer below the seed. Some newer no-till drills include fertilizer banding capability. The Myers Ditcher Company of Montana makes a no-till drill which has planting capabilities similar to the Yielder (formerly Pioneer) no-till drill manufactured in Spokane, Washington. Both drills have fertilizer banding capabilities which place the fertilizer a short distance from the seed row. Haybuster Manufacturing, Incorporated makes no-till drills with fertilizer banding capability in both double disk and hoe-type opener models. New fertilizer banding no-till drills can cost as much as $26,000 per meter width of drill. Some farmers are finding these new drills affordable (Holmberg, 1984). However, low cost openers developed for banding fertilizer using existing drills have a much greater chance for widespread grower acceptance than does the purchase of expensive new equipment.

Anhydrous ammonia application equipment is often used to band fertilizer prior to planting. Chisel shanks have been used (Allen, et al., 1976) to place anhydrous ammonia in fertilizer placement studies. Some farmers are now using this type of equipment in a combined operation at planting time.

Equipment is on the market that allows deep banding of dry fertilizer. These machines can be used prior to planting or in combination with planting equipment. Granular nitrogen (N) or nitrogen and phosphorous (N-P) fertilizers are often banded with pneumatic or gravity delivery systems mounted on, or integral with heavy-duty or intermediate-duty cultivators. Air seeders of various types are commonly used for banding dry fertilizer before planting.

Farmers have modified conventional cultivating equipment (ie. chisel plows, harrows, sweeps, etc.) to place both liquid and dry fertilizer 10 cm (4 in) deep or more into the soil. Chisel points have been replaced with banding knives to reduce soil disturbance and to lower power requirements (Domier, et al., 1983). This equipment could also be used in combination with planting equipment.

Conventional Equipment Modifications:

There is a recognized need for modification of conventional grain drill openers for banding fertilizer below the seed. Original equipment manufacturers, farmers, and some small farm equipment manufacturers are involved in such development. Scientists have focused investigations on the grain drill opener when evaluating modifications of conventional grain drills to place fertilizer below the seed (Schaff, et al., 1979).

The opener acts as a tillage tool to prepare the seed bed. The results obtained from this tillage operation depend on many tool and soil factors. The desired seed bed is firm and moist, resulting in rapid transfer of moisture to the seed. The soil covering the seed should present a surface that is resistant to drying. The generalized tillage relationships are mathematically represented (Gill and Vanden Berg, 1967) in the following equations:

$$F = f(T_s, T_m, S_i) \qquad (1.1)$$

$$S_f = g(T_s, T_m, S_i) \qquad (1.2)$$

where:
F = forces on the tool to cause movement
T_s = tool shape
T_m = manner of tool movement
S_i = initial soil condition
f = functional relation between F, T_s, T_m, S_i
S_f = final soil condition
g = functional relation between S_f, T_s, T_m, S_i

The only factor the designer can control in Equations 1.1 and 1.2 is the tool shape (T_s), which may be mathematically described. However, simple mathematical equations often cannot be used to represent the complex surfaces involved. Most tillage-tool shapes have been developed by cut-and-try methods or on the basis of qualitative analysis (Kepner, et al. 1980). Manner of tool movement (T_m) is influenced by the distribution of forces acting on the tool, the direction of travel of the tool, and the velocity of travel of the tool. The user may vary the depth of planting and speed of operation which influence the manner of tool movement. The initial soil condition (S_I) is influenced by the following soil properties:

1. Slope
2. Structure
3. Density
4. Strength
5. Texture
6. Mineral content
7. Chemical composition
8. Moisture content.

The tool may be operated through a wide range of soil conditions in any particular field operation, significantly complicating attempts at quantifying performance.

In previously mentioned studies (Hyde, et al., 1982), a modified John Deere HZ opener was used for fertilizer placement. The seed was applied through the rear portion of the opener or through a trailing double disk opener with an attached firming wheel. The John Deere HZ grain drill opener was further modified (Wilkins, et al., 1982) to band fertilizer approximately two inches below the seed. This modified deep-furrow opener was eventually developed into the USDA opener and is now manufactured by Garrison Fabrication in Maupin, Oregon.

Haybuster Manufacturing of Jamestown, North Dakota has developed different fertilizer banding openers for use on the Haybuster 8000 no-till drill. To date, no tests have been performed to compare performance of Haybuster 8000 fertilizer banding openers with other fertilizer banding openers.

An evaluation was conducted for six different grain drill opener types (Wilkins, et al., 1983). The openers included deep furrow, disk, and several hoe types. Field tests were conducted where seedbed moisture was limiting. Results indicated that opener type significantly affected seed distribution, soil moisture content, and bulk density in the seed bed. This in turn affected wheat seedling emergence. The best emergence was produced with the USDA deep furrow opener that placed over 70 percent of the seed in contact with soil that contained more than the limiting moisture content. Yield results in these studies showed that deep placement of fertilizer sometimes improved yields for conservation tillage systems.

In 1983 field tests were conducted at Montana State University to compare three types of openers (Larsen and Dubbs, 1983). A modified banding opener was designed and constructed in the Agricultural Engineering research shop and compared with Acra-plant and shovel-type openers. The modified opener placed the fertilizer in the center of the furrow and slightly deeper than the seed. Stand counts of Clark barley and Newana spring wheat indicated that the desired separation of the seed and fertilizer were not obtained. There were no significant differences in yield for the modified banding opener, Acra-plant openers, and the standard shovel openers when the same amounts of fertilizer were used. The results from these tests are shown in Table 1, and indicate that there was a response to increased rates of fertilizer.

Table 1. Yield Results From 1983 Opener Trials (Larsen and Dubbs, 1983).

Crop and Opener	Fertilizer applied KG/Ha (lb/ac)	Yield* MG/Ha (Bu/Acre)
Clark Barley		
Regular	0-0-0	2.58 (47.9)abc
Modified	28-34-0 (25-30-0)	2.30 (42.8)ab
Acra-plant	28-34-0 (25-30-0)	2.22 (41.2)a
Regular	28-34-0 (25-30-0)	2.37 (44.0)abc
Modified	56-34-0 (50-30-0)	2.43 (45.1)abc
Acra-plant	56-34-0 (50-30-0)	2.75 (51.1)bc
Regular	56-34-0 (50-30-0)	2.81 (52.3)c
Newana Spring Wheat		
Regular	0-0-0	1.30 (19.3)a
Modified	28-34-0 (25-30-0)	1.52 (22.6)a
Acra-plant	28-34-0 (25-30-0)	1.43 (21.3)a
Regular	28-34-0 (25-30-0)	1.67 (24.8)ab
Modified	56-34-0 (50-30-0)	2.06 (30.6)bc
Acra-plant	56-34-0 (50-30-0)	2.20 (32.8)c
Regular	56-34-0 (50-30-0)	2.28 (33.9)c

*Numbers within each grain type followed by the same letter are not significantly different at $p = 0.05$.

Very few tests have been performed to compare performance of modified fertilizer-banding grain drill openers with conventional fertilizer application methods. Results from available tests have been quite variable. Tests in central Oregon with modified openers sometimes resulted in increased grain yields relative to conventional openers and never reduced yields (Wilkins, et al., 1982).

To date, no tests have been performed to compare performance of modified fertilizer-banding grain drill openers with the newer no-till drills that have fertilizer banding capability. A test comparing conventional hoe opener drills with a commercial no-till drill (Yielder) was considered for these studies. However, the 1984 cost for renting a Yielder test plot drill for two weeks was $5,000 and the purchase price was $52,000 (Swanson, 1983) making it financially prohibitive to use in this project.

Problem Statement:

The intent of this research project was to develop and test modified grain drill openers that could be used to replace conventional openers. In order to be successful, the modified openers must improve fertilizer use efficiency.

Objectives:

The purpose of this research project was to investigate modifications of conventional grain drill openers to place fertilizer below the seed. The specific objectives were:

1. Develop grain drill openers with the capability of banding fertilizer below the seed to replace openers on conventional grain drills.

2. Conduct field tests to evaluate different openers on fields representative of Montana conditions.

3. Test the potential of using these modified openers on conventional drills under no-till conditions.

CHAPTER 2

MATERIALS AND METHODS

Opener Design Criteria:

Objective 1 was partially met by designing new openers. The criteria used for developing new openers and for selecting commercial openers for tests were:

1. The opener must place the fertilizer in a concentrated band below the seed with adequate separation between the seed and fertilizer.
2. The opener must place the seed at the proper depth, generally in contact with firm, moist soil.
3. The opener must provide a proper seed bed to encourage good moisture transfer to the seed and for proper germination for establishment of good stands.

Based on available information (Babowicz and Hyde, 1983), openers were designed to place fertilizer 50 mm (2 in) below the seed. Longer openers required to band fertilizer at greater depths would not lift high enough for adequate travel clearance with the available hoe-type drill.

Drill Test Frame:

The openers used in this project were designed to fit on a John Deere LZ drill, as it is typical of many commercially available units in the state. A conventional opener from this drill was used as a model for the mounting geometry and for the opener length in the design of the modified openers. Mounting components for the openers developed had to match equivalent components on the conventional openers. Openers developed could easily be adapted to other commercially available drills.

The maximum amount of granular fertilizer the LZ drill could deliver was 168 Kg/Ha (150 lb/ac). New sprockets were added to the fertilizer drive mechanism in order to deliver the high rates (195 kg/ha (174 lb/ac)) of granular fertilizer used in these studies.

Openers Used in the Field Tests:

Field experiments were conducted to evaluate the effect of different furrow opener designs on small grain stand and yield. The USDA opener, constructed by Garrison Fabrication (Garrison, 1984), and the chisel banding opener used on the Haybuster 8000 no-till drill (Egeland, 1984) were purchased for comparison in the opener tests. These openers were selected because they were the only chisel type openers available at the time of the study that banded fertilizer below the seed. These openers had to be modified for mounting on the John Deere LZ drill used in the study. The experimental, commercial, and conventional openers used for field tests are shown in Figure 1 and are described below. The number associated with each opener corresponds to the number shown in Figure 1.

1. Acra-plant openers are commercial openers that are commonly used in Montana. They are a narrow chisel-type opener that place the seed (and fertilizer when used) in a narrow band.

2. The standard John Deere openers are a 75 mm (3 in) shovel that place the seed (and fertilizer when used) in a band 50 to 75 mm (2 to 3 in) wide.