DRILL DEVELOPMENT FOR REMOVAL OF HERBICIDE TREATED SOIL

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PREFACE

Components were selected or designed to remove atrazine treated soil and crop residue from the furrow to minimize wheat seedling injury, while maintaining weed control between drill rows. Thus, high rates of herbicides could be used to insure weed control while minimizing wheat injury. Removing the residue reduced seedling injury caused by toxic chemicals released by decaying residue and diseases that live on residue.

I express my sincere gratitude to Dr. John B. Solie, my thesis adviser, for his advice, assistance, and friendship throughout this research. I also express sincere appreciation to my wife, Gayle, for her encouragement and love, and for her drafting services and help in my research.

Thanks are also due to my parents, Mr. and Mrs. Steve Dowell, for their love and support throughout my college career. Finally, I like to thank the staff of the Oklahoma State University Agricultural Engineering Laboratory for their assistance in building this project.

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CHAPTER I

INTRODUCTION

Conservation tillage practices are being used by wheat farmers for economic, as well as agronomic reasons. USDA projects that 85% of all cultivated cropland will be in some form of conservation tillage by the year 2000. Included in this estimate is 45% of that land in a no tillage farming practice (Shafer, 1981). Economically, a farmer can reduce fuel and machinery maintenance costs by not tilling the ground as often. Agronomically, soil erosion and soil moisture evaporation are reduced due to increased residue cover in a conservation tillage practice. Soil compaction due to wheel traffic will also be reduced if the farmer travels over the fields fewer times.

However, many problems must be overcome if conservation tillage is to be successfully used in wheat production. Weed and volunteer crop growth must be controlled by some method other than clean tillage. Herbicides can be used to control weeds and volunteer crop growth. However, herbicides that are available to farmers are costly and some must be accurately placed at specific rates. If too little herbicide is applied, poor weed control will result. On the other hand, too much may result in injury to the wheat.

These expensive herbicides can offset the savings realized through reduced labor and fuel (Epplin et al., 1983). Behavior of herbicides in the soil is not fully understood, thus a pre-emergent herbicide used to control both weeds and volunteer crop growth may not break down by fall planting and cause injury to the emerging crop seedling (Burnside et al., 1963 and Lowder and Weber, 1982).

Problems can also arise when residue is left on the surface. Tillage tools or grain drills must be capable of handling large amounts of residue (Krall et al., 1978). Allelopathy, release of toxic substances by decaying residue, can severely inhibit the growth of young wheat seedlings (Cruse and Elliott, 1984). Also, plant disease problems intensify because surface residue can also carry diseases which attack the growing plant (University of Illinois, 1980).

Many of these problems can be solved by proper grain drill design combined with proper herbicide selection and use. Herbicides are available that control weeds, particularly downy brome (*Bromus tectorum* L.) which is of primary concern to many farmers in this region (Fig. 1). This plant matures about the same time as winter wheat and has a seed similar in size to wheat, thus it is difficult to separate downy brome seeds from wheat at harvest. Downy brome sprouts in the fall and matures in the spring, thus it is difficult to control by tillage in a winter wheat cropping system. Herbicides available to insure control of

Fig. 1. Downy brome competing with winter wheat.

downy brome must be used at high rates and damage to the wheat plant may occur.

One possible solution to the problem of using marginally safe or toxic herbicides in wheat is to design a grain drill capable of removing soil contaminated with these herbicides from the drill row while maintaining weed control. If weed seeds are left on the surface, complete control of the weeds would result since no seeds would be left to germinate in the furrow below the layer of soil that was removed. At the same time this contaminated soil is removed, residue would be removed to minimize allelopathy and disease problems.

Objectives

The objectives of this research were to:

1. Design and construct a grain drill to remove herbicide contaminated soil and crop residue from the furrow.

2. Evaluate the effects of herbicide and crop residue removal by selected drill components on stands, seedling stress, forage yields, and grain yields.

CHAPTER II

LITERATURE REVIEW

A literature search was conducted to choose the optimum drill components to remove the soil and residue, determine how herbicides behave in the soil, and determine allelopathy effects on wheat seedlings.

Drill Components

Coulters

Many modifications have been made to conventional planters in attempts to adapt them to conservation tillage conditions. The most common modification is the placement of a rolling coulter in front of the furrow opener to cut plant residue. Vaishnav et al. (1982) evaluated three common sizes of disc coulters for their ability to cut crop residue as influenced by the soil cone index and straw density. They found a 46.0 cm coulter cut nearly 100% of the straw for straw densities from 1000 to 5000 kg/ha and at all depths of penetration tested. Krall et al. (1978) reported that a smooth coulter did a cleaner job of cutting through straw than a notched coulter. Coulters 40.6 cm in diameter or larger were recommended for cutting through heavy residue to prevent bunching.

Klocke (1979) indicated that using no tillage drills with no coulters was not satisfactory. Residue bridged between the openers and plugged the machine. He concluded that drills can be designed to seed under no tillage conditions. However, the cost of such a machine would be higher than a conventional drill due to size and weight required to accommodate rolling coulters and wider spacing of opener shanks. He used spring teeth with seed tubes attached to the back side of the teeth. Vibration of the teeth helped move loose trash through the machine, but the flat front and severe curvature of the opener occasionally bunched the stubble. Often these bunches fed back over the row and interfered with covering. Because of this bunching problem, the front row of coulters were spaced 10.2 to 15.2 cm from the opener points. When the coulters were mounted within 5.1 cm of the openers, straw clogged between them. The drill performed better when spear points and a 50.0 cm diameter smooth coulter were used. Also vertical clearance was increased to 61.0 cm. He used 1800 N of force per row to penetrate hard soils.

Schaaf et al. (1980) conducted an intensive study on performance of nine different coulters. They found that penetration ability was indirectly proportional, while vertical force was directly proportional, to the diameter of the coulter. Also, coulter shape had no significant effect on draft or vertical force requirement. However, coulter shape influenced furrow formation and amount of soil disturbance. They found large diameter coulters had good trash clearance ability, the optimum size being 45.7 cm diameter.

Openers

Morrison and Abrams (1978) mounted double disc openers on either side of the coulter. This eliminated plugging and the openers served as scrapers for the coulter. Schaaf et al. (1981) showed that a spike had the least vertical and draft forces when compared to a shovel, semi deep furrow, spear point, hoe, double disc, lister, planting and anhydrous knife. The double disc opener had the highest vertical force requirements. The semi-deep furrow, lister, planting, and anhydrous knife openers had highest draft force requirements.

Klocke (1979) used trapezoidal shaped wings on his hoe openers to hold dirt out of the furrow while the seed was deposited. Krall et al. (1978) showed a very narrow opener such as the double disc or slot openers handled the straw better and created better seedbeds as compared to spear points and 10.0 cm shovels. The double disc had to follow the slot of the coulter to obtain adequate penetration in firm soil and to prevent hair pinning of straw in furrow.

Press Wheels

Krall et al. (1978) reported that all types of press wheels worked well. Schaaf et al. (1981) reported that press wheel width should be equal to or less than the width of soil influenced by the opener.

Concave Discs

If a concave disc is mounted on the drill to remove residue or soil, such as disc furrowers used on row crop planters, then one should be selected that will require the minimum draft and vertical force. Gill et al. (1981) found that the smallest vertical, draft and side forces occurred with 64.6, 91.8, and 113.4 cm radii of curvature discs. This was at a disc angle of 23^{o} to 34^{o}.

Reaves et al. (1981) showed a 61.0 cm diameter disc with 122.0 cm radius of curvature had smaller draft, vertical, and side forces. Gill et al. (1980) stated that the optimum angle to run a disc was about 25^{o} to 32^{o}. Gordon (1941) found that as the disc diameter was increased from 51.0 to 62.0 cm that the draft, vertical, and side forces tend to decrease slightly.

Herbicides

Herbicide characteristics and movement in the soil must be known to determine how much herbicide contamination will cause plant injury. Atrazine (2-chloro-4-ethylamino-6-isopropylamino-s-triazine) was selected and its characteristics researched. Fenster et al. (1965) showed 100% weed control, including downy brome control, at atrazine rates of 2.24 kg/ha in Nebraska. In a silt loam, atrazine rates of

2.24 kg/ha did not cause injury to wheat planted 6 to 12 months later. In a fine sandy loam, wheat injury occured at rates of 1.79 kg/ha. When atrazine was applied at 3.6 kg/ha severe wheat injury occured in both soil types. Atrazine is labeled for use in Oklahoma at 0.56 kg/ha in wheat.

Burnside et al. (1963) showed atrazine leached to 30-45 cm depths, but in small amounts. Occasionally rates of 2 kg/ha injured wheat plants, but tillering increased to make up for losses. Ashton (1961) showed atrazine did not move out of the top 2.5 cm of soil with no application of water. When furrow irrigated, the herbicide moved laterally through the soil about 7.5 cm.

Birk and Roadhouse (1964) showed atrazine moved very little out of the top 1.7 cm of soil at rates from 2 to 20 kg/ha. Roadhouse and Birk (1961) showed very little evidence of lateral movement of simazine (2-chloro-4,6-bis(ethyl-amino)-s-triazine), which behaves similarly to atrazine, in soil. They found that movement was more likely a function of rain than concentration.

Lowder and Weber (1982) showed that liming increases atrazine longevity and so does the addition of sodium hydroxide. More atrazine was found in sandy clay loam than in loamy sand. No tillage plots contained higher amounts of atrazine than conventional till plots. They used rates of 1.5 to 3.0 kg/ha and showed weed control was better at higher rates. Kells et al. (1980) also showed addition of lime added to longevity of atrazine. Burschel (1961) found decomposition of simazine was highly dependent on temperature. A decrease from 25°C to 8.5°C caused a 7 fold decrease in rate of decomposition.

Harris and Warren (1964) reported that adsorption is higher for atrazine at lower temperatures. Nearpass (1965) also reported that clay content, organic matter and soil acidity effects adsorption of atrazine.

Slack et al. (1978) reported more rapid decrease in phytotoxic effects of simazine under no tillage as compared to conventional tillage may be due to higher organic matter, adsorption, and moisture in surface soil of no tillage ground. They also showed that no tillage treatments dissipate s-triazines faster than conventional tillage, which is in conflict with Lowder and Weber (1982). Burnside et al. (1961) showed simazine in soil was not deactivated by microbial activity from October to April but from May to July deactivation was rapid. Talbert and Fletchall (1964) reported little degradation in atrazine and simazine from September to June occurred in Missouri. Upchurch and Mason (1962) reported for equal toxicity that 5 times more herbicide was required with 20% organic matter than 40%.

Allelopathy Effects

Leaving residue in the drill rows can have a detrimental effect on the growth of the crop. Cruse and Elliott (1984) found toxic substances released from no tillage corn crops affected the newly emerged corn seedlings. They showed that, under lab conditions, root growth was cut by 30% on seedlings up to the four leaf stage. This damage occurred when seedlings or their roots came in direct contact with corn residue located on the surface to 2.5 cm below the surface. The problem was more prevalent in wet soils or soils with an aeration problem.

Cruse and Elliott (1984) also showed that wheat residues can be extremely toxic to emerging wheat plants. They showed that acetic and butyric acid secreted by wheat residues diminished or completely eliminated no tillage wheat stands. The problem was especially prevalent along a path where the combine deposited straw. They also found the problem to be worse in cool, wet falls. During normal falls, the toxic acids oxidized and escaped before affecting the seedlings. When the ground is wet, soil microbes do not seem to break down the toxins fast enough.

Cruse and Elliott suggested clearing a 15 cm residue free path to prevent the seedling from coming in contact with the residue. They also recommended not to push chaff into the furrow when planting. They recommended clearing the 15 cm path after planting.

McCalla and Duley (1949) showed wheat straw mulch at 4000 to 8000 kg/ha reduced the germination of corn to 44%. Borner (1960) showed cold-water extracts of wheat inhibited root growth. Guenzi and McCalla (1962) showed sorghum, corn and wheat cold-water extracts inhibited the growth of shoots and germination of wheat.

Guenzi et al. (1967) reported wheat, oat, corn, and sorghum residues, collected at time of harvest contained water-soluble materials that were toxic to growth of wheat seedlings. The order of increasing toxicity was wheat, oat, corn, and sorghum residues. State of decomposition was considered. Wheat and oat residues essentially contained no water-soluble toxic components after 8 weeks of exposure to field environmental conditions. Corn and sorghum residues had considerably more toxic materials at harvest and required about 22 to 28 weeks of decomposition. There were variations among varieties of wheat straw on effects of germination and shoot growth.

CHAPTER III

DRILL DESIGN

From the review of literature, about 3.5 cm of top soil treated with atrazine and the residue needed to be removed to minimize seedling injury. To accomplish this, a single drill unit was built to accommodate a concave disc mounted in front of a furrow opener, and as an alternative method, an opener modified to displace the soil and residue. Design criteria established here were used to design an eight row plot drill.

Component Selection and Single Unit Design

Components were selected that required the least draft and vertical forces while creating a good seed bed. Straw handling characteristics of the components were also considered. Various manufacturers were also consulted to determine which components worked best for them. Where literature and outside sources failed to give adequate or consistent design information, field tests were performed to establish design criteria.

A 46 cm coulter with depth bands, manufactured by Fleisher Manufacturing, Inc, Columbus, Nebraska, was selected to penetrate the soil with a minumum of vertical force and draft (Fig. 2). Two types of conventional furrow openers were selected. First, a John Deere spear point hoe was selected because it penetrates hard soils with a minimum vertical force. The spear point opener was mounted on LZ shank opener manufactured by John Deere, Iowa City, Iowa (Fig. 2). The narrow design of the hoe would minimize draft forces. Second, a double disc opener was selected for the minimum draft force requirements and good trash handling characteristics (Fig. 3). The opener selected was manufactered by the Tye Company, Lockney, Texas.

Openers selected for use on the plot drill would be used in two different row spacings, a 25 cm and a twin, or paired row, spacing (Fig. 4). The twin row spacing allows more room to place the residue and contaminated soil when removed from the furrow.

There was not sufficient literature to choose an optimum press wheel. Three types of press wheels were tested in the field to determine, by observation, which created the best seedbed environment. The three press wheels tested were: a 2.5 cm by 25.0 cm press wheel made by International Harvester, Edmonton, Alberta (Fig. 3), a dual angled 2.5 cm by 25.0 cm press wheel made by Marliss, Jonesboro, Arkansas (Fig. 5), and a 2.5 cm by 25.0 cm "walking" press wheel made by Fleisher Manufacturing (Fig. 2).

Concave discs were selected to clear residue and soil

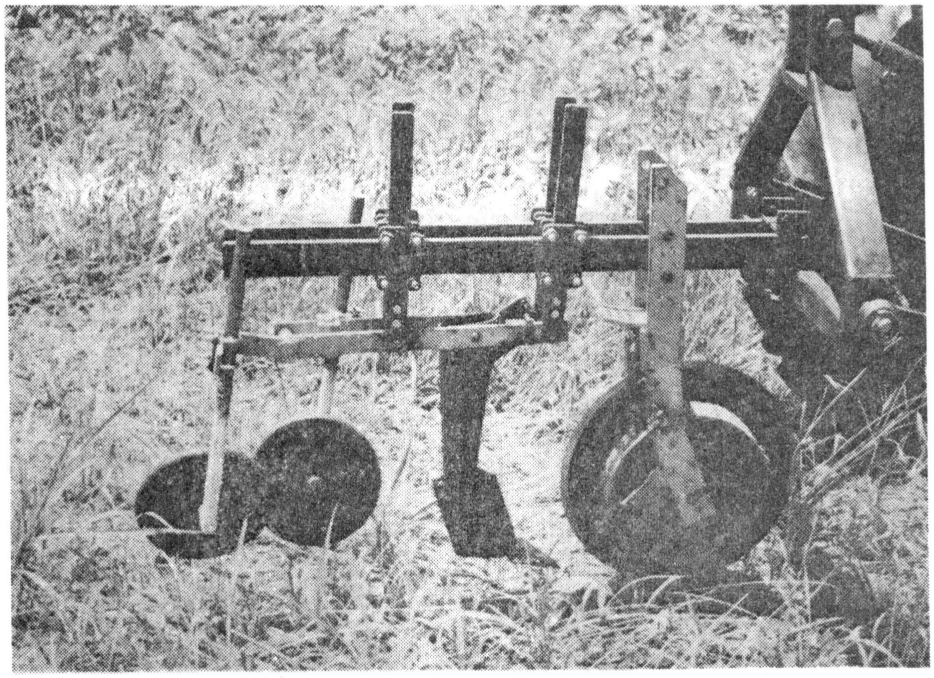


Fig. 2. 46 cm gauge coulter, hoe opener, and walking press wheels.

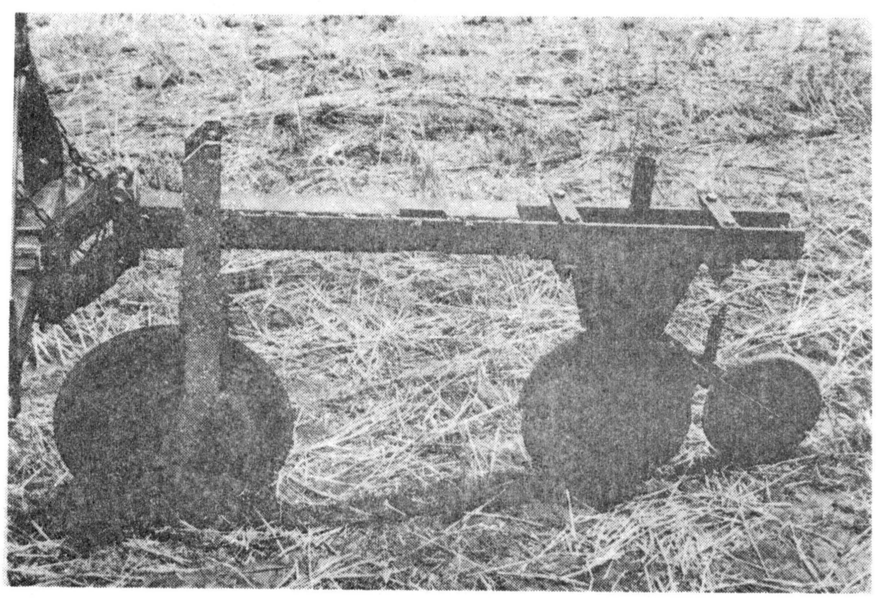


Fig. 3. 46 cm gauge coulter, double disc opener, and 2.5 cm by 25.0 cm press wheel.

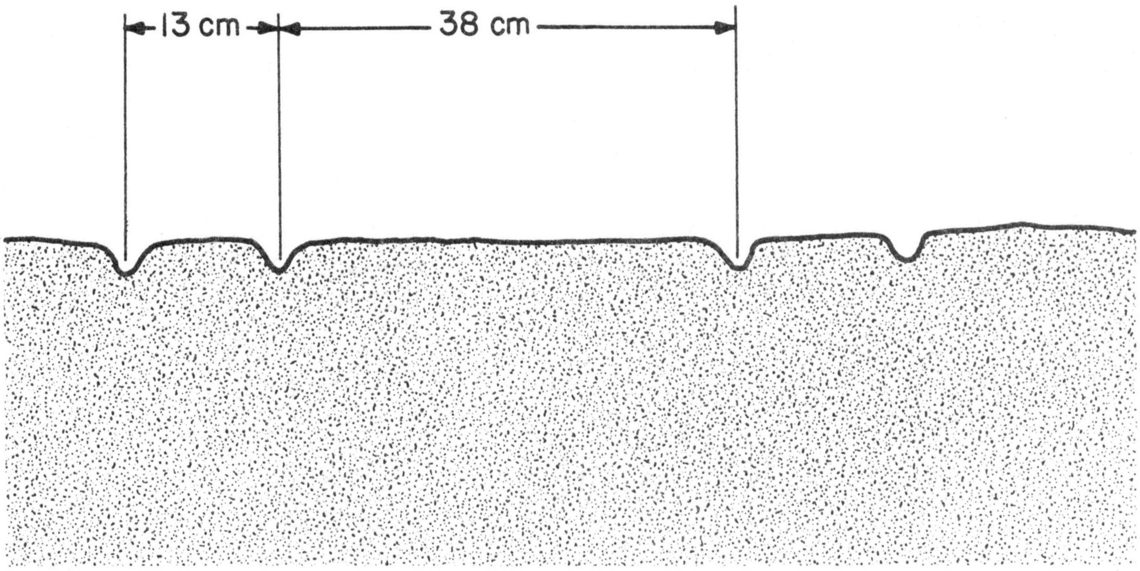


Fig. 4. Twin, or paired, row spacing.

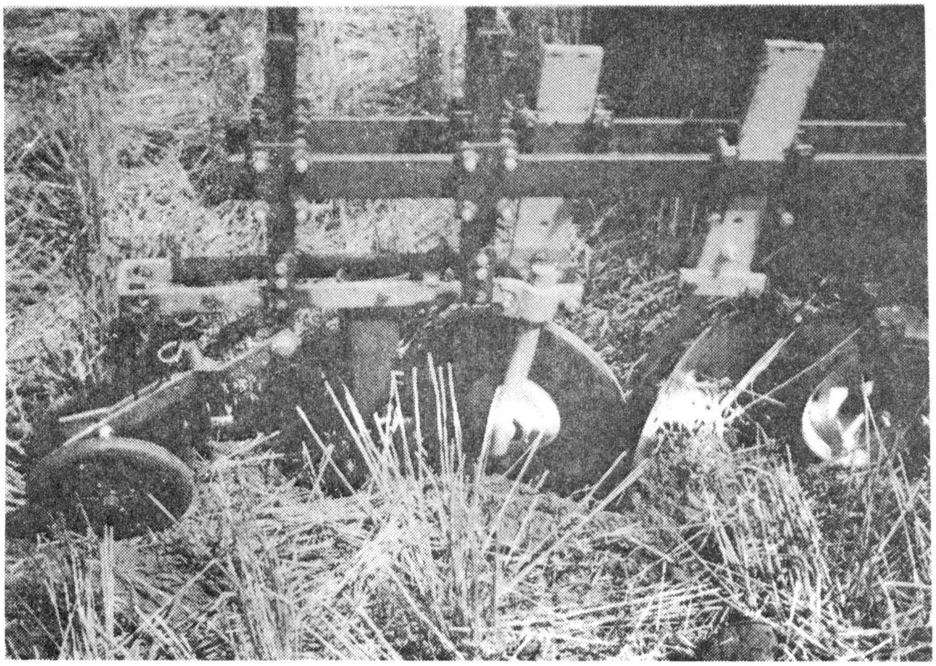


Fig. 5. Gauge wheel, offset 36 cm concave discs for atrazine treated soil removal, hoe opener, and dual angled 2.5 cm by 25.0 cm press wheels.

from the furrow. These were selected to require minimum vertical, draft, and side forces for the discs to penetrate and move the soil and residue for the width of cut desired. To clear a 10 cm path for openers on a 25 cm row spacing, offsetting 36 cm concave discs shown in Figure 5 were used and compared to a single 46 cm concave disc (Fig. 6). A 56 cm concave disc was chosen to clear a single 20 cm path for the twin row openers spaced 13 cm apart (Fig. 7).

As an alternative to the concave discs, three modified openers were designed to combine the soil moving characteristics of the disc into a single opener. One design utilized two pieces of metal welded on each side of the hoe to push the soil and residue from the furrow (Fig. 8). The two other designs were adaptions of a furrower to the hoe opener. The furrower was cut in half and welded on each side of the hoe opener in one design (Fig. 9). The other design involved mounting the furrower directly to the hoe opener (Fig. 10).

A three point mounted single drill unit was constructed to test the components selected. The unit was designed based on force requirements and with flexibility for mounting these components. The unit was built to withstand an estimated maximum draft force of 3.1 kN and 2.7 kNm of torque caused by the concave disc as determined from literature. Estimates from testing were used to further develop the unit. The unit was designed to remain parallel to the ground while floating on a four bar linkage

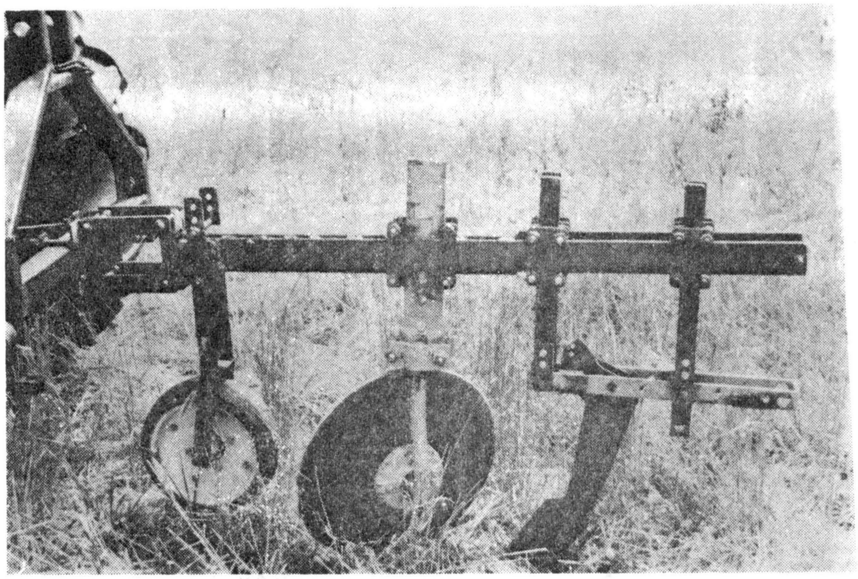


Fig. 6. Gauge wheel, 46 cm concave disc for atrazine treated soil removal, and hoe opener.

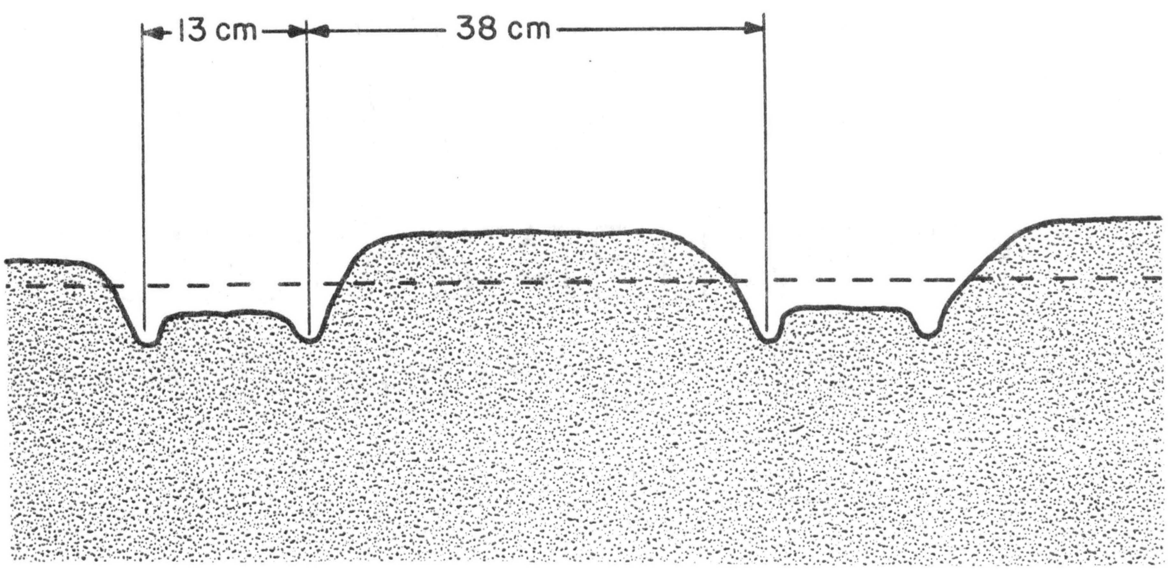


Fig. 7. Atrazine treated soil removed with 56 cm concave disc for twin row openers.

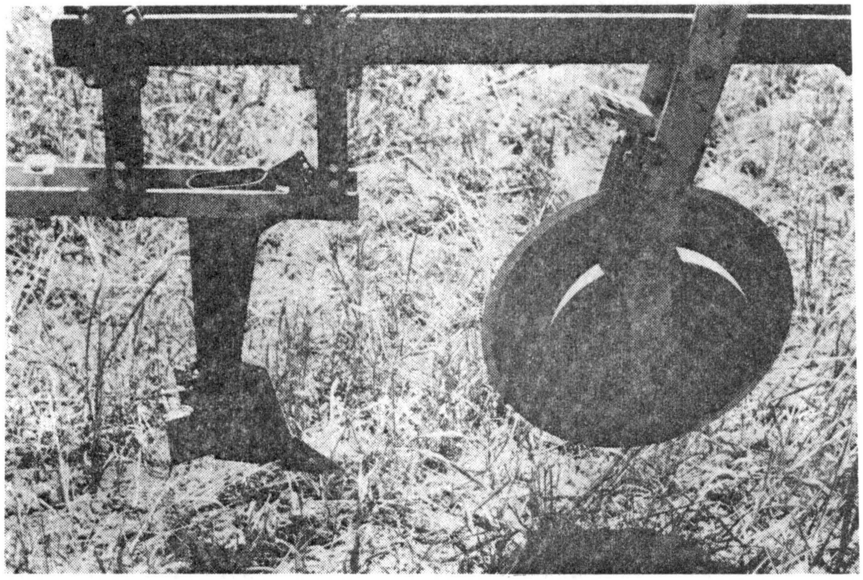


Fig. 8. 46 cm gauge coulter and hoe opener modified with wings to remove atrazine treated soil and residue.

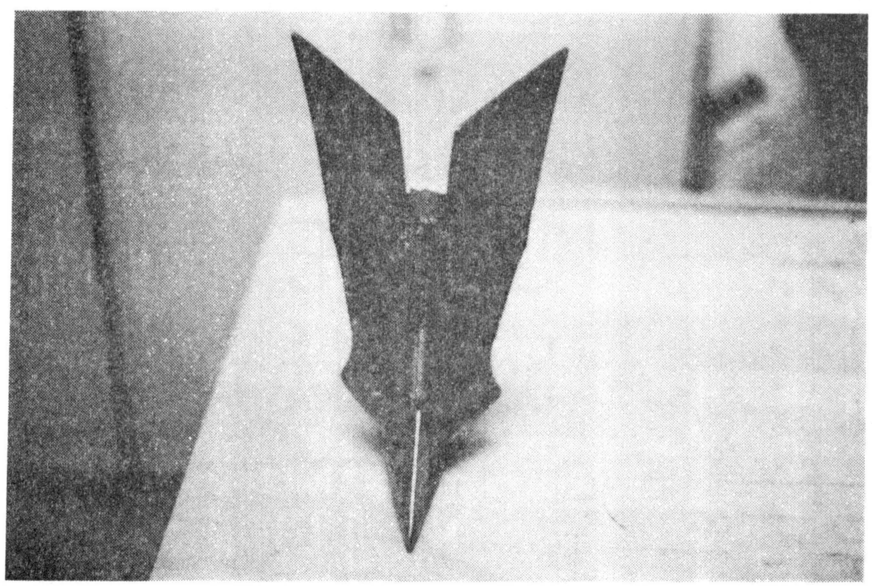


Fig. 9. Hoe opener modified with furrower to remove atrazine treated soil.

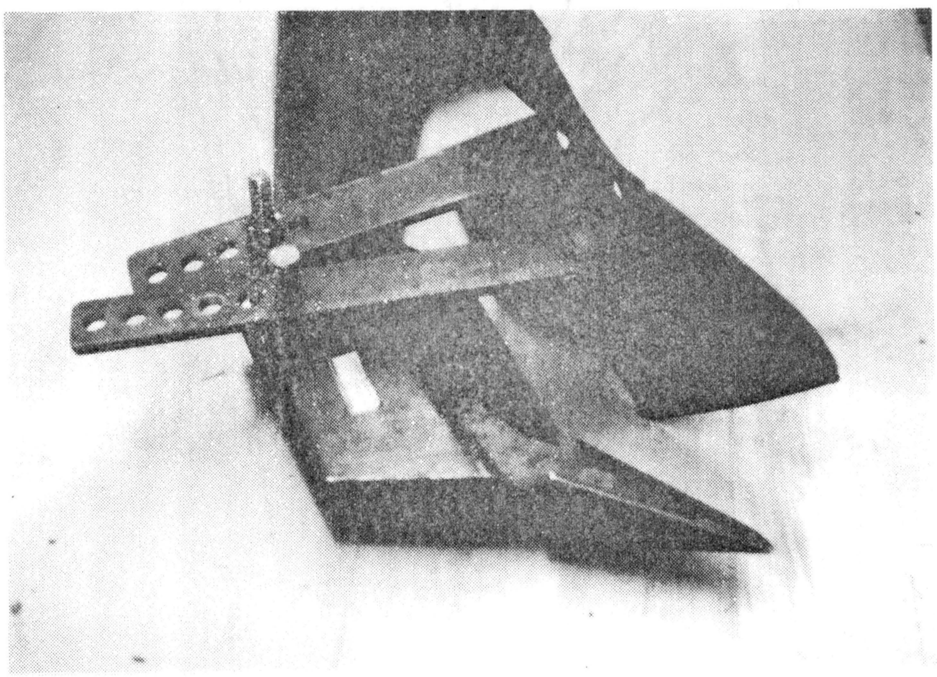


Fig. 10. Adjustable furrower connected to hoe opener used to remove atrazine treated soil.

connecting to the seeder frame. This characteristic was important to maintain accurate seeding depth over uneven ground.

The seeding unit combinations tested with this one row unit were:

1. Gauge coulter followed by a hoe opener (Fig. 2),

2. Gauge coulter followed by a double disc opener (Fig. 3),

3. Gauge wheel followed by a 46 cm concave disc and hoe opener (Fig. 6),

4. Gauge wheel followed by a 46 cm concave disc and double disc opener,

5. Gauge coulter and twin hoes placed 13 cm apart,

6. Gauge coulter followed by a 56 cm concave disc and twin hoe openers,

7. Gauge coulter followed by a 56 cm concave disc and twin double disc openers (Fig. 11),

8. Gauge coulter followed by a winged hoe (Fig. 8),

9. Gauge coulter followed by a modified furrower hoe (Fig. 9),

10. Guage coulter followed by a furrower connected to the hoe (Fig. 10).

Three press wheels were tested with each combination of opener and coulter to determine the effect of each combination on seedbed formation and soil movement.
Each combination was evaluated for soil and straw handling ability and seedbed formation.

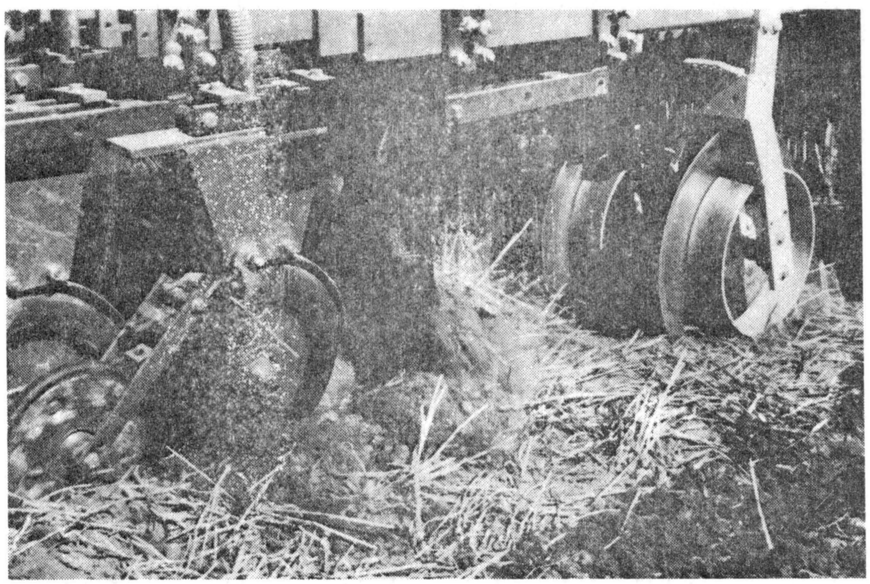


Fig. 11. 46 cm guage coulter followed by 56 cm concave disc to clear atrazine treated soil, and twin double disc openers.

Component and Drill Unit Performance

All tests were performed in a hard, dry, loam soil at Lake Carl Blackwell Experimental Range, Stillwater, Ok, with residue amounts estimated at over 4000 kg/ha. Cone index was estimated at over 4000 kPA. One test site had no tillage since harvest (Fig. 12), and the other test site had been worked once with a sweep plow.

Individual Components. The 46 cm coulter worked well in all conditions by cutting all straw encountered. The depth band on the coulter aided in cutting the straw by pinning the straw to the soil surface as the coulter cut the residue.

The hoe opener penetrated the soil well in all conditions. Under extremely dry conditions, the hoe opener fractured the soil into clods, creating a poor seedbed. The double disc opener had penetration problems in hard soils.

The 2.5 cm by 25.0 cm press wheel worked best in both the no tillage and minimum tillage conditions. The narrow design allowed the press wheel to follow in the furrow behind the opener and firm soil over the seed. The dual angled 2.5 cm by 25.0 press wheel did not perform well. When one of the press wheels encountered a clod or uneven surface, the other wheel lost contact with the soil. Difficulty was encountered with the walking press wheel when vertical or lateral adjustment for seed cover and firming was needed. Light construction of the dual angled and

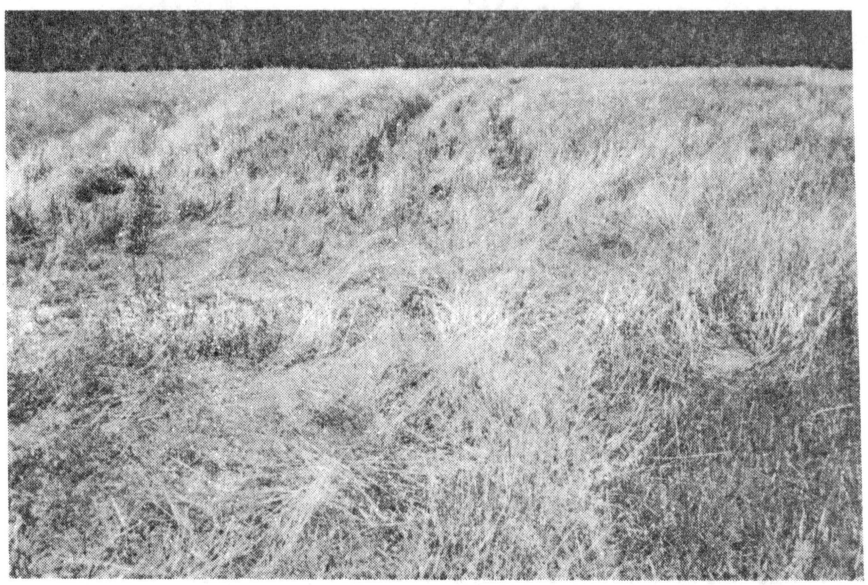


Fig. 12. Summer no tillage testing conditions.

walking press wheels did not provide adequate compaction and design of the press wheels was not rugged enough for a no till environment. These press wheels are designed to close the sides of the furrow over the seeds, but with the hard ground associated with no tillage condition, this was not accomplished.

The 36 and 46 cm concave discs were operated at a depth of 2.5 to 5.0 cm while maintaining a width of cut of about 7.6 cm. Problems were encountered with the steep angle of the 36 cm concave disc that needed to be maintained in order to cut a 7.6 cm wide swath. Excessive vibration, lack of penetration, and excessive side draft occurred as a result of this steep angle. The distance the soil was thrown could not be adequately controlled because of the steep angle. Two opposing 36 cm concave discs were also used to eliminate side draft and reduce the steep angle required when one disc is used. This reduced the distance the soil was thrown. However, additional draft and vertical force were required, and adjustment of the discs relative to each other was difficult to maintain.

The 46 cm diameter disc worked very well to clear a path for a single opener. With the disc set at about a 25° angle, a swath 7.6 cm wide could be cleared. The soil could be consistently placed in a ridge approximately 10 cm wide.

The 56 cm diameter disc worked very well in the twin row configuration. A path about 20 cm wide could be cleared for each set of openers placed 13 cm apart at a disc angle of about 25°. The soil cleared from this furrow could be consistently placed in a ridge 25 cm wide.

Unit Testing. With the individual components tested, combinations of these components were tested in the field to determine straw and soil handling ability.

1. The guage coulter and hoe opener worked well. However, some straw wrapped around the opener in heavy residue. Penetration was not a problem.

2. The gauge coulter and double disc opener moved through heavy residue better than the hoe opener, but some residue was rolled over by the opener, thus seed would be placed in straw pushed into the soil by the double disc opener. Penetration was a problem in hard soils.

3. The gauge wheel, 46 cm diameter concave disc and hoe opener had problems plugging with residue between the concave disc and opener. This was corrected by mounting the hoe within 10.0 cm of the concave disc to stop straw from swinging around the concave disc and catching on the hoe. The adjustable gauge wheel made the depth of penetration easy to change.

4. The gauge wheel, 46 cm concave disc, and double disc opener had some penetration problems. Plugging was not a problem since the disc opener would roll over straw creating a poor seed bed. Clearance between the concave disc and double disc was limited to 10.0 cm to prevent this from occurring.

5. The gauge coulter followed by twin hoes had

plugging problems which were eliminated by increasing the spacing between ranks of openers to about 45 cm. Although only one coulter was used, the cut straw would separate and flow around each hoe without plugging. Twin double discs were not used in this arrangement since these openers would roll over the straw instead of allowing the straw to flow around the openers.

6. The gauge coulter followed by the 56 cm concave disc and twin hoes worked well. Penetration was not a problem. The concave disc moved residue far enough not to interfere with the hoes.

7. The gauge coulter, 56 cm concave disc, and twin double disc openers had penetration problems in hard soils, but otherwise performed well.

8. The gauge coulter followed by the winged hoe moved soil and residue from the furrow, but the wings slid along the surface of the soil causing penetration problems in hard soils. In tilled soil, the wings moved the residue and top 2.5 cm of soil fractured by the hoe out of the furrow. The wings would clear a 5.0 to 7.0 cm path at the top of the furrow down to about 2.5 cm which is the width of the hoe.

9. The gauge coulter followed by the hoe modified by splitting furrower halves and welding to the sides of the spear point penetrated the soil better than the winged hoe. However, too much soil was moved and could not be consistently placed without throwing the soil into the next furrow.

10. The furrower mounted on the hoe was set to clear 2.5 cm of soil while allowing the seed to be placed 3.8 cm deep. This design allowed easy adjusting for the amount of soil removed relative to the placement of the seed, but did not penetrate satisfactorily.

Design of Openers for Spring Plots

Research was conducted to combine the soil moving characteristics of the concave disc into a single modified opener in the spring of 1985. Concave discs were removed and openers were placed within 10.0 cm of the coulter for more precision placement of the seed. A 25 cm row spacing was used for all configurations.

The hoe opener was used as a basis for developing the modified opener because of the good penetration and soil moving characteristics. The hoe was modified by the addition of wings to clear herbicide contaminated soil from the drill row while attempting to maintain good residue handling and soil penetrating characteristics. No previous research had been conducted on how to design wings for an opener to move small amounts of soil accurately, thus the openers were developed by building and testing models. Hoes were designed to clear paths of contaminated soil 2.5, 5.0, and 10.0 cm wide for use in evaluating how far the herbicide needed to be moved from the seedling while not throwing the soil into the adjacent furrow. The 2.5 cm furrow was created by using the spear point hoe opener with no modifications. Wings were made to clear larger amounts of soil.

Wings were made by forming a template of 16 gauge sheet metal to the desired shape and size. Wings were made from 12 guage flat iron for field testing with the templates. A toe was made to fit on the front of the hoe to separate the contaminated soil from the clean soil (Fig. 13). The design concepts behind this opener were to use the metal toe to separate the treated soil from the clean soil. Wings were used to roll this treated soil between the rows. The clean soil would flow under the metal toe undisturbed by the wings.

Preliminary field tests showed that the metal toe would ride across the top of hard dry soil, not clearing the contaminated soil as needed. In wet conditions, soil and residue built up between the metal toe and the bottom of the opener, not allowing soil to flow freely. Also, residue collected below the metal toe when not cut by the coulter, particularly when the unit was first lowered into the ground.

From this preliminary modified opener testing, it was determined that the metal toe caused poor penetration and plugging problems. The metal toe was removed and only the wings and the natural soil moving action of the hoe were used to move the soil.

A 5.0 cm path was cleared by mounting wings on the sides of the opener with the bottom of the wings extending

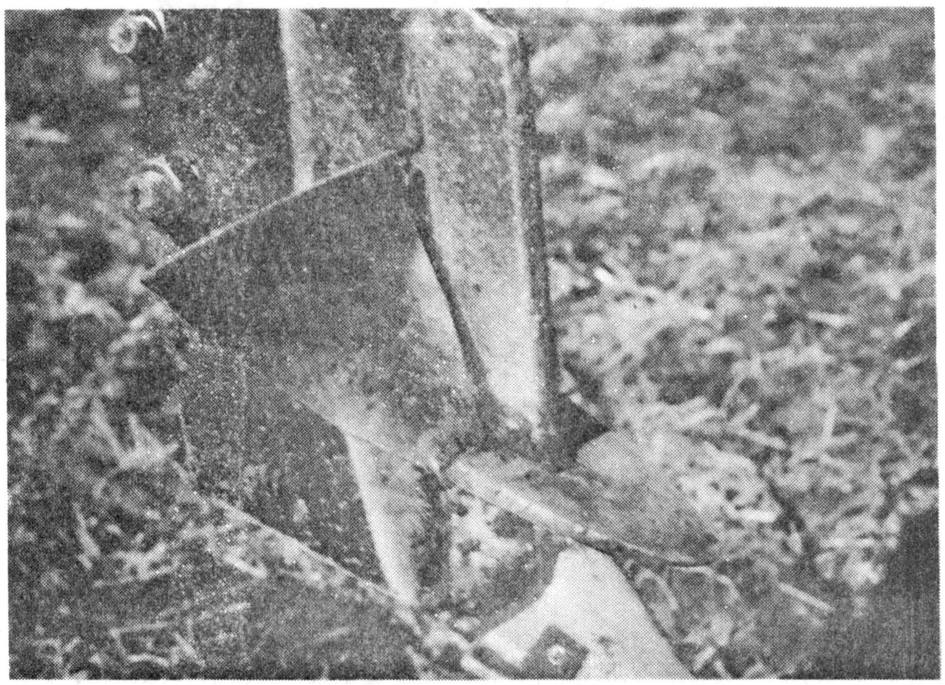


Fig. 13. Modified hoe opener with toe to separate atrazine treated soil from clean soil.

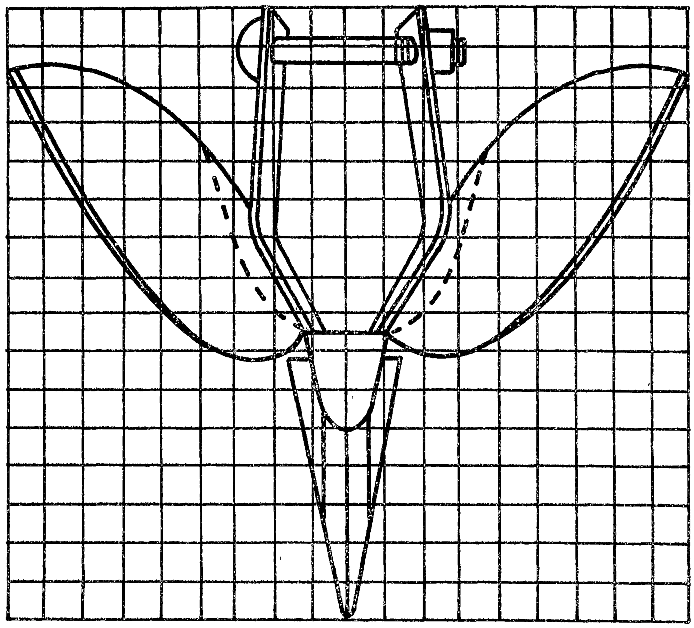
to about 5.0 cm above the bottom of the furrow (Fig. 14). The wings were curved and pitched to clear the desired width of furrow (Fig. 15). The bottom of the wings were above the surface of the ground when the unit was stationary. However, as the opener was pulled through the soil, the toe of the opener forced soil to flow up and around the opener. With the wings placed in the correct position, contaminated soil separated from the clean soil above ground level and was thrown between the rows (Fig. 16).

The 10.0 cm path was cleared by mounting larger wings on the hoe opener (Fig. 17). To move this much soil, the larger wings were extended below the soil surface. The design of the opener is shown in Fig. 18.

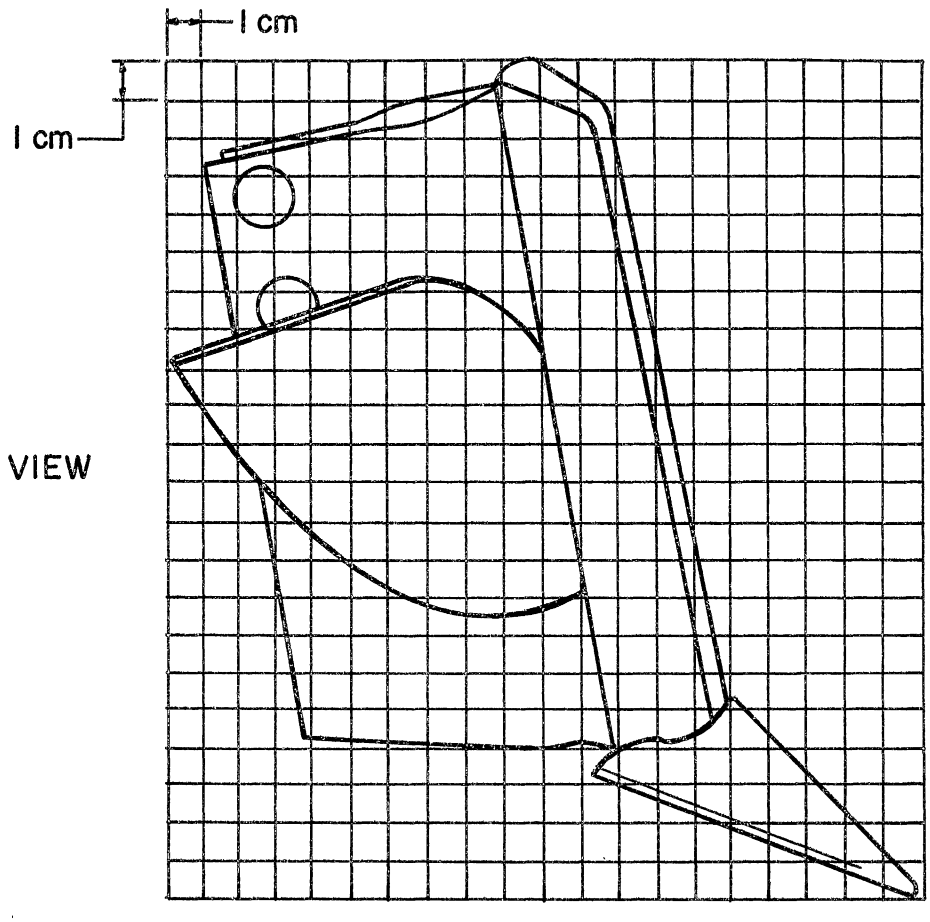
In an attempt to lift more soil to separate the contaminated soil from a path 10.0 cm wide above ground level, the bottom of the hoe opener was widened by welding wings onto the cast iron point of the 5.0 cm winged hoe. Testing showed a wider path could be cleared with this arrangement, but more extensive tests need to be conducted to determine if force requirements will be reduced compared to the 10.0 cm opener made by extending wings below ground level.

To keep contaminated soil from falling back into the furrow, the sides of the furrow were firmed with a 10 cm by 30 cm John Deere Vee type rubber press wheel. This press wheel firmed the bottom of the furrow above the seed, as well as the sides of the furrow (Fig. 14).

Fig. 14. 5.0 cm winged hoe used to remove treated soil, with Vee press wheel to firm seed bed.



TOP VIEW



SIDE VIEW

Fig. 15. Wings designed to clear atrazine treated soil from a 5.0 cm path.

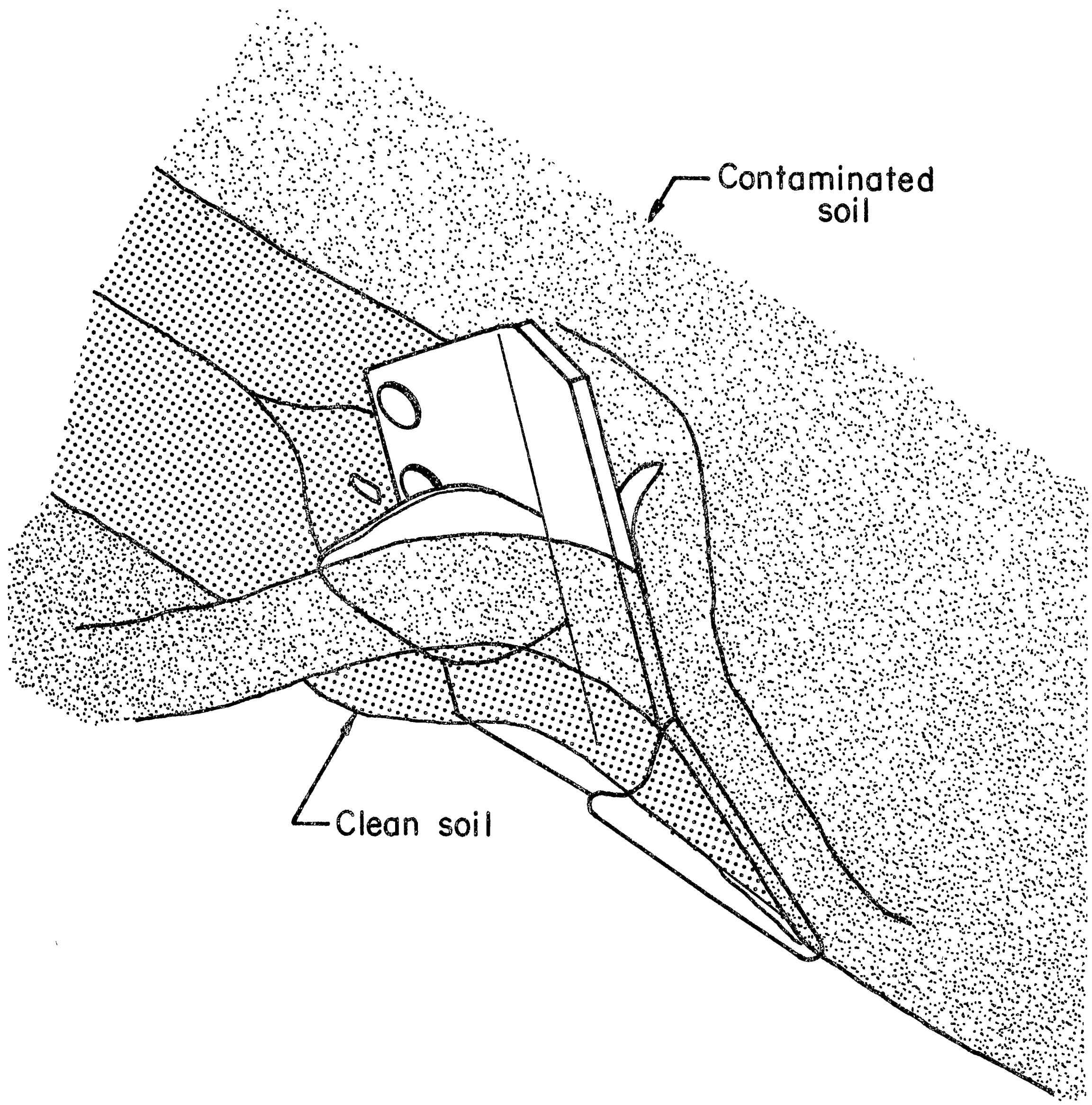


Fig. 16. Above ground separation of atrazine treated soil from clean soil with 5.0 cm winged hoe.

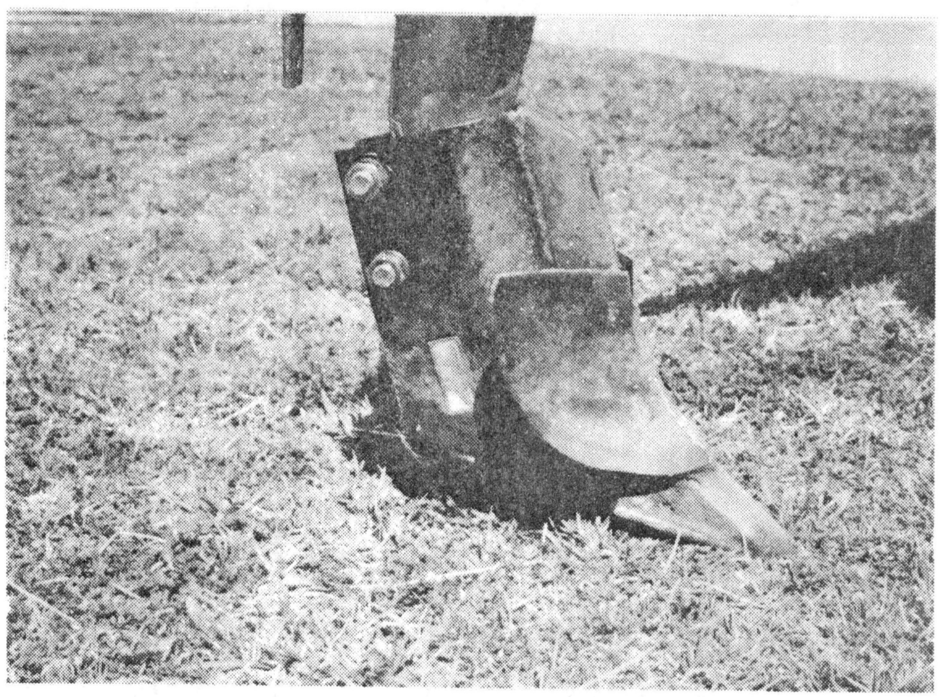


Fig. 17. 10.0 cm winged hoe used to remove atrazine treated soil.

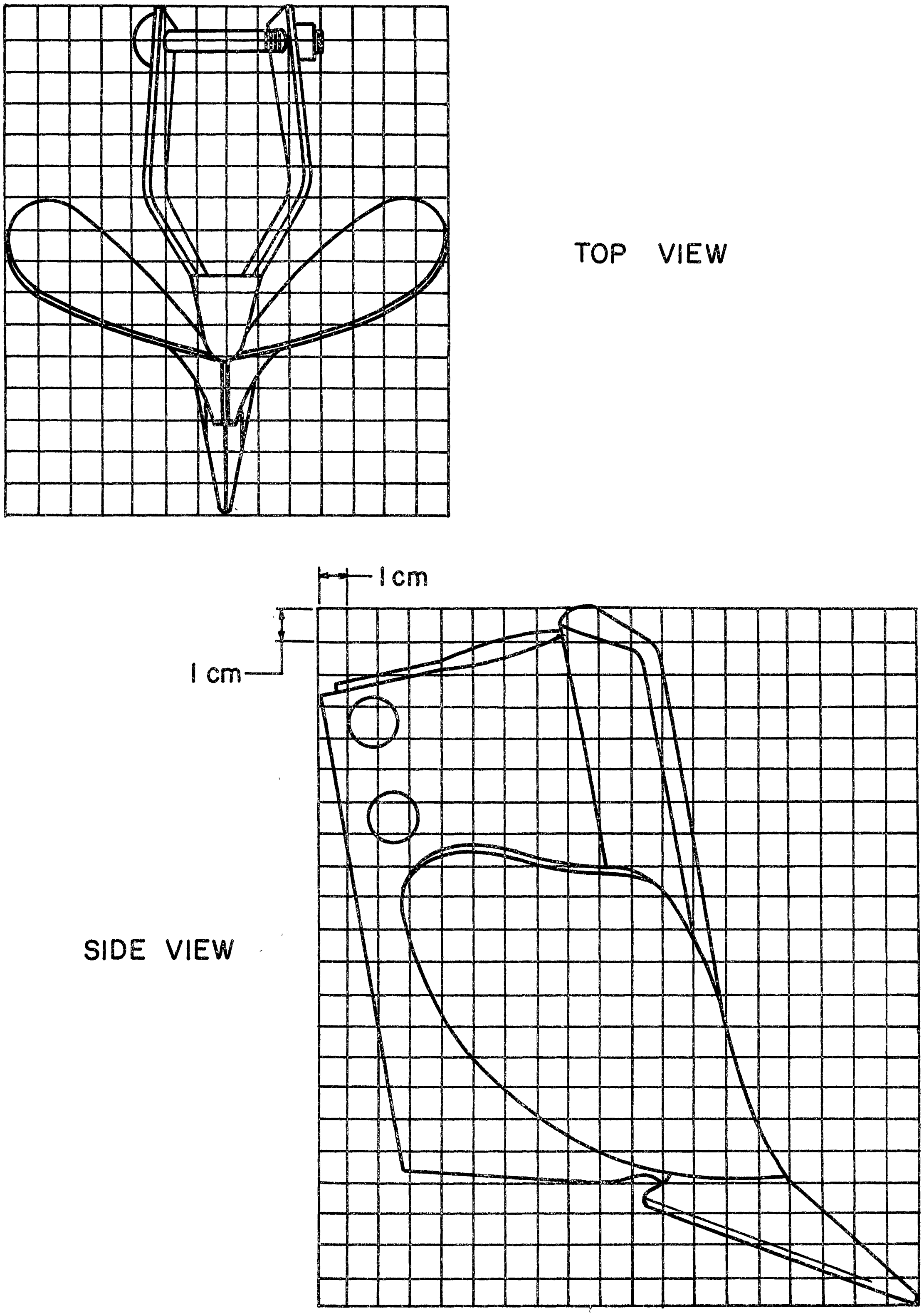


Fig. 18. Wings designed to clear atrazine treated soil from a 10.0 cm path.

Experimental Drill Design

Using the results from the one row unit, eight opener units were constructed. Four units were built 122 cm long, (Fig. 19), and four units built 135 cm long, (Fig. 20), to provide spacing between ranks of components, thus allowing residue to flow more freely. A four bar linkage connected each unit to the seeder and allowed each unit to float individually. The units were designed so each set of openers and press wheels could be attached and adjusted quickly.

A Wil-Rich air seeder, manufactured by Wil-Rich, Inc., Wahpeton, North Dakota, was mounted on a three-point frame to which the opener units were attached (Fig. 21). The seed box held about 110 kg of wheat and the fertilizer box held 80 kg of fertilizer. Seed was metered from the seed box into plastic seed cups by rubber rollers turned by a ground driven wheel. High velocity air produced by a gasoline engine driven fan moved the seed from the seed cups to the furrow openers through flexible seed tubes.

Hydraulic cylinders with a 6.3 cm bore and 20 cm stroke provided down pressure for each unit. The cylinders could apply 2200 kN of force per unit at 690 kPa. Air pressure was provided by an air compressor driven by the tractor engine. Air pressure was controlled by a manually adjusted regulator mounted by the tractor seat. Compressed air was stored in a reservoir on the seeder. The reservoir supplied or stored air as needed when cylinders contracted or

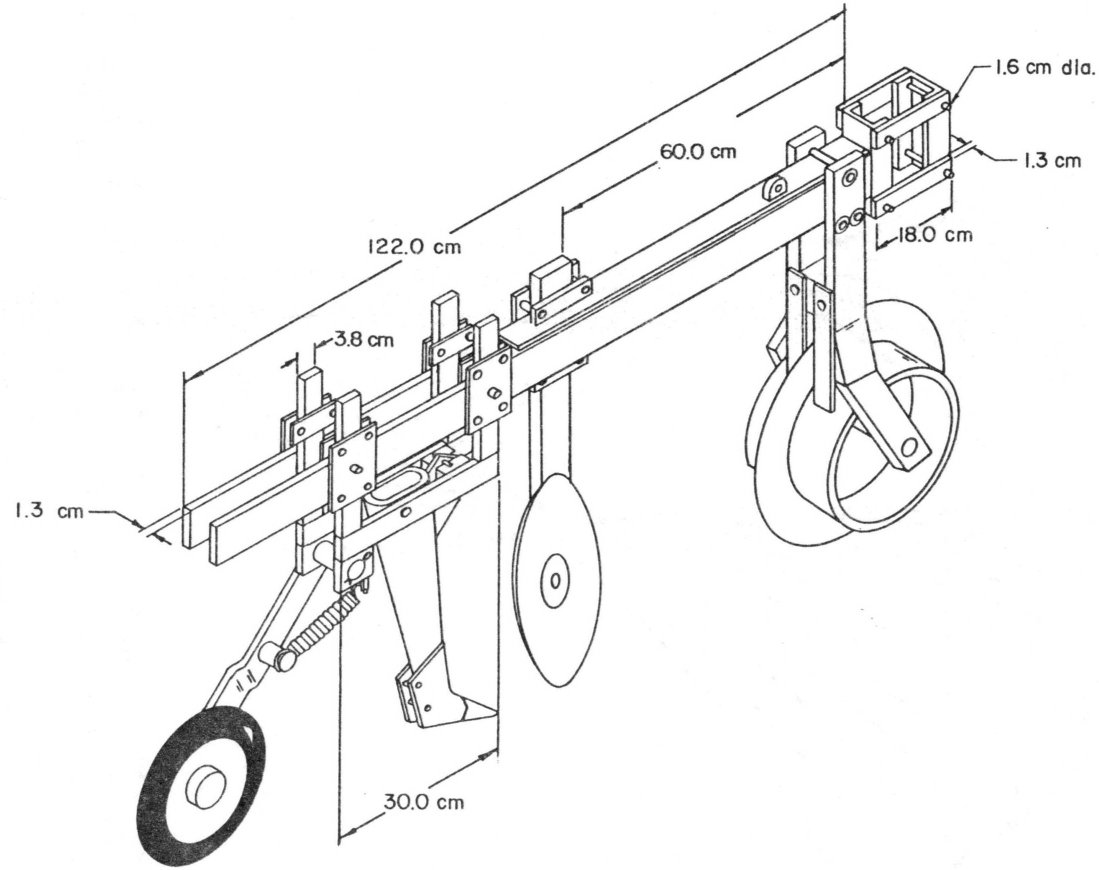


Fig. 19. Short opener unit with 46 cm gauge coulter, 46 cm concave disk to clear atrazine treated soil, hoe opener, and Vee presss wheel.

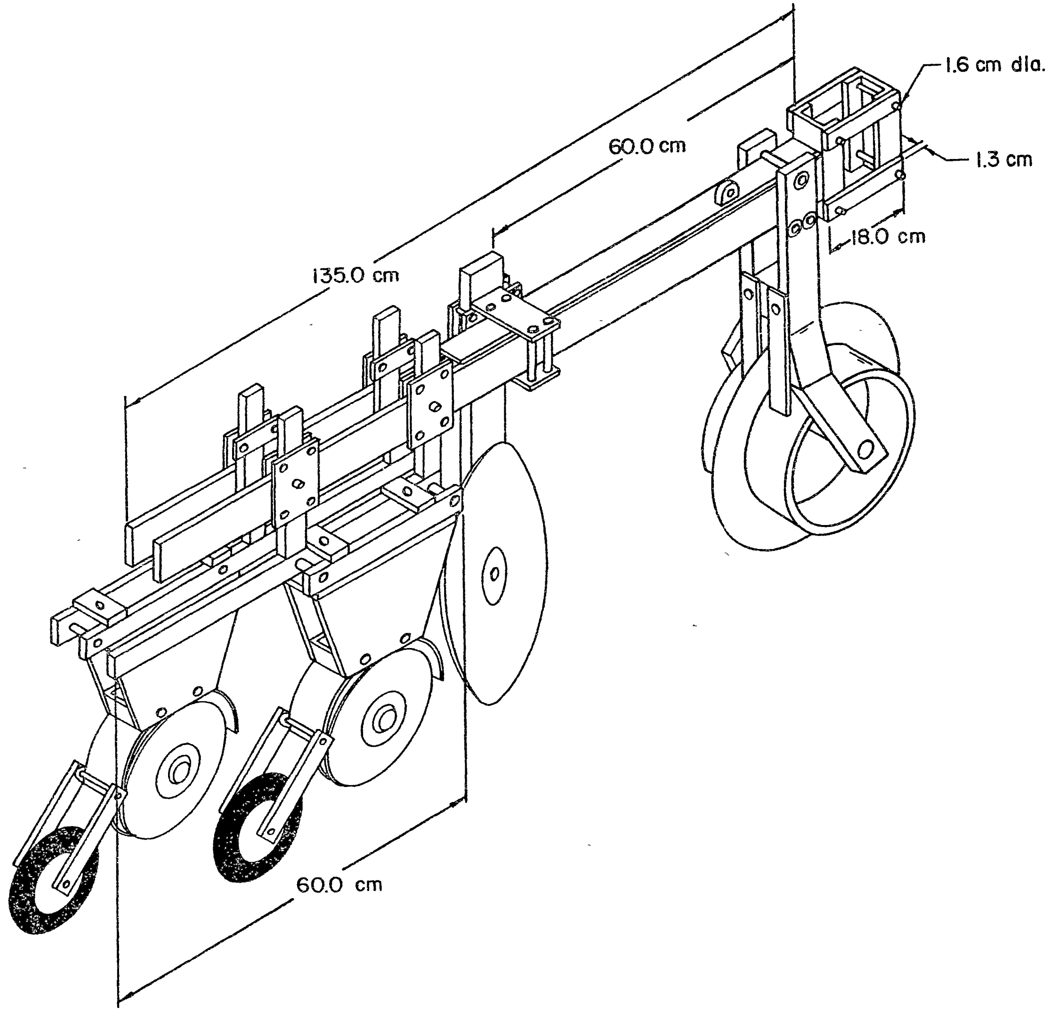


Fig. 20. Long opener unit with 46 cm gauge coulter, 56 cm concave disk to clear atrazine treated soil, twin double disk openers, and 2.5 cm by 25 cm press wheel.

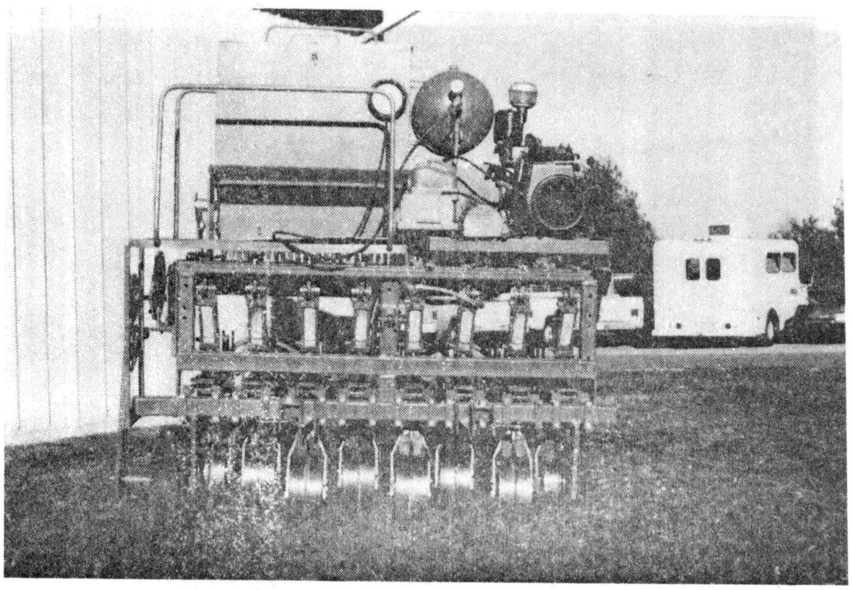


Fig. 21. Ground driven, three-point mounted air seeder, to which units were attached, with air system for down pressure.

extended. In the worst case, if all cylinders were contracted fully, the air pressure increased 24 kPa.

CHAPTER IV

METHODS AND PROCEDURE

Introduction

Experiments were conducted to determine the seedling environment created by each set of components selected, and to determine if a concave disc or a winged hoe opener could be used to remove herbicide contaminated soil and residue from the drill row while maintaining weed control. The components were tested in no tillage and conservation tillage environments and in herbicide treated soils. The previous crop in all experiments was wheat.

Component Evaluation Procedures

Six different component combinations were evaluated in no tillage and minimum tillage conditions. Plots were replicated at each location with date of planting as a factor. The combinations were:

1. Gauge coulter and hoe opener with the units placed on a 25 cm row spacing (Fig. 22),

2. Gauge coulter and double disc opener with the units placed on a 25 cm row spacing (Fig. 23),

3. Gauge coulter followed by 46 cm concave disc and hoe opener. Units placed on 25 cm row spacing (Fig. 24),

Fig. 22. 46 cm guage coulter and hoe openers on 25 cm row spacings with 2.5 cm by 25 cm press wheels.

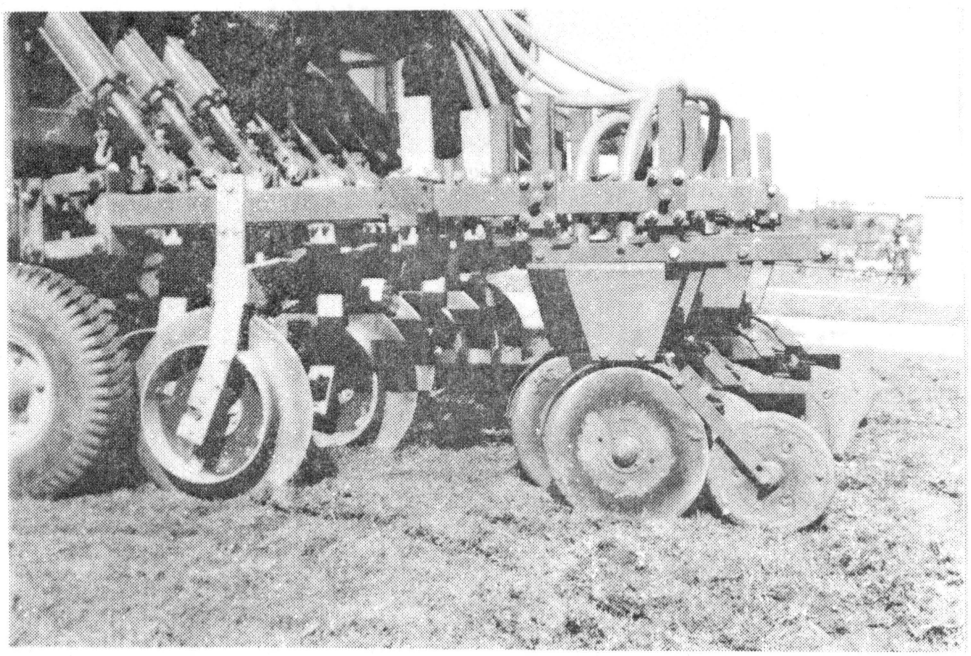


Fig. 23. 46 cm gauge coulter and 25 cm spaced double disc openers with 2.5 cm by 25 cm press wheels.

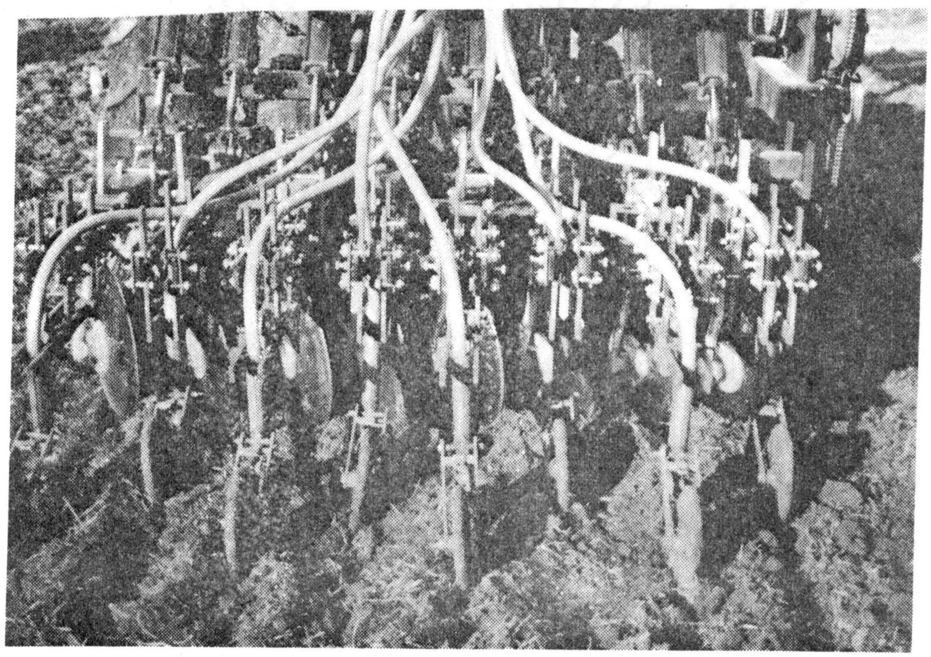


Fig. 24. 46 cm gauge coulter followed by 46 cm concave discs to remove treated soil and residue followed by 25 cm spaced hoes with 2.5 cm by 25 cm press wheels.

4. Gauge coulter followed by twin hoe openers,

5. Gauge coulter followed by a 56 cm concave disc which was followed by twin hoe openers (Fig. 25),

6. Gauge coulter followed by a 56 cm concave disc and twin double disc openers (Fig. 11).

A 2.5 cm by 25 cm press wheel was used with all combinations of coulters and openers.

No Tillage Experiments

Experiments were located at Perkins Research Station, Perkins, Ok., in a sandy loam, 54% sand, 28% silt and 19% clay. Average straw density, straw length, and percent of ground covered by straw are given in Table I. Surface residue was found by the line transect method. With this method, the occurance of straw was recorded for 30.5 m by noting if there was straw directly below marks 30.5 cm apart. This gave the percent of ground covered by straw and was an average of five replications (Canfield, 1941). Straw density was found by collecting, drying, and weighing all straw on the surface of the soil in a one meter square area as described by Whitfield et al. (1962). The straw was washed to remove all soil and dried for 48 hours at 70^{o} Celsius. The straw was weighed and average straw length recorded. This was an average of nine samples.

Plots were sprayed with Glean (2-chloro-N-((4-methoxy-6-methyl-1,3,5-triazin-2-yl)aminocarbonyl) benzenesulfonamide) at a rate of 1.12 kg/ha on July 20, 1984 to control

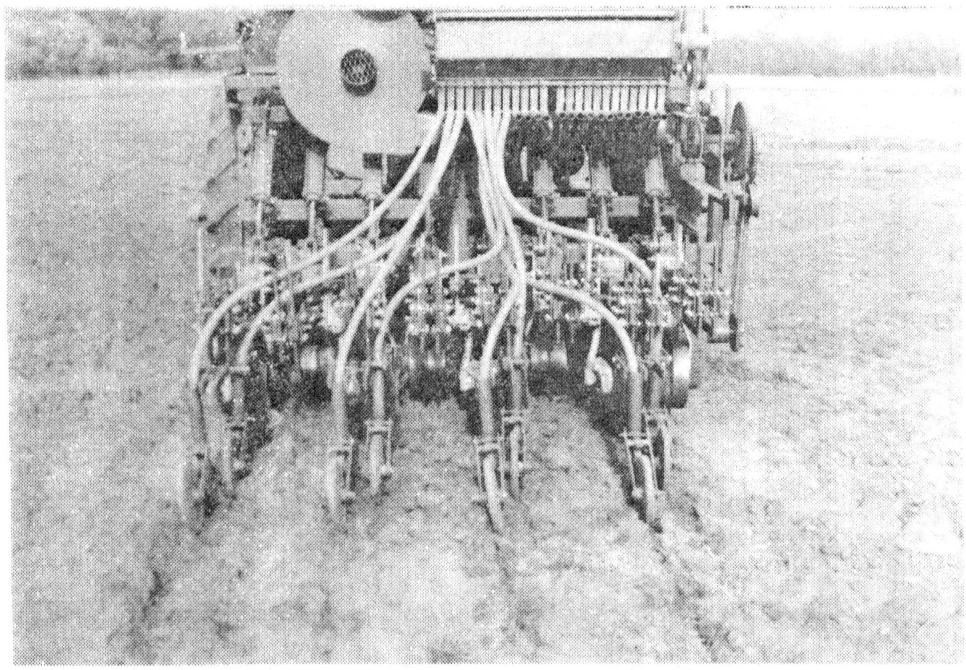


Fig. 25. 46 cm gauge coulter, followed by a 56 cm concave disc used to remove treated soil and residue for twin hoe openers with 2.5 cm by 25 cm press wheels.

Table I. Straw density, length, and coverage for Perkins no tillage and Blackwell minimum tillage experiments.

Location	Straw Density kg/ha	Straw Length cm	Coverage %
Perkins October 1	1230	23.0	62
Perkins October 18	1150	23.0	53
Blackwell October 10	2074	23.7	69
Blackwell November 5	55	12.7	20

weed growth for most of the summer. Plots were sprayed again on September 29 with 1.75 L/ha of Paraquat (1,1-dimethyl-4, 4-bipyridinium ion) plus 0.5 % of Ortho X-77 non ionic surfactant (alkylarylpolyoxyethylene glycols free fatty acids isopropanol) at 187 L/ha to control existing weed and volunteer growth. Cone index data was taken in every other plot and soil samples were taken to determine soil moisture content in every fourth plot on October 1 and 18 (Table II). Cone index data was collected using a tractor mounted, hydraulically operated, digital recording soil penetrometer system developed by Riethmuller et al. (1982). Cone index was measure each 20 mm to a depth of 300 mm. Soil samples were taken by a hydraulically operated soil probe mounted on the penetrometer frame. Plots were planted on October 2 and 19 with Tam 101 wheat (Triticum aestivum L.). A randomized block design was used with four replications for each combination (Fig. 38, Appendix A).

Stand counts were taken as the seedlings emerged. Seedling stress was evaluated by counting the number of tillers and leaves per plant as described by Klepper et al. (1982). The plots were monitored throughout the growing season for plant growth and disease stress.

Experiments were cut for yields on May 30 with a Gleaner model 'A' combine, manufactured by Allis-Chalmers Corporation, Independence, Missouri, with a 3.1 m header. Samples were weighed, and moisture content and test weights recorded.

Table II. Soil moisture and cone index data at Perkins no tillage and Blackwell minimum tillage experiments for top 15.2 cm of soil.

Location	Soil Moisture % DWB		Cone Index kPa	
	0-7.6 cm	7.6-15.2 cm	0-7.6 cm	7.6-15.2 cm
Perkins October 1	10.56	8.89	460	2805
Perkins October 18	11.27	11.17	1160	3551
Blackwell October 10	10.22	8.87	320	4052
Blackwell November 5	20.81	19.48	300	745

Minimum Tillage Experiments

Two minimum tillage experiments were located near Lake Carl Blackwell Experimental Range Area. Soil was 43% loam, 32% sand, and 26% clay. Average straw density, straw length, and percent straw cover are given in Table I. Cone index readings and soil samples were taken on October 10 and November 5, 1984. Soil moisture and cone index are recorded in Table II. Plots were tilled with a 3.7 m two section sweep plow, made by Miller Weeder Corporation, Stratton, Nebraska, approximately 5.0 cm deep on October 6. A 3.7 m two section Miller W rod weeder with semi chisels was used on October 10 to level ground and break up existing clods. A 3.1 m mulch treader, made by Richardson Manufacturing Co., Inc., Cawker City, Kansas, was used on November 5 before the second planting to control existing weed growth while leaving as much residue as possible on the surface.

Plots were planted using the same drill component combinations used in the no tillage experiments on October 11 and November 6 with TAM 101 wheat. A randomized complete block design with 4 replications was used (Fig. 39, Appendix A). Emergence counts and seedling stress were evaluated as discussed previously.

The first set of experiments were harvested for grain yields on June 10 and the second set on June 25 with the Gleaner model 'A' combine. Total weight, moisture content, and test weight were recorded.

Atrazine Toxicity Experiments

Two approaches were used to attempt to remove atrazine contaminated soil from the drill rows. One approach was to use a concave disc, the other was to use a modified winged opener.

Concave Disc Experiments

Experiments were located at Lake Carl Blackwell Experimental Range Area. Soil was 43% loam, 32% sand, and 26% clay. The plots had no tillage prior to planting. Plots were sprayed with 1.75 L/ha of Paraquat plus 0.5% of Ortho X-77 non ionic surfactant at 187 L/ha on September 29, 1984. A group balanced block in a strip plot design with one strip having two factors was used (Fig. 40, Appendix A). Atrazine was applied on October 15 and plots were seeded on October 17 with TAM 105 wheat (Triticum aestivum L.).

Seeding methods used were hoe openers, double disc openers, and the 56 cm concave disc followed by the twin hoe openers. The 46 cm coulter with depth bands and the 2.5 by 25.0 cm press wheels were used with all three methods. Atrazine rates of 0.56, 1.12, 2.24, and 3.36 kg/ha were used. Checks were split in half with one half receiving no chemical and the other half was sprayed with 1.12 kg/ha of glyphosate (N-(phosphonomethyl) glycine) after planting and prior to emergence of wheat.

Initial emergence was recorded and plant growth was monitored throughout the growing period to determine effects of atrazine toxicity on the wheat plant and on weed growth.

The experiment was harvested for grain yields on June 17 with a 1.5 m Kincade model Sp 50 combine, manufactured by KEM Company, Haven, Kansas. Grain samples were weighed before and after cleaning to determine amount of weeds and other foreign matter present in each treatment.

Winged Opener Planting Procedures

A set of experiments were designed to test how effectively the modified hoe openers and Vee press wheels would perform in atrazine treated soil. The openers used were the 2.5 cm hoe opener, 5.0 cm winged hoe opener, and 10.0 cm winged hoe opener. Press wheels used were 2.5 cm by 25.0 cm press wheel, and 10 cm by 30 cm rubber Vee type press wheel with adjustable springs for down pressure.

Two locations were used to test the openers in soil treated with atrazine. The first set of experiments were located at Perkins Research Station in a sandy loam soil, 56% sand, 26% loam, and 19% clay. These plots were sprayed with a 1.12 kg/ha rate of glyphosate on March 8, 1985 to control existing wheat and weed growth. Existing growth was about 12.0 cm tall. The plots were sprayed with atrazine at rates of 0.56, 1.12, 2.24, and 3.36 kg/ha the morning of March 14 and plots were planted with Natadorus wheat (*Triticum aestivum* L.) that afternoon (Fig. 41, Appendix A). The second set of experiments were located at Lake Carl Blackwell Experimental Range Area. Soil was 43% loam, 32%

sand, and 26% clay. The plots were sprayed with a 1.12 kg/ha rate of glyphosate to control existing wheat and weed growth, which was about 2.0 cm tall. Plots were sprayed with the same rates of atrazine as at Perkins and planted with Natadorus wheat on March 15 (Fig. 42, Appendix A).

In all experiments, seeding depth was maintained at about 2.5 cm. Experiments will be referred to as Perkins spring atrazine experiments and Blackwell spring atrazine experiments.

Plant growth was monitored by visually rating plant vigor. Stand counts were not taken as plants emerged in order to minimize any soil disturbance that would be caused by traffic in the plots. Stand counts were taken during early tillering of the wheat on April 26 at Blackwell and on May 3 at Perkins. Seed depth and plant height were also recorded at the time stand counts were taken.

Forage was collected from one square meter located in one half of each plot on May 24 at Blackwell and on May 30 at Perkins. Wheat, and weeds were separated and bagged individually. The forage was then dried at 50^{o} Celsius for 5 days and weighed.

Both experiments were cut for grain yields on July 2 with the Kincade model Sp 50 combine. Sample sizes of 1.5 m by 4.2 m were cut from each treatment. Samples were weighed before and after cleaning to determine amount of weeds and other foreign matter present in each treatments.

Experimental Design

All data was analyzed using SAS (Statistical Analysis System) on the IBM 3081D computer. An analysis of variance and Duncans analysis was performed on all data. For the group balanced block in a strip plot design, with one strip having two factors, a test of hypothesis was performed. This design is discussed by Gomez and Gomez (1983). The error terms used to test the hypothesis are given in Appendix B.

CHAPTER V

RESULTS AND DISCUSSION

Drill Component Test

Component Performance

At the Perkins no tillage experiments, hoe openers consistently had good penetration, residue handling, and uniform coverage of seeds. Double disc openers performed well except penetration was a problem in combine tire tracks remaining from the previous harvest. The 46 cm concave disc followed by the hoe had good penetration in all plots but plugged with residue in one plot at the October 2 planting. A pinch point existed at the axle of the concave disc and the face of the adjacent disc. Plugging also occurred between the concave disc and the hoe directly behind it. The 56 cm concave disc followed by the twin hoes handled the soil and residue well and penetration was not a problem. When the twin double discs were used with the 56 cm concave discs, penetration was a problem, causing non-uniform emergence.

At the Blackwell minimum tillage experiments, penetration was not a problem. Coulters plugged once when excessive down pressure was applied and the depth bands were forced into the softer soil. The hoe, twin hoe and 56 cm concave disc followed by the twin hoes each plugged once due to large amounts of existing straw. The 46 cm concave disc followed by the hoe opener had severe plugging problems at the October 11 planting. For the October 19 planting at Perkins and the November 6 planting at Blackwell, the plugging problem was solved by increasing the distance between ranks of openers to about 45 cm and by aligning the 46 cm concave discs in a straight row across the planter so that there was no spacing between the ranks of concave discs.

Plant Response to Components

The seedling environment created by each of these openers was evaluated by determining seedling stress according to Klepper et al. (1982) and yields in each plot. The number of main stem leaves indicates the stage of seedling development once the plant emerges. Rate of leaf appearance is not influenced by stress, except when appearance ceases altogether under severe stress. Variation in number of main stem leaves for seed planted at the same time is due to non uniform seedling emergence. Once seedlings emerge, they produce leaves at a rate determined by the environment, and this is therefore a measure of how fast seedlings emerged and how many seedlings were established. This parameter contains information on stand as well as on seedling development. Adverse environmental conditions can cause tillers to be omitted or delayed. Fig. 26 shows the tillers and main stem leaves.

Seedling stress was evaluated when the plant had from three to four tillers. Excessive moisture in November 6 planting at Blackwell and plugging of the 46 cm concave disc with the hoe opener at the October 11 planting at Blackwell prevented collection of stress data in those plots.

The mean total tillers produced (Table III), sum of main stem leaves and plant height (Table IV), were good indicators of seedling stress for the October 2 planting at Perkins. The hoe opener had significantly more total tillers per plant and the 56 cm concave disc with the twin hoes had significantly less sum of main stem leaves per meter. Examining all results at both Blackwell and Perkins showed generally the hoe, double disc, and 46 cm concave disc followed by the hoe opener had the lowest seedling stress at all plantings (Tables III, IV, V, and VI).

At Perkins, the double disc openers, and 46 cm concave disc followed by the hoe opener had the highest yields for both plantings (Table VII), which corresponded to the reduced seedling stress. All twin row openers produced the lowest yields when compared to the 25 cm row spacings. This indicated that competition between rows for sunlight, moisture, and nutrients resulted in lower yields.

For the October 11 planting at Blackwell, no significant difference of the openers on yields, test weight, or moisture content was observed (Table VIII). The

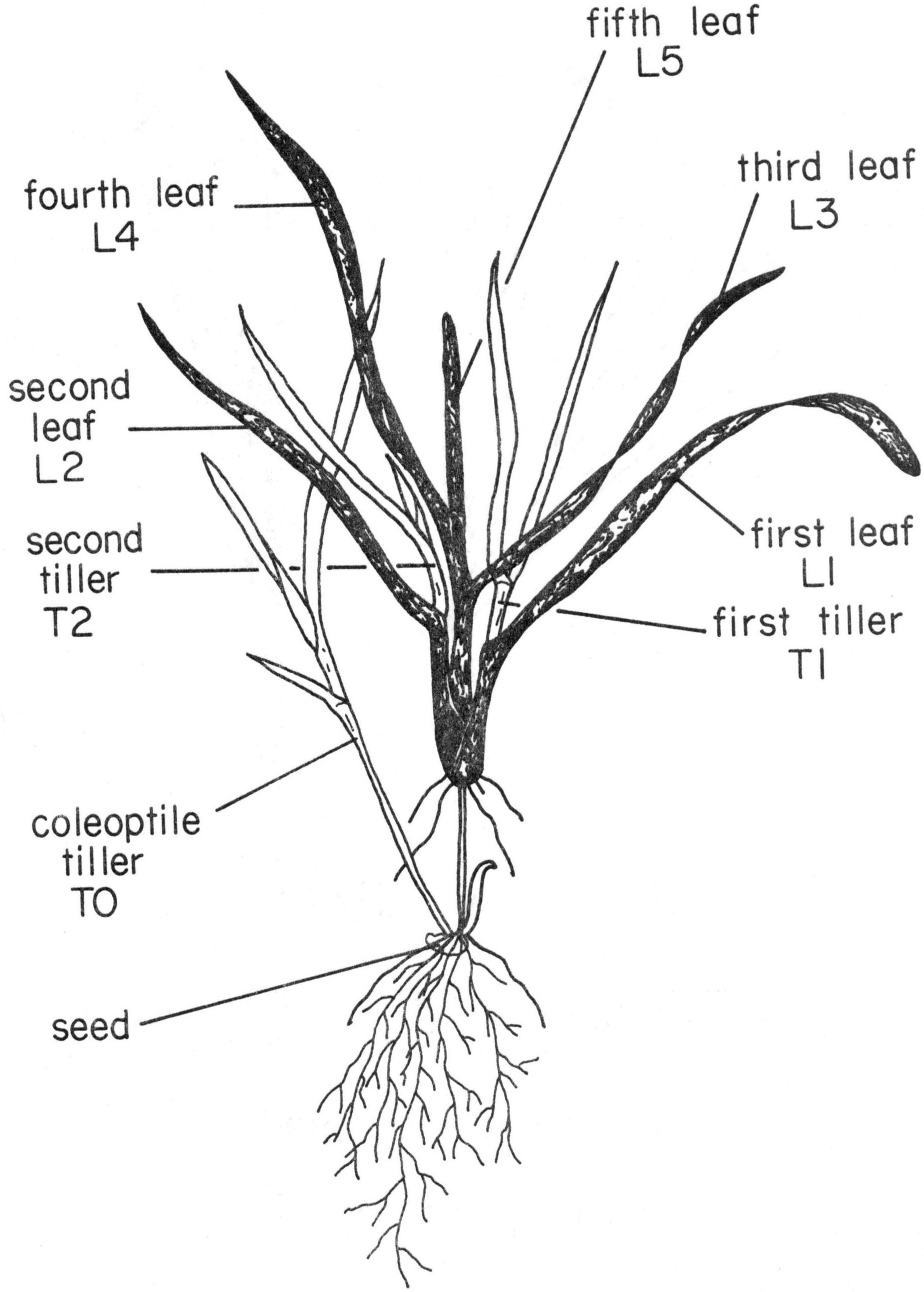


Fig. 26. Wheat plant showing leaf and tiller identification for seedling stress evaluation according to Klepper et al. (1982).

Table III. Influence of planting method on tillers produced at Perkins no tillage experiments.

Planting Date	Method	T0** %	T1 %	T2 %	T3 %	Tillers Per Plant
October 2	Hoe	0.0a*	62.5a	95.0a	95.0a	4.58a
	Double disc	0.0a	55.0a	97.5ab	82.5a	3.28b
	Twin hoe	0.0a	42.5a	90.0ab	81.3a	2.66b
	Concave twin hoe	2.5a	43.8a	96.3ab	81.3a	2.80b
	Concave twin disc	0.0a	43.8a	90.0ab	73.8a	2.58b
	Concave hoe	0.0a	52.5a	85.0 b	92.5a	3.05b
October 19	Hoe	0.0a*	50.0ab	85.0a	25.0a	1.68a
	Double disc	2.5a	77.5a	95.0a	32.5a	2.28a
	Twin hoe	0.0a	65.0ab	87.5a	35.0a	1.88a
	Concave twin hoe	0.0a	45.0 b	95.0a	23.8a	1.66a
	Concave twin disc	0.0a	56.3ab	91.3a	28.8a	1.88a
	Concave hoe	0.0a	52.5ab	95.0a	50.0a	2.03a

*Values in a column followed by same letter are not significantly different at P=0.05.

**T0, T1, T2, and T3 refer to specific tillers on the plant (Fig. 26).

Table IV. Influence of planting method on wheat growth and seed placement at Perkins no tillage experiments.

Planting date	Method	Main stem leaves	Main stem leaves/m	Height cm	Depth cm
October 2	Hoe	5.6a*	279a	12.6a	4.3a
	Double disc	5.2ab	292a	11.5abc	3.9ab
	Twin hoe	5.2ab	283a	10.5 c	3.5ab
	Concave twin hoe	5.3ab	291a	11.4abc	4.0ab
	Concave twin disc	5.0 b	210b	11.1 bc	3.1 b
	Concave hoe	5.3ab	284a	12.1ab	4.2ab
October 19	Hoe	4.92ab*	288a	8.13a	3.8b
	Double disc	4.96ab	270a	7.87a	2.9c
	Twin hoe	4.87 b	294a	7.99a	4.0b
	Concave twin hoe	4.85 b	285a	8.21a	4.1b
	Concave twin disc	5.20a	276a	7.96a	2.9c
	Concave hoe	4.99ab	282a	8.86a	5.1a

*Values in a column followed by same letter are not significantly different at P=0.05.

Table V. Influence of planting method on tillers produced at Blackwell minimum tillage experiments planted on October 11.

Method	TO** %	T1 %	T2 %	T3 %	Tillers Per Plant
Hoe	7.5a*	85.0	100.0a	37.5	2.73a
Double disc	5.0a	92.2a	95.0a	28.1a	2.55a
Twin hoe	3.2a	85.3a	97.1a	25.8a	2.20a
Concave twin hoe	0.0a	83.6a	96.3a	23.2a	2.27a
Concave twin disc	1.3a	78.1a	98.6a	26.7a	2.27a

*Values in a column followed by same letter are not significantly different at P=0.05.

**TO, T1, T2, and T3 refer to specific tillers on the plant (Fig. 26).

Table VI. Influence of planting method on wheat growth and seed placement at Blackwell minimum tillage experiments planted October 11.

Method	Main stem leaves	Main stem leaves/m	Height cm	Depth cm
Hoe	4.58a*	288a	10.94ab	3.6 c
Double disc	4.48a	270a	10.70 b	3.8 bc
Twin hoe	4.36a	294a	10.89ab	4.7a
Concave twin hoe	4.37a	285a	11.59a	4.4ab
Concave twin disc	4.49a	276a	10.01ab	4.3abc

*Values in a column followed by same letter are not significantly different at P=0.05.

Table VII. Influence of fall planting methods on wheat yields at Perkins no tillage experiments.

	Planting Date					
	October 2			November 19		
Method	Yield kg/ha	Test Wt. kg/m^3	Moist. %	Yield kg/ha	Test Wt. kg/m^3	Moist. %
Hoe	1979ab*	759a	14.1a	1555ab	669b	20.2a
Double disc	2006ab	766a	13.5a	1671ab	718a	16.6ab
Twin hoe	1740ab	756a	13.9a	1513b	695ab	15.3b
Concave twin hoe	1670b	740a	18.4a	1566ab	689ab	18.4ab
Concave twin disc	1929ab	766a	18.1a	1517b	673ab	18.1ab
Concave hoe	2262a	756a	13.4a	1867a	702ab	17.2ab

*Values in a column followed by same letter are not significantly different at P=0.05.

Table VIII. Influence of fall planting methods on wheat yields at Blackwell minimum tillage experiments.

	Planting Date					
	October 11			November 6		
Method	Yield kg/ha	Test Wt. kg/m^3	Moist. %	Yield kg/ha	Test Wt. kg/m^3	Moist. %
Hoe	1456a*	695a	13.7a	1451ab	708a	10.4a
Double disc	1412a	714a	12.6a	1717a	692a	10.3a
Twin hoe	1475a	702a	14.0a	1393ab	692a	10.9a
Concave twin hoe	1323a	708a	13.8a	1060bc	679a	12.1a
Concave twin disc	1348a	708a	13.1a	827c	675a	10.7a
Concave hoe	-----	----	-----	1567a	702a	10.2a

*Values in a column followed by same letter are not significantly different at P=0.05.

hoe and twin hoe openers had the lowest stands although not significantly different, (Table IX), but produced the highest yields. Thus as noted at Perkins, tillering made up for reduced stands. The concave twin discs and concave twin hoes had the lowest yields. It was observed that rain water stood in the furrow created by the concave discs used with the twin row arrangements. This water stunted or completely drowned out the wheat (Fig. 27).

In the November 6 planting at Blackwell, different openers had a highly significant effect on yields (Table VIII). As seen at Perkins, the double disc, hoe, and 46 cm concave disc followed by the hoe opener produced highest yields. These yields were significantly higher than the concave twin hoe and concave twin disc plots. All 25 cm row spacings yields were higher than twin row spacing yields. At the time of planting and after stands were established, soil was extremely wet. These conditions, combined with the use of the concave disc with the twin openers, caused lower yields, lower test weights, and higher moisture contents at harvest. Plots planted with concave disc and twin rows were noticably greener than 25 cm row spaced plots, and appeared to be about two weeks later in maturity due to stunting caused by water standing in the furrow.

Plant Response to Atrazine Toxicity

Fall Concave Disc Experiments

Herbicide rate had a significant effect on yields

Table IX. Influence of fall planting methods on plants per meter.

Location	Method	Days from planting										
		6	7	8	9	10	11	12	13	14	15	16-21
Perkins	Hoe	8	23	33							50a*	
Planted	Double disc	7	17	23							56a	
October 2	Twin hoe	14	26	44							56a	
	Concave twin hoe	2	14	20							56a	
	Concave twin disc	2	12	17							45a	
	Concave hoe	16	33	36							54a	
Perkins	Hoe				2		28		59			59a*
Planted	Double disc				18		42		62			55a
October 19	Twin hoe				6		39		58			61a
	Concave twin hoe				5		39		57			59a
	Concave twin disc				12		38		59			53a
	Concave hoe				1		11		42			57a
Blackwell	Hoe						26			40		43a*
Planted	Double disc						22			39		47a
October 11	Twin hoe						25			29		44a
	Concave twin hoe						22			36		47a
	Concave twin disc						26			43		46a
Blackwell	Hoe			1	8	12						47a*
Planted	Double disc			1	15	15						52a
November 6	Twin hoe			2	12	12						46a
	Concave twin hoe			1	5	7						34a
	Concave twin disc			2	7	9						46a
	Concave hoe			2	11	11						39a

*Values in a column followed by same letter are not significantly different at P=0.05

Fig. 27. Uneven stands of wheat caused by water standing in 56 cm concave disc furrows at Blackwell component experiments.

(Table XVI, Appendix C). The 0.56 and 1.12 kg/ha rate of atrazine and the glyphosate check had significantly higher yields than all other rates including the 0 kg/ha rate (Table X). This indicated that the use of herbicide increased yields by controlling weeds in the 0.56 and 1.12 kg/ha plots as compared to the 0 kg/ha plots. The 56 cm concave disc with the twin hoes had no significant reduction in yields up to 2.24 kg/ha atrazine rate (Table XI). The concave twin hoe produced significantly higher yields at the 2.24, and 3.36 kg/ha rates than the hoe or double disc openers. The reduction in toxicity of atrazine and residue on the wheat by moving the soil and residue from the drill row accounted for the increase in yields where herbicide was used. The increase in yields for the 0 kg/ha rate using the concave disc was due to the observed reduced weed competition caused by tillage action of the concave disc at planting (Fig. 28).

Herbicide rate and the combination of opener used and herbicide rate had a highly significant effect on the foreign material in the grain (Table XVII, Appendix C). The 0 and 1.12 kg/ha rate of glyphosate had significantly more foreign material than other rates because of increased amounts of weeds present (Table X). Foreign material included both weeds and chaff. Thus, foreign material present for concave disc plots was less than the hoe and double disc plots at lower rates because mechanical tillage and increased herbicide contamination between rows reduced

Table X. Influence of atrazine rate on wheat yields at Blackwell no tillage experiments planted October 17.

Rate kg/ha	Yields kg/ha	Foreign Mat. kg/ha	Test Wt. kg/m^3
0.0	1172.3b	1027.7a	653a
0.56	1767.5a	796.5b	625b
1.12	1659.1a	542.0c	616bc
2.24	819.3b	312.8d	604c
3.36	415.4c	191.4d	609c
gly.**	1790.3a	981.8a	643a

*Values in a column followed by same letter are not significantly different at P=0.05.

**Glyphosate was applied post planting at 1.12 kg/ha.

Table XI. Influence of atrazine toxicity and method of planting on stands and wheat yields at Blackwell no tillage experiments planted October 17.

Method	Rate kg/ha	Stand plants/m	Yields kg/ha	Foreign Mat. kg/ha	Test Wt. kg/m^3
Hoe	0.0	41.3abcd	1076.8bcde*	1072.3a	660a
	0.56	49.3abc	1707.7ab	898.7abc	624bcde
	1.12	41.6abcd	1868.3a	563.3defg	618de
	2.24	17.7ef	712.6efg	276.8ghi	592f
	3.36	10.8ef	167.5gh	177.2hi	605ef
	gly.**	50.8ab	1796.7a	1074.8a	647ab
Double disc	0.0	41.6abcd	843.3def	1027.0ab	656a
	0.56	38.3bcd	1699.2ab	853.8abcd	628bcde
	1.12	33.2cd	1363.7abcd	530.9efg	608ef
	2.24	14.2ef	331.0fgh	268.7ghi	602ef
	3.36	3.1f	34.0h	54.1i	605ef
	gly.	39.5bcd	1763.9a	1133.0a	644abc
56 cm disc Twin hoe	0.0	48.8abc	1596.8abc	983.7ab	644abc
	0.56	58.0a	1895.8a	636.9cdef	624bcde
	1.12	57.3a	1745.3a	531.7efg	621cde
	2.24	39.1bcd	1414.3abcd	392.9fgh	615def
	3.36	25.0de	1044.8cde	339.9ghi	615def
	gly.	48.6abc	1810.4a	737.7bcde	637abcd

*Values in a column followed by same letter are not significantly different at P=0.05.

**Glyphosate was applied post planting at 1.12 kg/ha.

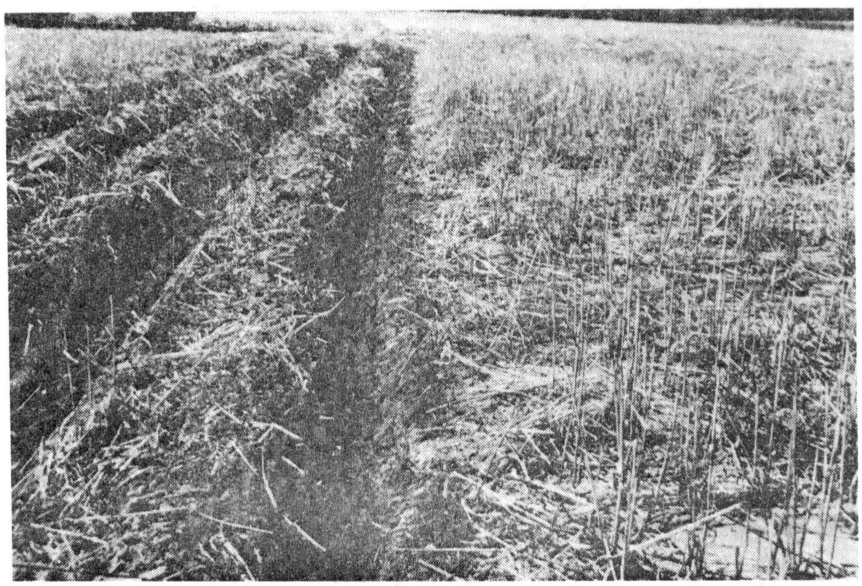


Fig. 28. Tillage action of 56 cm concave disc used to clear furrow for twin row openers.

weeds. Foreign material was higher in the concave plots than the hoe or double disc plots at higher rates because wheat yields were higher (Fig. 29, Table XI). High rates of atrazine reduced weeds and wheat in the hoe and double disc plots where contaminated soil was not removed.

Atrazine rate was the only factor having a significant effect on test weight (Table XVIII, Appendix C). From Table XI it was seen that the 0 kg/ha rate of atrazine, and application of glyphosate had significantly higher test weights. Thus, any amount of atrazine applied caused a reduction in test weight.

Spring Modified Opener Results

Effect on Stand. The rate of herbicide applied had a highly significant effect on spring wheat stands at Perkins, while the different hoes used had a significant effect (Table XIX, Appendix C). The combination of herbicide rates and openers used, and herbicide and press wheels also had a significant effect on stands. The 10 cm winged hoe with either press wheel was the only opener that could be used at atrazine rates up to 1.12 kg/ha without any significant reduction in stands (Table XII). All other combinations of hoes and press wheels resulted in a significant reduction in the stand of wheat at atrazine rates of 1.12 kg/ha and higher. Observing the controls indicated that the 2.5 cm hoe with the 2.5 by 25.0 cm press wheel resulted in the lowest stands (Fig. 30).

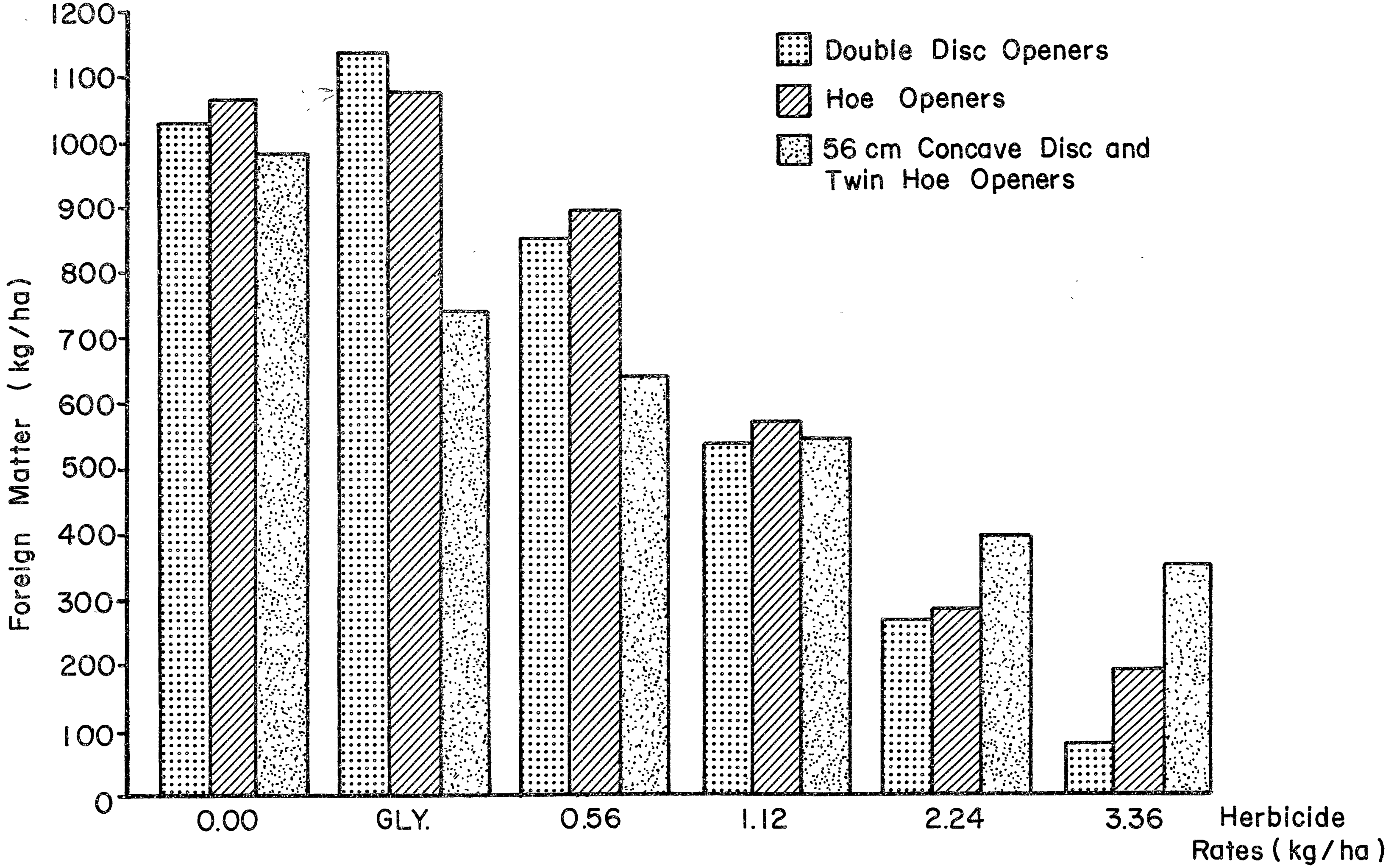


Fig. 29. Influence of opener types, 2.5 cm by 25 cm press wheels and atrazine rates on foreign material in grain at Blackwell.

Table XII. Plant response to atrazine toxicity in spring modified opener experiments at Perkins.

Hoe	Press Wheel	Rate kg/ha	Stand plants/m	Forage kg/m^3	Yield kg/ha	Foreign Mat. kg/ha
2.5 cm	2.5 cm	0.0	6.0bcdef	85.3abcdef	165.0abcde	198.8a
2.5 cm	vee	0.0	12.2abcde	103.5abcde	155.2abcdef	106.5abc
5.0 cm winged	2.5 cm	0.0	7.4abcdef	52.5defg	189.0abc	101.4abc
5.0 cm winged	vee	0.0	13.6abc	124.8abcd	231.0ab	107.3abc
10.0 cm winged	2.5 cm	0.0	12.8abcd	136.3ab	233.4a	87.6bc
10.0 cm winged	vee	0.0	15.4a	136.5ab	226.7abc	80.9bc
2.5 cm	2.5 cm	0.56	3.7fgh	64.8bcdefg	147.7bcdef	172.9ab
2.5 cm	vee	0.56	6.0bcdefgh	58.5cdefg	178.0abcd	69.5bc
5.0 cm winged	2.5 cm	0.56	6.0bcdefgh	45.3efg	167.0abcde	50.3c
5.0 cm winged	vee	0.56	14.0ab	131.0abc	196.4abc	50.7c
10.0 cm winged	2.5 cm	0.56	10.7abcdefg	85.8abcdef	218.0abc	36.9c
10.0 cm winged	vee	0.56	14.6a	145.8a	204.7abc	63.3c
2.5 cm	2.5 cm	1.12	4.2efgh	33.5efg	93.9efgh	87.2bc
2.5 cm	vee	1.12	5.0defgh	53.0defg	76.2fghi	97.4abc
5.0 cm winged	2.5 cm	1.12	5.9bcdefgh	38.5efg	92.3efgh	55.8c
5.0 cm winged	vee	1.12	5.4cdefgh	97.8abcde	97.8defg	40.1c
10.0 cm winged	2.5 cm	1.12	10.2abcdefg	50.8defg	144.6cdef	26.3c
10.0 cm winged	vee	1.12	11.9abcdef	94.5abcde	144.6cdef	43.6c
2.5 cm	2.5 cm	2.24	0.8h	10.0fg	29.5ghi	69.1bc
2.5 cm	vee	2.24	1.2h	7.5fg	23.6ghi	70.7bc
5.0 cm winged	2.5 cm	2.24	0.7h	15.8fg	25.5ghi	60.1bc
5.0 cm winged	vee	2.24	0.8h	10.5fg	29.5ghi	66.8bc
10.0 cm winged	2.5 cm	2.24	0.7h	5.5g	31.0ghi	57.0c
10.0 cm winged	vee	2.24	0.7h	8.5fg	19.6ghi	64.0bc
2.5 cm	2.5 cm	3.36	1.4h	0.5g	7.9i	7.1c
2.5 cm	vee	3.36	0.2h	0.5g	10.6hi	11.8c
5.0 cm winged	2.5 cm	3.36	2.5h	2.0g	3.9i	3.1c
5.0 cm winged	vee	3.36	1.5h	0.8g	7.5i	4.3c
10.0 cm winged	2.5 cm	3.36	0.9h	5.0g	5.1i	2.0c
10.0 cm winged	vee	3.36	0.7h	1.0g	1.6i	1.6c

*Values in a column followed by same letter are not significantly different at P=0.05.

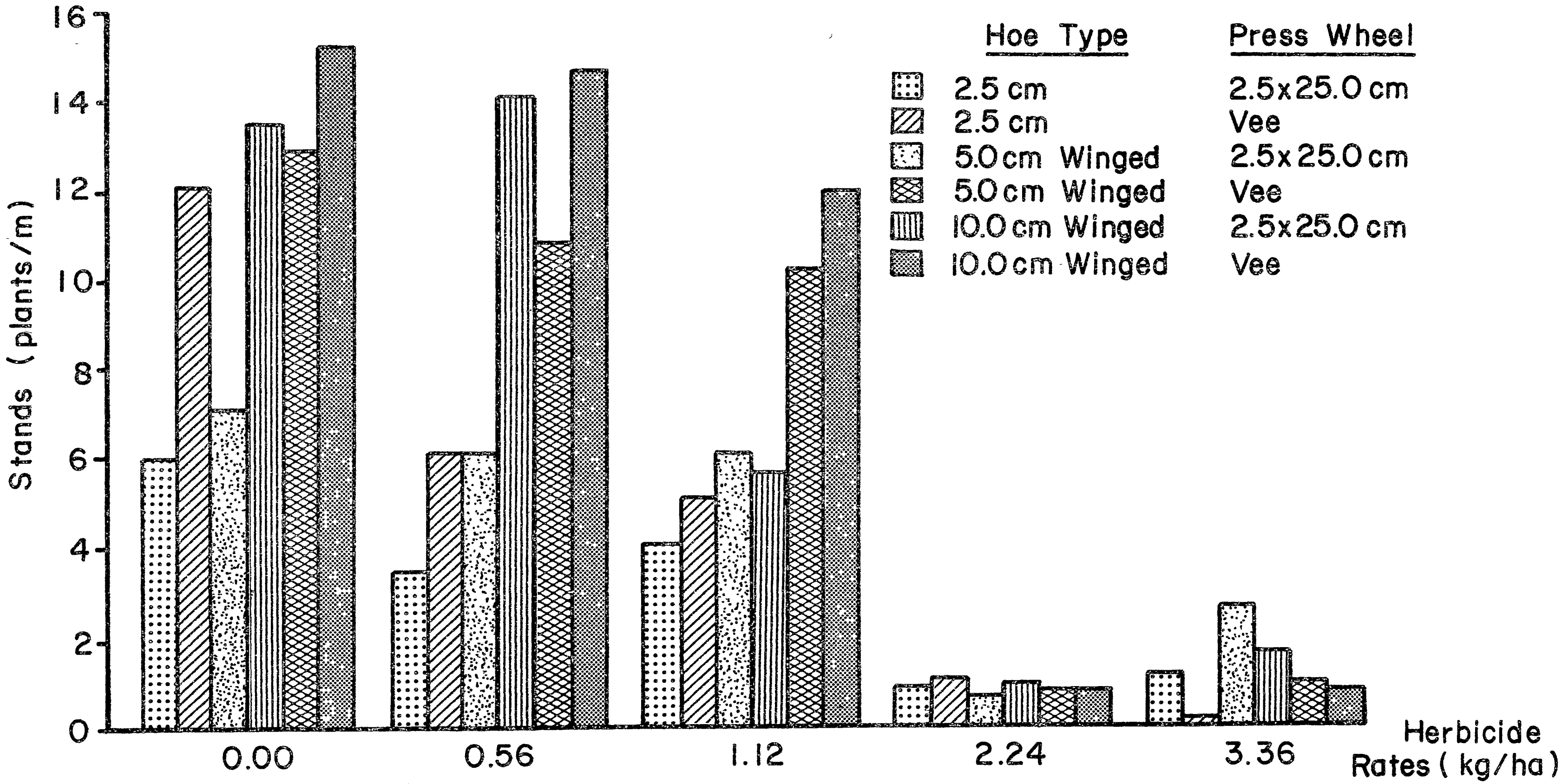


Fig. 30. Effect of openers, press wheels, and atrazine rates on stands at Perkins.

At Blackwell, hoe openers and the combination of the hoe openers with different press wheels at different herbicide rates had a significant effect on the wheat stands, while atrazine rates had a highly significant effect on stands (Table XX, Appendix C). Both the 5.0 and 10.0 cm winged hoes with the Vee press wheels was used at herbicide rates up to 2.24 kg/ha with no significant reduction in stands (Table XIII). Fig. 31 shows improvements in stands where the Vee press wheel was used with the 5.0 and 10.0 cm winged hoes at rates of atrazine of 1.12 and 2.24 kg/ha. At lower rates, this difference was not significant because rates were not high enough to affect stands if the herbicide was not moved, which was evident when comparing the stands at the 0 and 0.56 kg/ha rates. At the 3.36 kg/ha rate, no amount of soil disturbance kept the atrazine from reducing stands.

<u>Effect on Forage</u>. Similar results were seen with the forage data as with the stand results at Perkins. However, the press wheels had a more pronounced effect on the forage produced at the 0, 0.56, and 1.12 kg/ha rates for the winged hoes (Fig. 32). Atrazine rates again had a highly significant effect, while press wheels had significant effect on the forage produced (Table XXI, Appendix C). Only the 5.0 and 10.0 cm winged hoes with the Vee press wheels could be used at atrazine rates up to 1.12 kg/ha without a significant reduction in forage. All other combinations of hoes and press wheels produced significantly less forage at

Table XIII. Plant response to atrazine toxicity in spring modified opener experiments at Blackwell.

Hoe	Press Wheel	Rate kg/ha	Stand plants/m	Forage kg/m^3	Yield kg/ha	Foreign Mat. kg/ha
2.5 cm	2.5 cm	0.0	23.7cdef	330.3abcdef	424.3ab	161.1abc
2.5 cm	vee	0.0	29.7abcd	339.8abcde	288.7abcdef	158.1abc
5.0 cm winged	2.5 cm	0.0	35.7ab	334.5abcde	474.2a	134.0abc
5.0 cm winged	vee	0.0	29.5abcd	347.0abcde	479.7a	84.5abc
10.0 cm winged	2.5 cm	0.0	28.7abcd	355.0abcde	348.1abcde	101.0abc
10.0 cm winged	vee	0.0	33.7abc	458.8a	480.5a	110.4abc
2.5 cm	2.5 cm	0.56	28.8abcd	369.0abcd	324.5abcdef	147.3abc
2.5 cm	vee	0.56	23.7cdef	339.8abcde	291.1abcdef	82.5abc
5.0 cm winged	2.5 cm	0.56	32.0abcd	348.5abcde	405.0abc	82.5abc
5.0 cm winged	vee	0.56	37.0a	380.3abc	388.5abcd	92.7abc
10.0 cm winged	2.5 cm	0.56	29.7abcd	435.0a	380.7abcd	119.4abc
10.0 cm winged	vee	0.56	33.5abc	420.0ab	471.4ab	94.7abc
2.5 cm	2.5 cm	1.12	22.5cdefg	255.8abcdefghi	233.7abcdef	82.1abc
2.5 cm	vee	1.12	25.5abcde	289.3abcdefgh	266.0abcdef	102.1abc
5.0 cm winged	2.5 cm	1.12	30.0abcd	322.3abcdef	241.6abcde	103.7abc
5.0 cm winged	vee	1.12	36.9a	296.5abcdef	447.1ab	82.9abc
10.0 cm winged	2.5 cm	1.12	24.7bcde	383.5abc	354.3abcde	88.4abc
10.0 cm winged	vee	1.12	37.0a	374.5abcd	390.9abcd	73.1c
2.5 cm	2.5 cm	2.24	20.6defgh	328.3abcdef	280.5abcdef	99.4abc
2.5 cm	vee	2.24	11.8gh	221.0bcdefghi	266.0abcdef	122.2abc
5.0 cm winged	2.5 cm	2.24	12.7fgh	201.3cdefghi	203.9bcdef	93.9abc
5.0 cm winged	vee	2.24	25.9abcde	194.3cdefghi	324.5abcdef	61.7c
10.0 cm winged	2.5 cm	2.24	15.7efgh	288.8abcdefgh	331.6abcdef	80.1bc
10.0 cm winged	vee	2.24	26.5abcde	284.5abcdefgh	280.5abcdef	80.5bc
2.5 cm	2.5 cm	3.36	15.2efgh	123.3fghi	143.8cdef	123.8abc
2.5 cm	vee	3.36	12.7fgh	87.0hi	99.0ef	96.3abc
5.0 cm winged	2.5 cm	3.36	10.7h	71.8i	77.8f	126.1abc
5.0 cm winged	vee	3.36	12.0gh	156.0efghi	135.1def	206.6a
10.0 cm winged	2.5 cm	3.36	15.7efgh	111.8ghi	95.1ef	154.0abc
10.0 cm winged	vee	3.36	17.2efgh	166.8defghi	144.6cdef	201.5ab

*Values in a column followed by same letter are not significantly different at P=0.05.

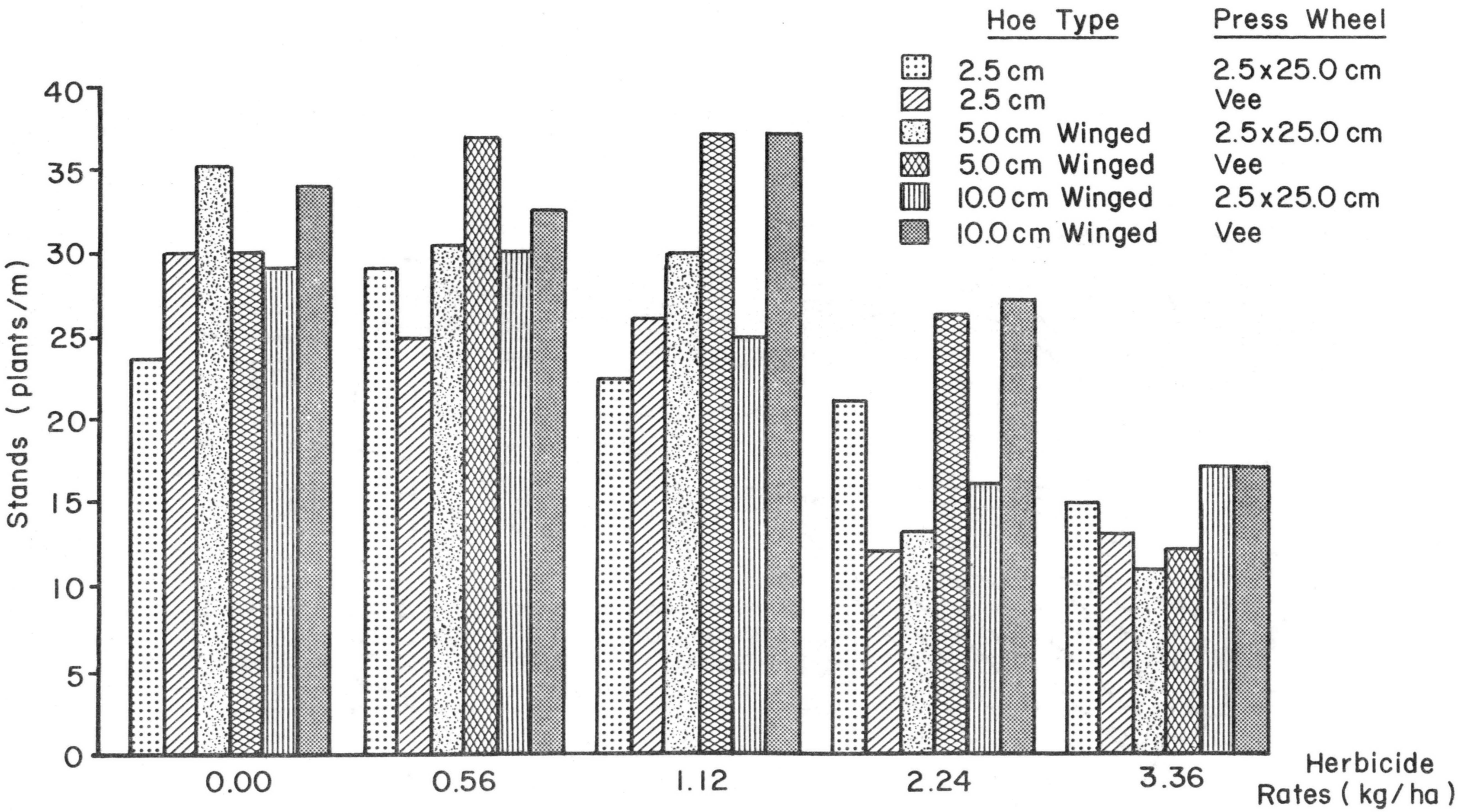


Fig. 31. Effect of openers, press wheels, and atrazine rates on stands at Blackwell.

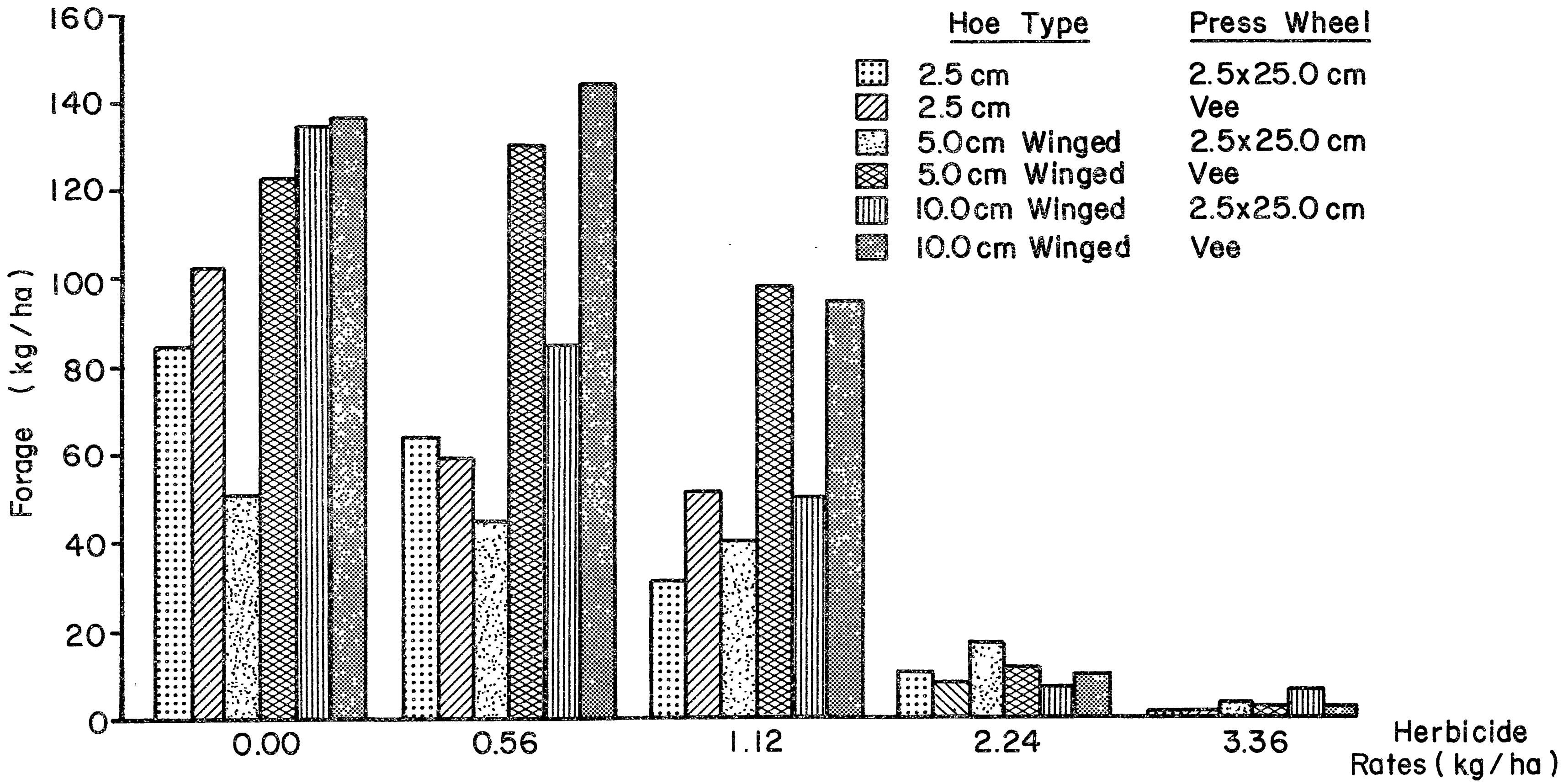


Fig. 32. Influence of openers, press wheels, and atrazine rates on forage yields at Perkins.

rates of 1.12 kg/ha rate and higher (Table XII).

Herbicide rate was shown to be the only factor having a significant effect on the amount of broadleaf weeds present in the plots (Table XXII, Appendix C). The dominant weeds present were lambs quarter (Chenopodiaceae albescens) and pigweed (Amaranthaceae Torreyi). There was a significant reduction in weeds when any rate of herbicide above the control was used (Table XIV). Thus, good control of broadleaf weeds was attained with atrazine at rates of 0.56 kg/ha or higher. Most of the weeds that were present in the herbicide treated plots grew only in the drill rows where the atrazine treated soil had been removed (Fig. 33).

At Blackwell, as seen when comparing Fig. 34 to Fig. 31, tillering of the wheat plant increased forage where stands were reduced. These differences seen before in the stands were less pronounced in the forage yields. However, from Table XXIII, Appendix C, it can be seen that herbicide still had a highly significant effect and hoe openers had a significant effect on forage produced. Fig. 34 revealed that the 10.0 cm winged hoe produced wheat with more forage than 2.5 cm hoe or 5.0 cm winged hoe at atrazine rates of 0, 0.56, and 1.12 kg/ha. This was also evident at the 2.24 kg/ha rate if the 2.5 cm hoe with the 2.5 by 25 cm press wheel was excluded. The 10.0 cm winged hoe with the Vee press wheel produced the most forage at the 3.36 kg/ha rate when compared to other openers at that rate. The 10.0 cm winged hoe was used in atrazine rates up to 2.24 kg/ha

Table XIV. Effect of atrazine rates on weed control in spring wheat forage.

Rate kg/ha	Weed Weight kg/m^3	
	Perkins	Blackwell
0.0	8.96a	38.8a
0.56	0.92b	4.5b
1.12	0.04b	5.9b
2.24	0.04b	0.9b
3.36	0.00b	0.6b

*Values in a column followed by same letter are not significantly different at P=0.05.

Fig. 33. Weeds growing in furrows of 10.0 cm winged hoe with application of 1.12 kg/ha of atrazine at Blackwell.

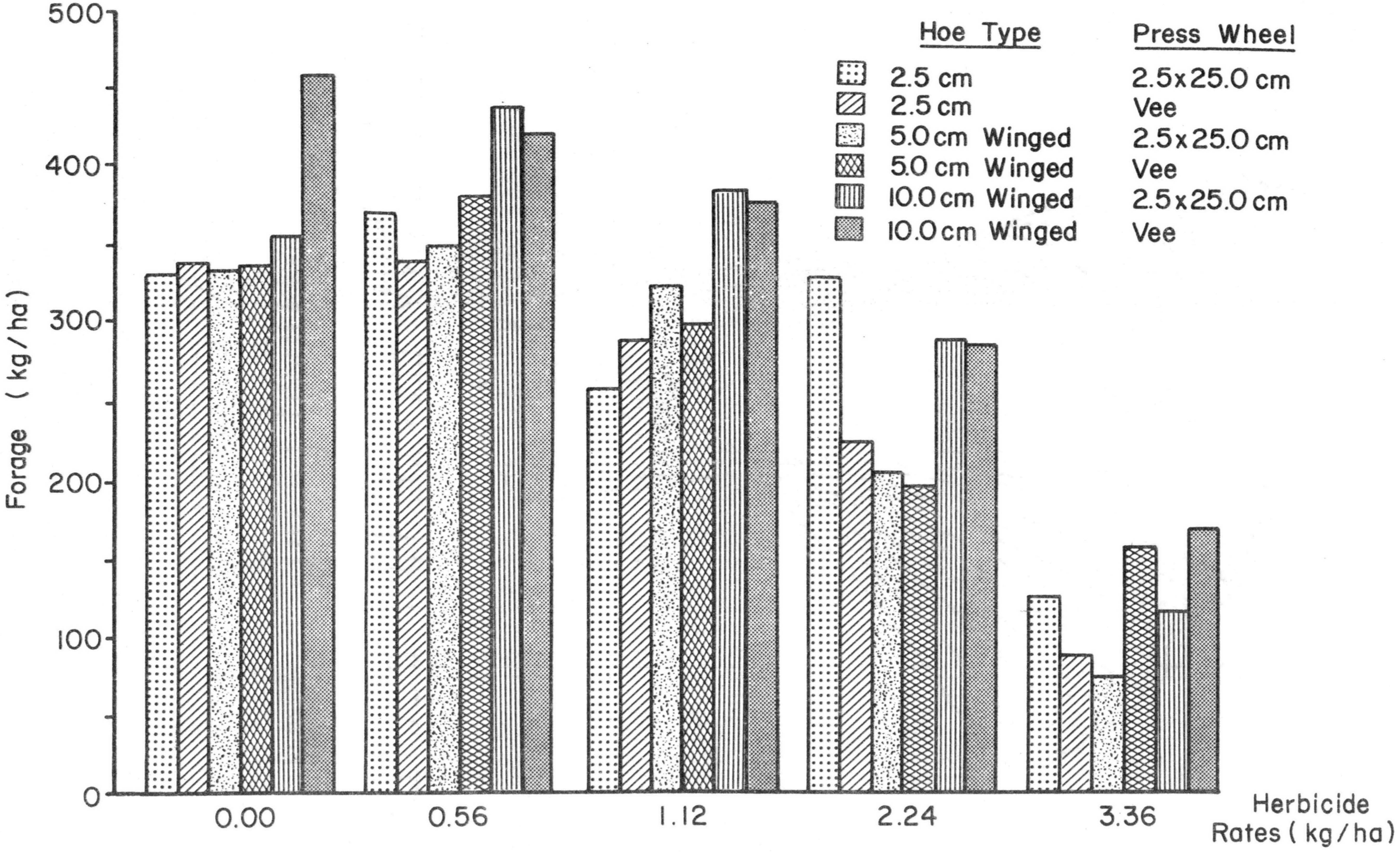


Fig. 34. Effect of opener, press wheels, and atrazine rate on forage yields at Blackwell.

without significant reductions in forage (Table XIII).

Chemical rate was the only factor which had an effect on amount of weeds present at Blackwell (Table XXIV, Appendix C). When any rate of herbicide above the control was used, no significant difference in weed control was observed (Table XIV). As seen from the 0 kg/ha rate in Fig. 35, there were significantly less weeds present when comparing the 2.5 cm hoe to the 5.0 and 10.0 cm winged hoes with the Vee press wheels. This reduction was most likely due to increased tillage action of the winged hoes and the soil firming of the Vee press wheels which created a better seed bed for the wheat seedlings to become established. Thus, the wheat could compete with and choke out the weeds.

<u>Effect on Grain Yields</u>. Herbicide had a highly significant effect on wheat yields, Table XXV, Appendix C, and hoe openers were shown to have a highly significant effect on foreign matter in the grain (Table XXVI, Appendix C). All openers were be used at rates of 0 and 0.56 kg/ha except the 2.5 cm hoe with the 2.5 cm press wheel without a significant reduction in yields (Table XII). But, it was seen that yields associated with the 2.5 cm hoe were lower at the 0, 0.56, and 1.12 kg/ha rates when compared to the 10.0 cm winged hoe (Fig. 36). This difference was not statistically significant, however.

Plots sown with the 2.5 cm hoe had significantly more weeds (Table XV). Plots sown with the winged openers may have had less weeds because of higher wheat stands in these

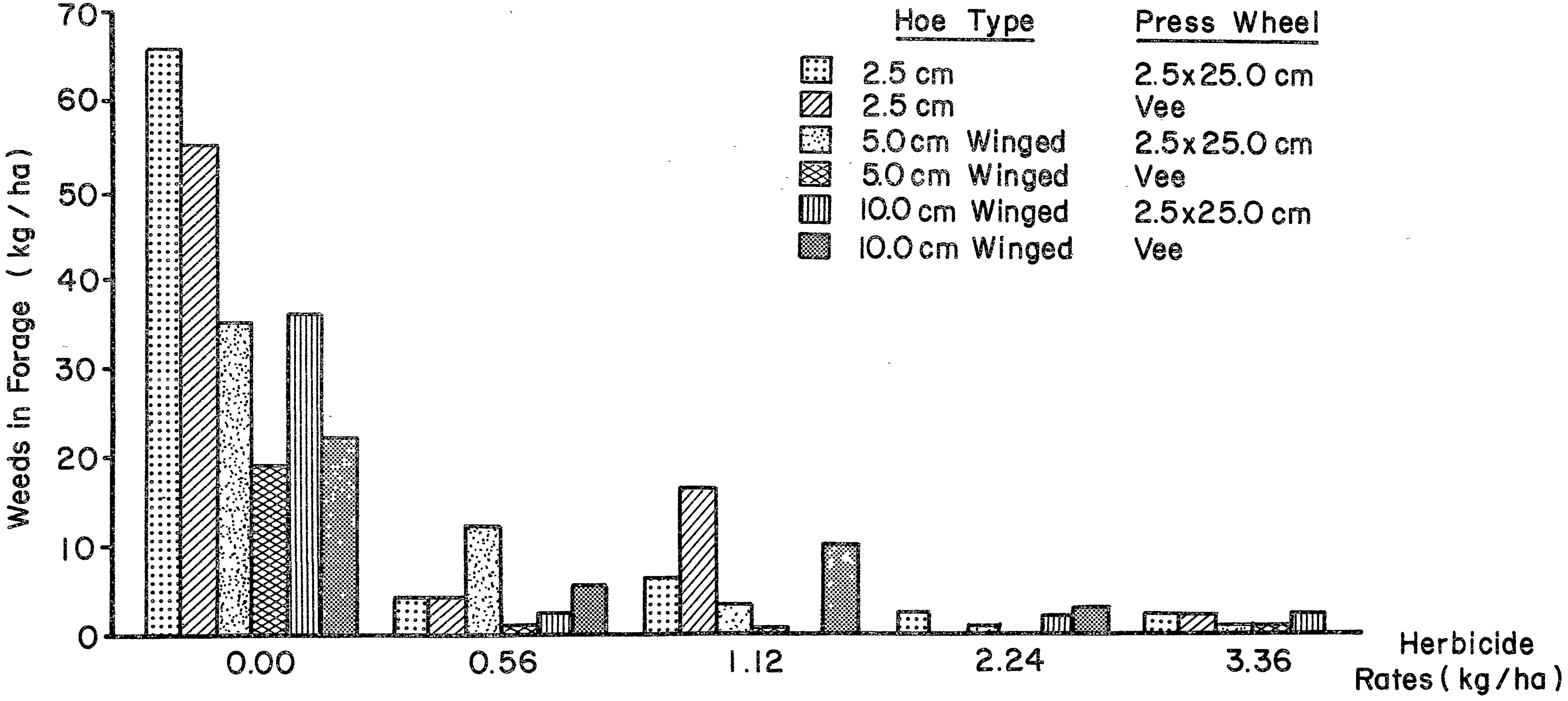


Fig. 35. Effect of opener, press wheels, and atrazine rate on weeds in forage at Blackwell.

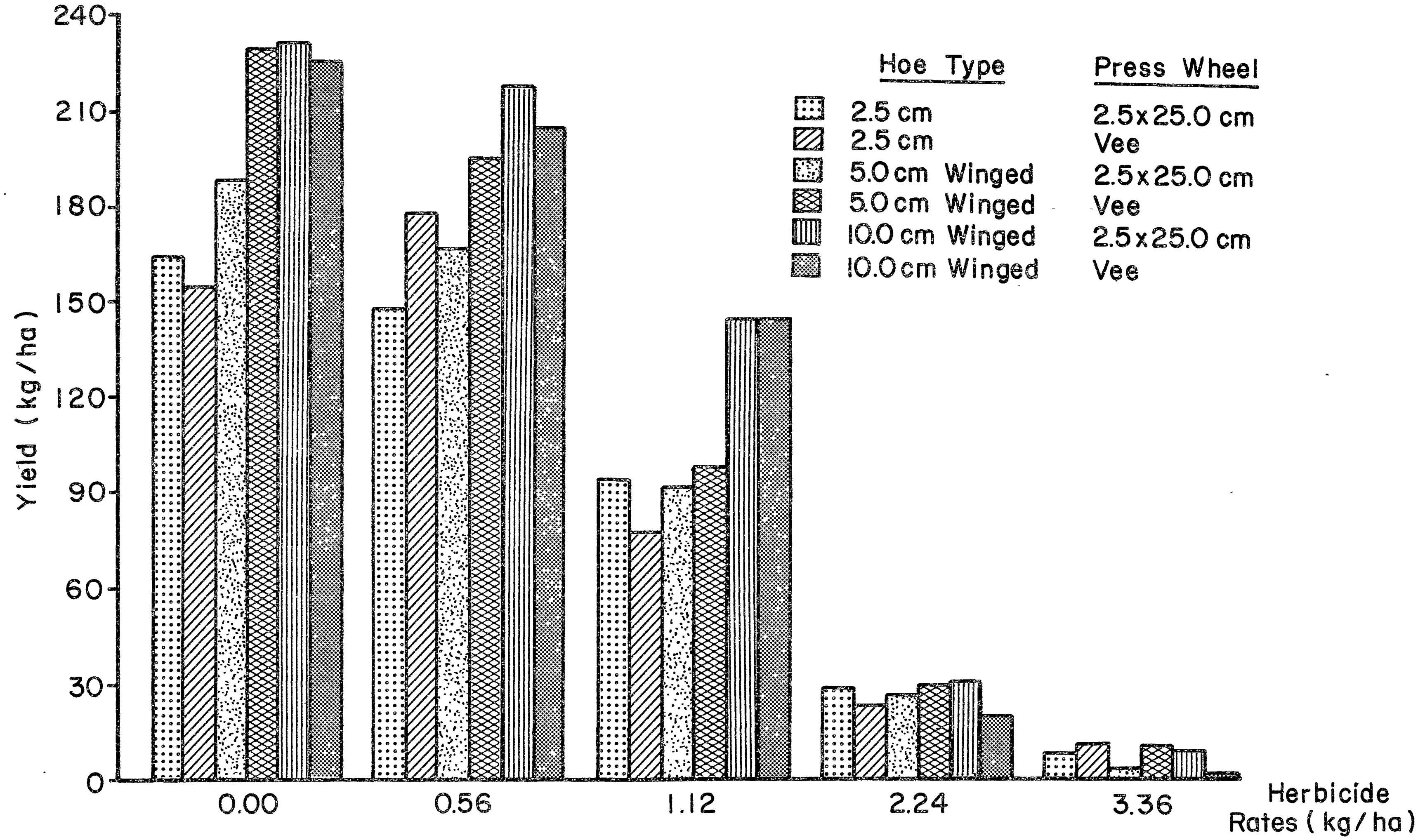


Fig. 36. Effect of opener type, press wheels, and atrazine rate on grain yields at Perkins.

Table XV. Effect of opener on weeds in grain for spring atrazine plots at Perkins.

Opener used	Foreign Material kg/ha
2.5 cm hoe	89.1a
5.0 cm winged hoe	54.0b
10.0 cm winged hoe	46.3b

*Values in a column followed by save letter are not significantly different at P=0.05

plots which competed and choked out the weeds.

Herbicide rate had a highly significant effect on yields (Table XXVII, Appendix C). No other factor had a significant effect on either yields or foreign materials (Table XXVIII, Appendix C). However, examining individual treatments showed that all hoe and press wheel combinations could be used at rates of 0, 0.56, 1.12, and 2.24 kg/ha without a significant reduction in yields, except for the 5.0 cm hoe with the 2.5 cm press wheel at the 2.24 kg/ha rate (Table XIII). Fig. 37 showed that generally the 5.0 and 10.0 cm winged hoes produced as high or higher yields than the 2.5 cm hoe at different herbicide rates.

Foreign material present at Blackwell was not a clear indication of herbicide weed control. Where good broadleaf weed control was attained, grass population increased, since atrazine was not as effective on grass as on broadleaf weeds. Broadleaf weed control was attained in all plots between the rows at herbicide rates above 0 kg/ha, but with the reduced stands associated with the spring wheat, weeds were able to flourish in the rows because of reduced competition with wheat. The weed seeds that sprouted had been placed below the layer of soil that was removed by the winged openers by previous tillage. If wheat stands would have been higher, as could be expected with a winter variety, or if weed seeds were removed from the furrow, better control of the weeds would be attained.

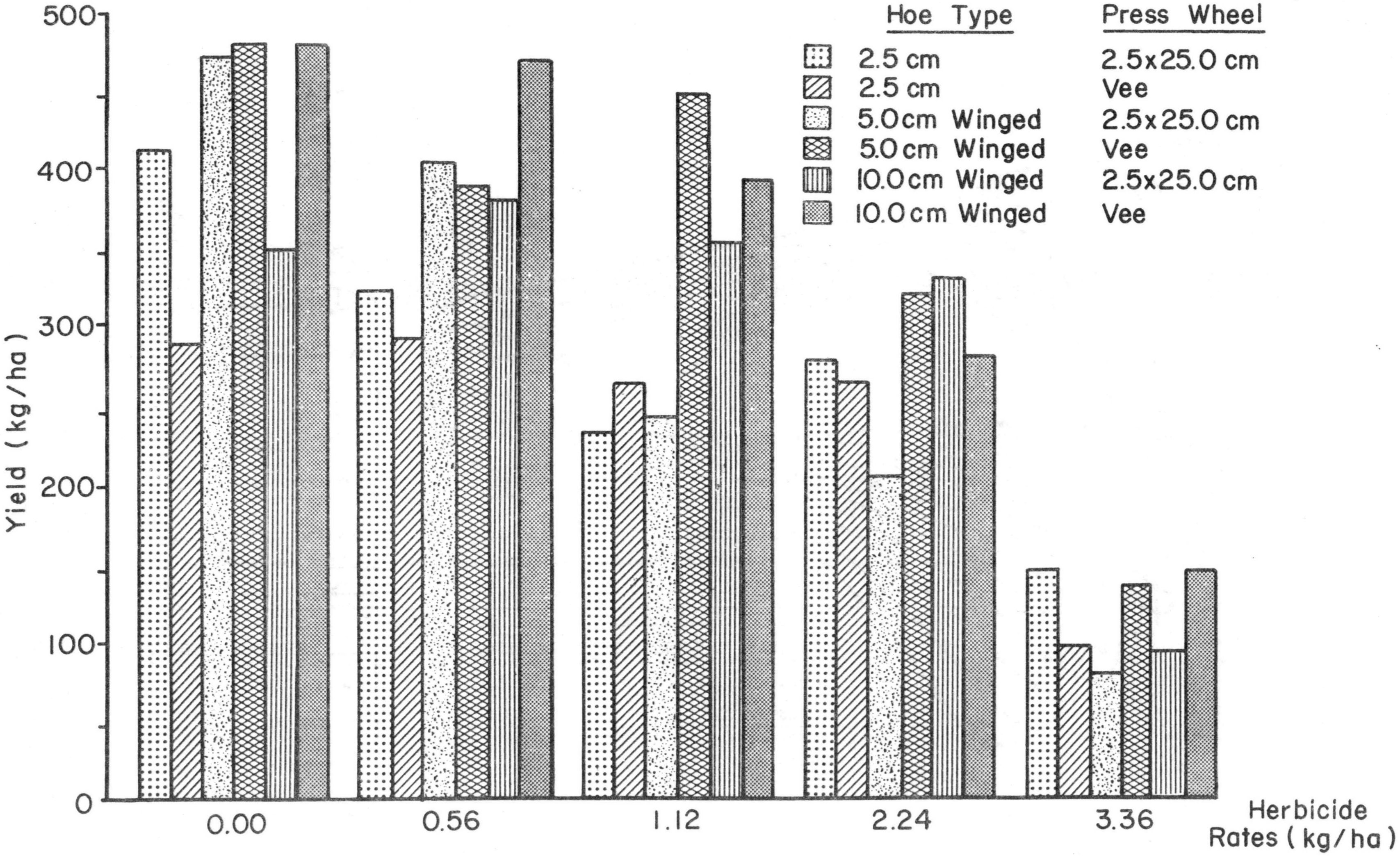


Fig. 37. Effect of openers, press wheels, and atrazine rate on grain yields at Blackwell.

CHAPTER VI

SUMMARY AND CONCLUSIONS

Plots sown with the hoe, double disc, and 46 cm concave disc followed by the hoe openers produced wheat plants with more total tillers, which corresponded to reduced seedling stress. All twin row plots had fewer tillers per plants and all plots sown with the 56 cm concave disc had lowest yields. The 56 cm concave disc created a large furrow that collected water which stunted or drowned plants. The twin rows caused plants to compete with each other for sunlight, nutrients, and moisture. The 46 cm concave disc followed by the hoe opener had higher yields than the hoe opener. This indicates that a reduction in allelopathy and diseases occured by removing the residue from the drill rows.

In fall planted atrazine plots, the 56 cm concave disc followed by the twin hoes was used in soil treated with up to 2.24 kg/ha of atrazine without significant reductions in wheat yields. Significant reduction in yields were observed in the hoe and double disc plots at this rate.

In spring planted atrazine plots in sandy soil, the 10 cm winged hoe opener with either the 2.5 cm by 25 cm or the Vee press wheel was used at rates up to 1.12 kg/ha without significant reduction in stands or forage yields. The 10 cm winged hoe was used at rates of 0.56 kg/ha without a significant reduction in grain yields. In a silty soil, the 10 cm winged hoe with the Vee press wheel was used at rates up to 2.24 kg/ha without significant reductions in stands, forage yields, or grain yields.

Weed control was attained at higher rates of atrazine between the rows, but weeds flourished in the rows where the herbicide had been removed. Weed seeds were placed deep enough in the soil by previous tillage operations so that they were not cleared by the modified openers at planting. If tillage was restricted to shallow depths, or restricted to no tillage at all, then all weed and volunteer wheat seed could be removed from the furrow and placed between the rows where high rates of atrazine are concentrated.

Conclusions derived from this research were:

1. A drill was designed and built to remove atrazine treated soil using a 46 cm concave disc followed by a hoe opener, a 56 cm concave disc followed by twin double disc and twin hoe openers, and 5 and 10 cm winged hoe openers. A 46 cm gauge coulter and, a 2.5 cm by 25 cm press wheel and 10 cm by 30 cm Vee press wheel were used.

2. All results indicated that atrazine treated plots sown with the 56 cm concave disc followed by the twin hoe openers and the 10 cm winged hoe with the Vee press wheel resulted in higher stands, more forage, and higher grain yields when compared to plots sown with a hoe, double disc, or 5.0 cm winged opener. However, component tests in

untreated soil revealed that the 56 cm concave disc and the twin row spacings caused increased seedling stress and lower yields than 25 cm row spaced openers. Therefore, soil treated with high rates of atrazine, and residue was most effectively removed with a 10 cm winged hoe used with a Vee press wheel.

Further research needs to be conducted to determine the optimum amount of soil that needs to be removed and other rates and herbicides need to be investigated. Different varieties of wheat need to be tested to determine their resistance to these herbicides. Also, reductions in toxicity of the residue and reduction in diseases by removing the residue need to be researched.

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APPENDIX A

PLOT PLANS OF COMPONENT AND ATRAZINE TOXICITY EXPERIMENTS

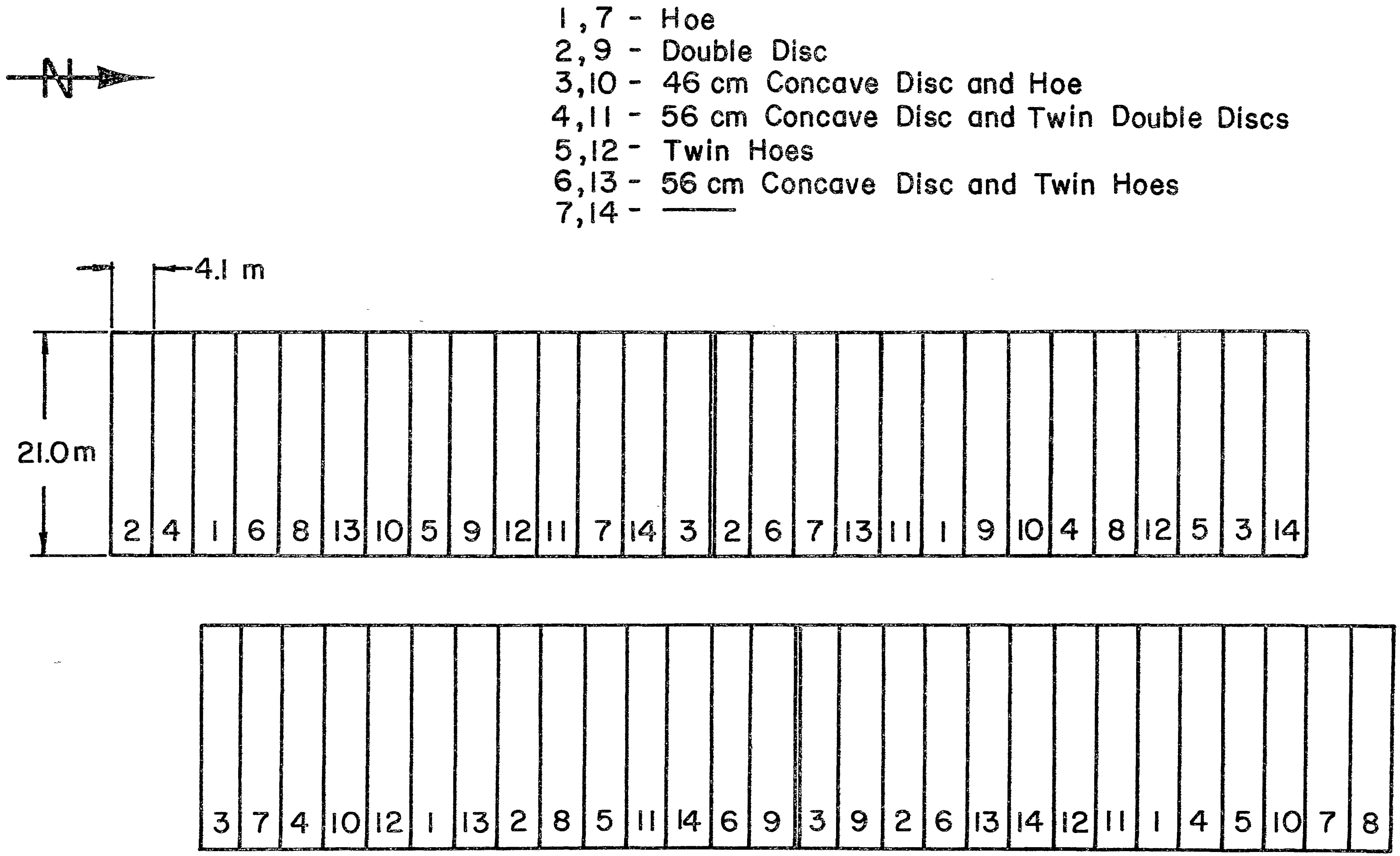


Fig. 38. Plot plan of Perkins fall no tillage component experiments.

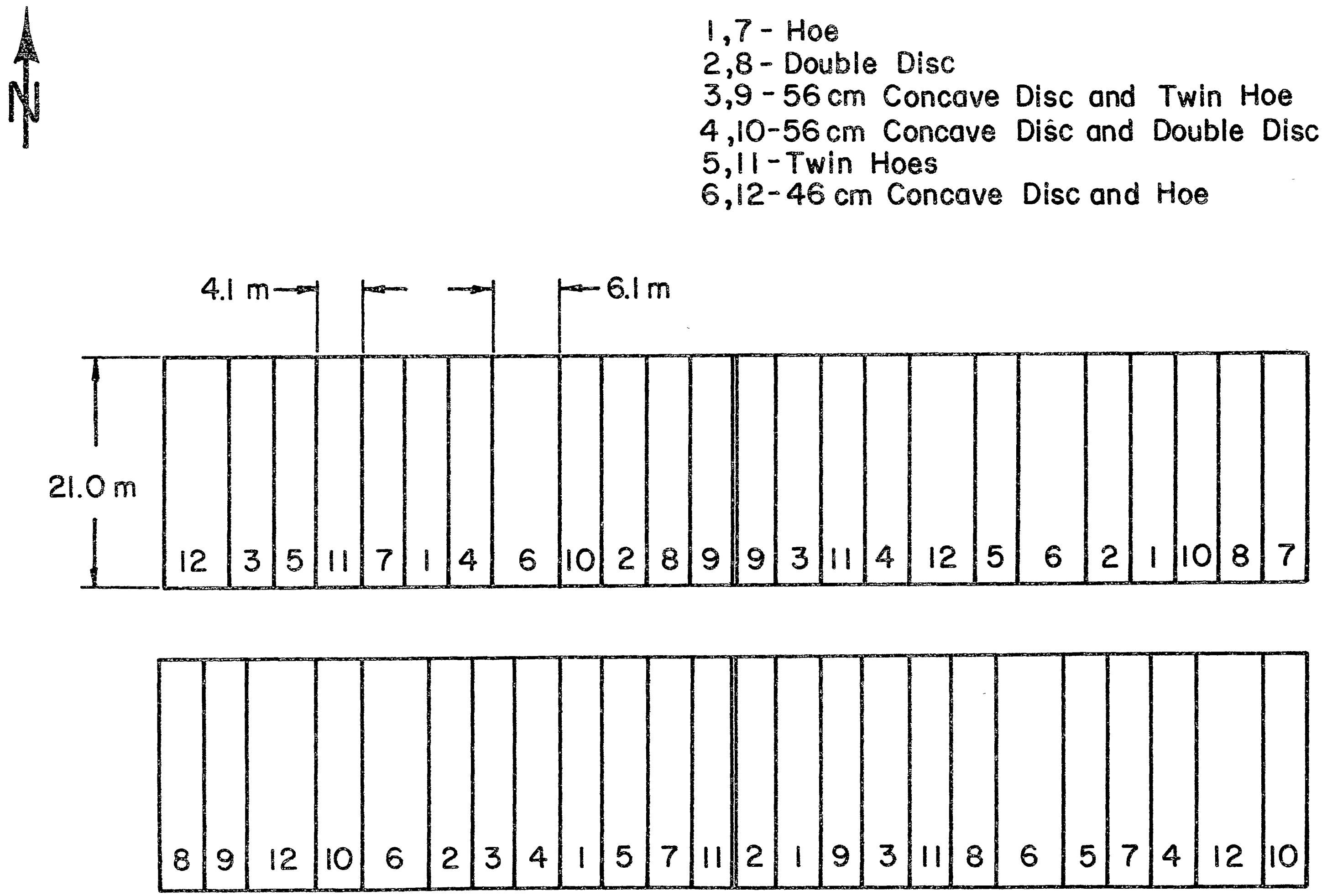


Fig. 39. Plot plan of Blackwell fall minimum tillage component experiments.

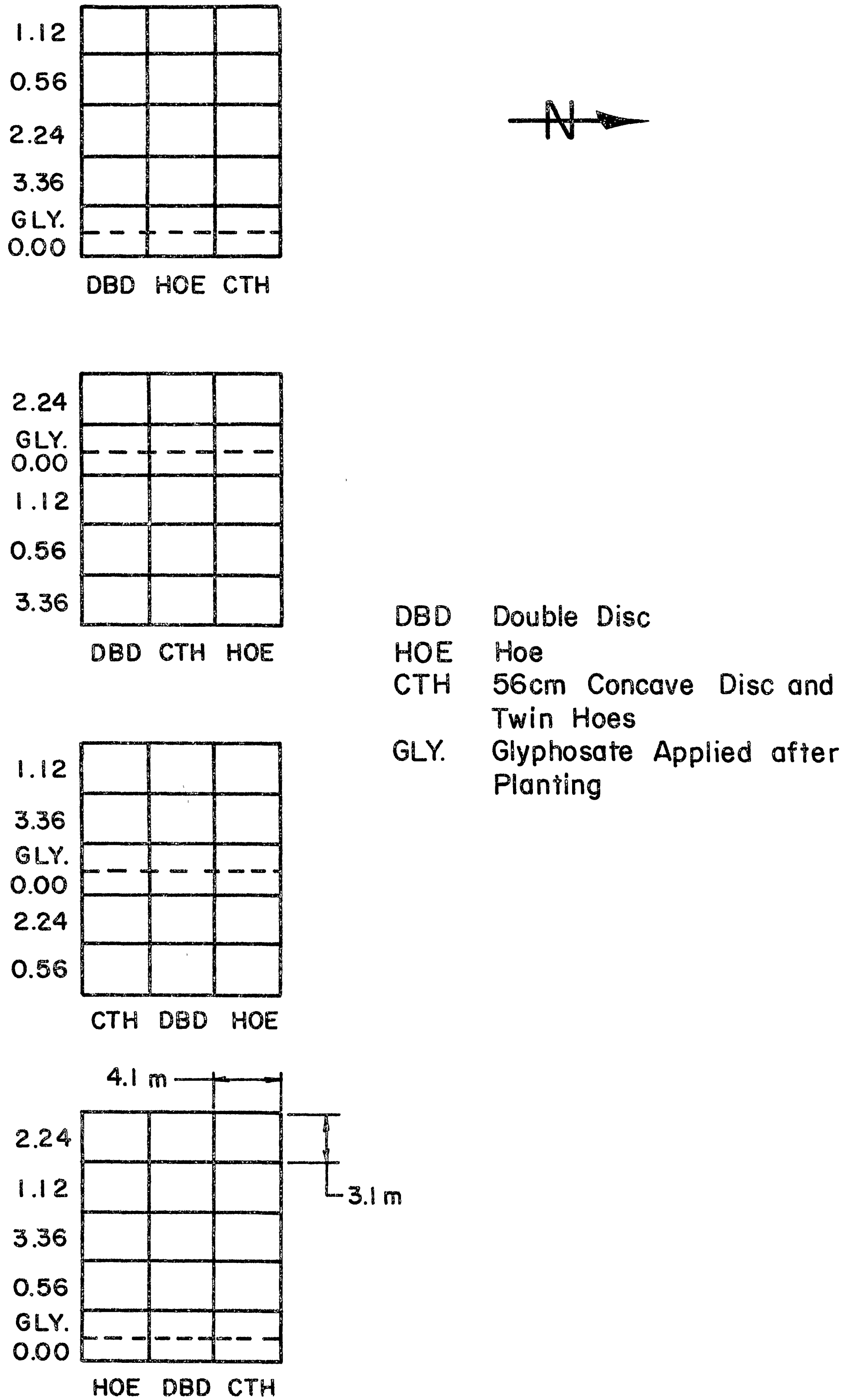
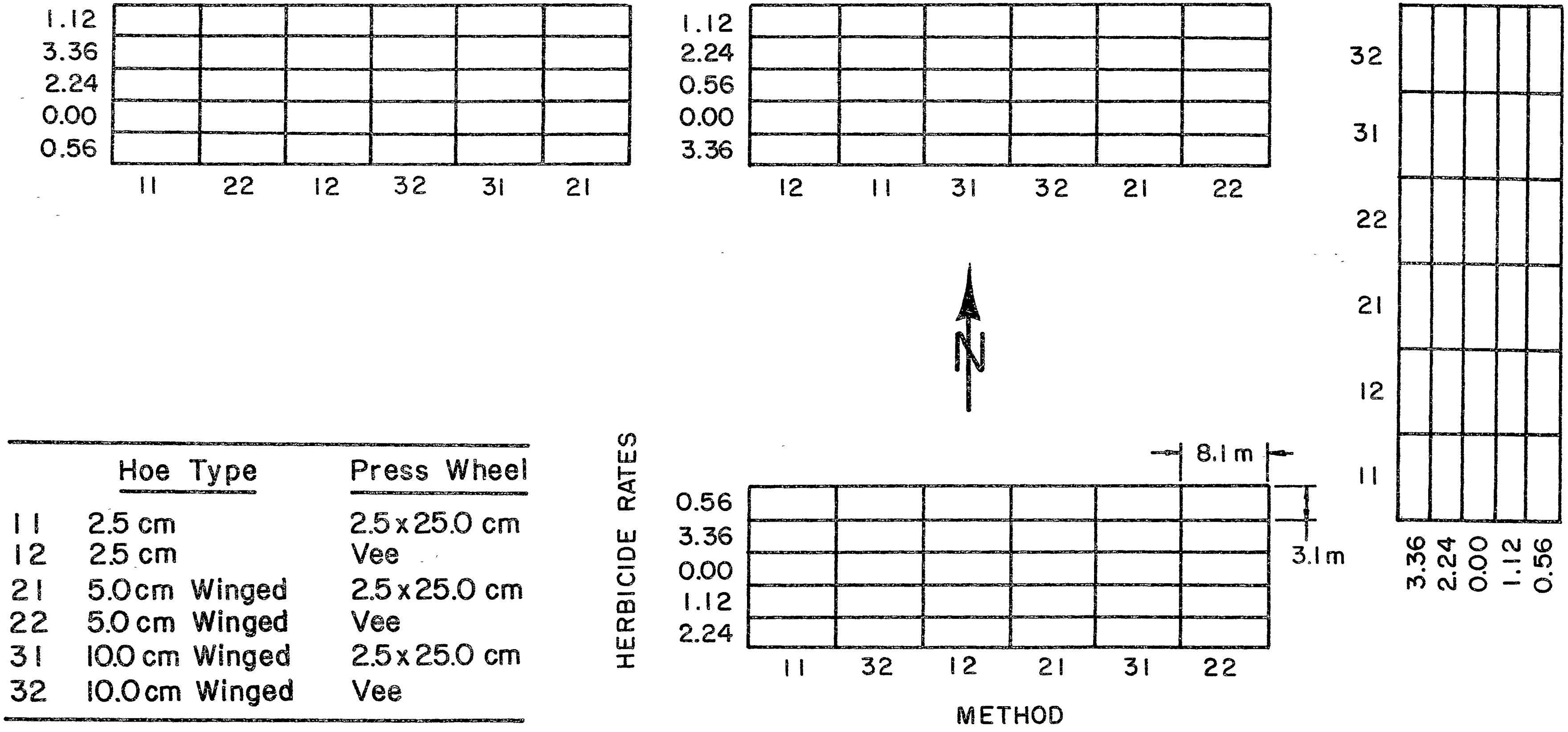
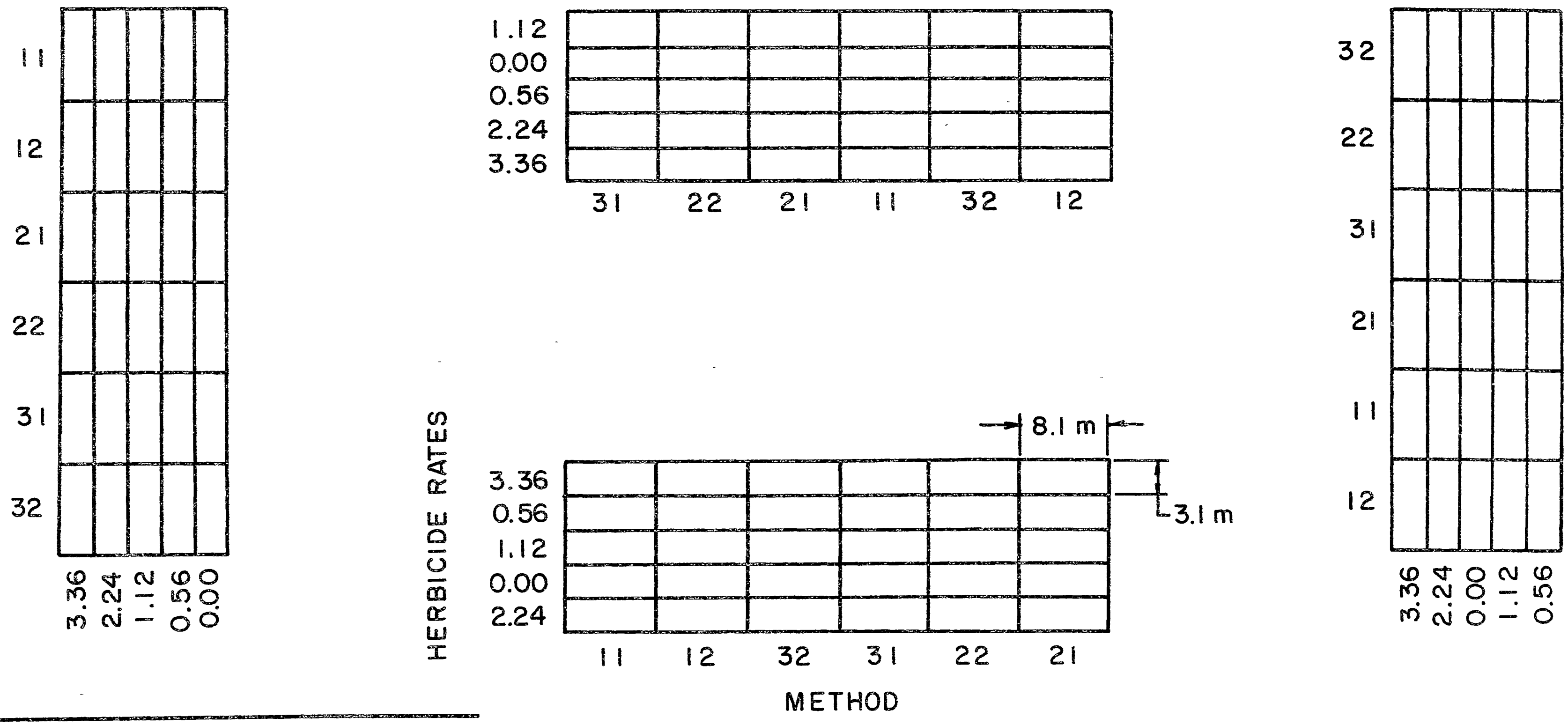


Fig. 40. Blackwell fall atrazine toxicity concave disc experiments.



	Hoe Type	Press Wheel
11	2.5 cm	2.5 x 25.0 cm
12	2.5 cm	Vee
21	5.0 cm Winged	2.5 x 25.0 cm
22	5.0 cm Winged	Vee
31	10.0 cm Winged	2.5 x 25.0 cm
32	10.0 cm Winged	Vee

Fig. 41. Perkins spring atrazine toxicity modified opener experiments.



	Hoe Type	Press Wheel
11	2.5 cm	2.5x25.0 cm
12	2.5 cm	Vee
21	5.0 cm Winged	2.5x25.0 cm
22	5.0 cm Winged	Vee
31	10.0 cm Winged	2.5x25.0 cm
32	10.0 cm Winged	Vee

Fig. 42. Blackwell spring atrazine toxicity modified opener experiments.

APPENDIX B

ERROR TERMS TO TEST HYPOTHESIS OF ATRAZINE TOXICITY EXPERIMENTS

Group Balanced Block in Strip Plot Design

4 Replications (r)

5 Herbicide rates (a)

3 Hoe types (b)

2 Press wheel types (c)

Source of Variation			Degrees of Freedom
Replications	r - 1	=	3
Herbicide rates	a - 1	=	4
Error term	(r - 1)(a - 1)	=	12
Hoe types	b - 1	=	2
Press wheel types	c - 1	=	1
Error term	(r - 1)(bc - 1)	=	15
Hoe types* Herbicide rates	(b - 1)(a - 1)	=	8
Press Wheels* Herbicide rates	(c - 1)(a - 1)	=	4
Hoe types* Press wheels* Herbicide rates	(b - 1)(c - 1)(bc - 1)	=	8
Error term	(r - 1)(a - 1)(bc - 1)	=	60
Total	rabc - 1	=	119

APPENDIX C

ANALYSIS OF VARIANCE TABLES

Table XVI. Fall atrazine plots at Blackwell no tillage experiments, yield response.

Source of Variation	Degrees of Freedom	Sum of Squares	F Value	PR>F
Atrazine Rate	5	19351694	38.28	0.0001
Openers	2	4105829	4.66	0.0602
Atrazine Rate * Openers	10	2569238	1.88	0.0881

Table XVII. Fall atrazine plots at Blackwell no tillage experiments, foreign material response.

Source of Variation	Degrees of Freedom	Sum of Squares	F Value	PR>F
Atrazine Rate	5	7314440	115.04	0.0001
Openers	2	64948	1.42	0.3133
Atrazine Rate * Openers	10	674594	4.49	0.0007

Table XVIII. Fall atrazine plots at Blackwell no tillage experiments, test weight response.

Source of Variation	Degrees of Freedom	Sum of Squares	F Value	PR>F
Atrazine Rate	5	128.75	18.53	0.0001
Openers	2	0.3252	0.14	0.8753
Atrazine Rate * Openers	10	13.3313	1.51	0.1909

Table XIX. Stand response for spring atrazine modified opener experiments at Perkins.

Source of Variation	Degrees of Freedom	Sum of Squares	F Value	PR>F
Atrazine Rate	4	2127.01	11.77	0.0004
Openers	2	287.36	5.09	0.0206
Press Wheels	1	114.86	4.07	0.0620
Openers * Press Wheels	2	5.87	0.10	0.9020
Atrazine Rate * Openers	8	269.78	2.77	0.0113
Atrazine Rate * Press Wheels	4	174.37	3.58	0.0110
Atrazine Rate * Openers * Press Wheels	8	52.29	0.54	0.8241

Table XX. Stand response for spring atrazine modified opener experiments at Blackwell.

Source of Variation	Degrees of Freedom	Sum of Squares	F Value	PR>F
Atrazine Rate	4	5688.94	19.75	0.0001
Openers	2	632.02	4.57	0.0281
Press Wheels	1	257.43	3.99	0.0643
Openers * Press Wheels	2	335.61	2.43	0.1219
Atrazine Rate * Openers	8	403.83	1.63	0.1342
Atrazine Rate * Press Wheels	4	232.83	1.88	0.1249
Atrazine Rate * Openers * Press Wheels	8	651.03	2.63	0.0152

Table XXI. Forage response for spring atrazine modified opener experiments at Perkins.

Source of Variation	Degrees of Freedom	Sum of Squares	F Value	PR>F
Atrazine Rate	4	208861.6	12.23	0.0003
Openers	2	12935.0	2.42	0.1226
Press Wheels	1	15640.8	5.86	0.0287
Openers * Press Wheels	2	6699.6	1.25	0.3135
Atrazine Rate * Openers	8	13871.5	1.07	0.3953
Atrazine Rate * Press Wheels	4	12830.4	1.98	0.1088
Atrazine Rate * Openers * Press Wheels	8	9632.1	0.74	0.6527

Table XXII. Weeds in forage response for spring atrazine modified opener experiments at Perkins.

Source of Variation	Degrees of Freedom	Sum of Squares	F Value	PR>F
Atrazine Rate	4	1470.28	4.04	0.0267
Openers	2	228.72	1.84	0.1931
Press Wheels	1	49.41	0.79	0.3868
Openers * Press Wheels	2	28.12	0.23	0.8003
Atrazine Rate * Openers	8	683.87	1.93	0.0717
Atrazine Rate * Press Wheels	4	130.88	0.74	0.5691
Atrazine Rate * Openers * Press Wheels	8	76.97	0.22	0.9866

Table XXIII. Forage response for spring atrazine modified opener experiments at Blackwell.

Source of Variation	Degrees of Freedom	Sum of Squares	F Value	PR>F
Atrazine Rate	4	1076322.6	43.80	0.0001
Openers	2	99663.0	4.05	0.0392
Press Wheels	1	1241.6	0.10	0.7551
Openers * Press Wheels	2	15971.7	0.65	0.5367
Atrazine Rate * Openers	8	40045.7	0.63	0.7502
Atrazine Rate * Press Wheels	4	25839.8	0.81	0.5226
Atrazine Rate * Openers * Press Wheels	8	32891.4	0.52	0.8393

Table XXIV. Weeds in forage response for spring atrazine modified opener experiments at Blackwell.

Source of Variation	Degrees of Freedom	Sum of Squares	F Value	PR>F
Atrazine Rate	4	25181.1	15.84	0.0001
Openers	2	1793.4	2.38	0.1267
Press Wheels	1	158.7	0.42	0.5263
Openers * Press Wheels	2	185.0	0.25	0.7855
Atrazine Rate * Openers	8	4502.3	2.09	0.0503
Atrazine Rate * Press Wheels	4	1234.6	1.15	0.3427
Atrazine Rate * Openers * Press Wheels	8	262.7	0.12	0.9981

Table XXV. Yield response for spring atrazine modified opener experiments at Perkins.

Source of Variation	Degrees of Freedom	Sum of Squares	F Value	PR>F
Atrazine Rate	4	0.3056	67.06	0.0001
Openers	2	0.0094	2.92	0.0848
Press Wheels	1	0.0001	0.08	0.7810
Openers * Press Wheels	2	0.0012	0.38	0.6926
Atrazine Rate * Openers	8	0.0094	1.39	0.2181
Atrazine Rate * Press Wheels	4	0.0007	0.21	0.9309
Atrazine Rate * Openers * Press Wheels	8	0.0015	0.22	0.9852

Table XXVI. Foreign material in grain response for spring atrazine modified opener experiments at Perkins.

Source of Variation	Degrees of Freedom	Sum of Squares	F Value	PR>F
Atrazine Rate	4	0.2444	2.72	0.0804
Openers	2	0.0697	7.41	0.0058
Press Wheels	1	0.0041	0.89	0.3598
Openers * Press Wheels	2	0.0186	1.97	0.1733
Atrazine Rate * Openers	8	0.0335	1.08	0.3900
Atrazine Rate * Press Wheels	4	0.0125	0.80	0.5283
Atrazine Rate * Openers * Press Wheels	8	0.0342	1.10	0.3762

Table XXVII. Yield response for spring atrazine modified opener experiments at Blackwell.

Source of Variation	Degrees of Freedom	Sum of Squares	F Value	PR>F
Atrazine Rate	4	0.5254	15.78	0.0001
Openers	2	0.0410	1.62	0.2308
Press Wheels	1	0.0102	0.81	0.3836
Openers * Press Wheels	2	0.0293	1.16	0.3409
Atrazine Rate * Openers	8	0.0375	1.51	0.1720
Atrazine Rate * Press Wheels	4	0.0124	1.00	0.4132
Atrazine Rate * Openers * Press Wheels	8	0.0414	1.67	0.1236

Table XXVIII. Foreign material in grain response for spring atrazine modified opener experiments at Blackwell.

Source of Variation	Degrees of Freedom	Sum of Squares	F Value	PR>F
Atrazine Rate	4	0.1139	1.14	0.3857
Openers	2	0.0040	0.25	0.7795
Press Wheels	1	0.0005	0.06	0.8082
Openers * Press Wheels	2	0.0016	0.10	0.9030
Atrazine Rate * Openers	8	0.0715	1.86	0.0837
Atrazine Rate * Press Wheels	4	0.0202	1.05	0.3887
Atrazine Rate * Openers * Press Wheels	8	0.0433	1.12	0.3604

2

VITA

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