USE OF A CHISEL PLOW IN THE CORN BELT VS. THE MOLDBOARD

by

JOHN E. FERDINAND

B. S., Emporia Kansas State College, 1974

A MASTER'S REPORT

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Agricultural Mechanization
Department of Agricultural Engineering

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1977

Approved by:

Ralph Lepper

Major Professor

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

Tillage has long been a topic of discussion among farmers, manufacturers and those doing research in the tillage field. Krause Plow Corporation desired a survey of current tillage practices in the field and of recent research results. To achieve this, an internship was arranged between Krause Plow Corporation and the Department of Agricultural Engineering, Kansas State University. The internship contract required a written report which would include information beneficial to both farm managers and Krause Plow Corporation. Detailed provisions of the contract are given in Appendix A.

Research for the project was done by conducting a literature search; compiling a file of literature; and contacting staff members of Agricultural Engineering, Agronomy, and Agricultural Research Service, United States Department of Agriculture departments at Kansas, Missouri, Nebraska, Iowa, Illinois, and Ohio land grant universities, and the National Tillage Machinery Lab; contacting Kansas farmers, machinery dealers, and manufacturers; conducting field tests; and a random survey of farmers in Iowa and Illinois (Appendix B includes a summary of results of the survey). From this information, an internship report to Krause Plow Corporation was written and delivered. This document is basically that report, but more technical in depth and scope.

Definitions of tillage systems and specific areas of the benefits of the chisel are covered section by section. A short section on no-tillage tells the advantages and disadvantages of the system and how the chisel plow can be used in rotation with a no-tillage system to prepare the soil for small grain and meadow crops.

The chisel plow is quite a versatile tool because it can be used in a number of ways and in many geographical areas. It is used in conservation

tillage and minimum tillage and is becoming even more popular as its benefits become better known to the American farmer.

DEFINITIONS

CONSERVATION TILLAGE: A broad term that includes several tillage systems, each of which must provide a good environment for the crop to be grown and at the same time conserve soil and water resources by maximizing or optimizing the retention of residue on the soil surface (1). In addition to the surface residues, the system may have a rough soil surface and utilize herbicides for weed control (1,2). Less expenditure of energy to produce a crop is also characteristic of conservation tillage (2).

MINIMUM TILLAGE: A term which does not define a system, but generally refers to a system that has fewer tillage operations than a conventional system (3). It is further defined as the least manipulation of the soil required for the production of a crop in existing soil conditions (3).

MULCH TILLAGE: Tillage or preparation of the soil in such a way that plant residues or other mulching materials are specifically left on or near the surface (3).

NO-TILLAGE: A system which utilizes a special equipped planter to plant directly into an untilled seedbed. The kill and control of weeds and grass is strictly by herbicides (also known as zero-tillage, slot plant, sod plant or slit plant).

TILL-PLANT: A system which employees a large sweep (about 1/3 of row spacing) to remove a layer of soil and the residue from the old crop row ahead of the planter opener (1). This system requires a 6-8" ridge which is made during lay by cultivation of the previous crop.

FACTORS THAT ARE INFLUENCED BY TILLAGE SYSTEMS

I. Timeliness

Tillage is a timely operation. Soil and weather conditions in a given season of the year dictate the amount of time suitable for the best tillage results. Field capacity in acres per hour can be significantly important to the timeliness of any operation.

Field capacity of a chisel and a moldboard can be computed by selecting a tractor and a soil type. For this example, a 270 drawbar horsepower tractor and a clay loam soil were selected. Using formulas and tables from Bowers, equipment size and acres per hour were computed for a chisel plow and a moldboard plow (4).

$$\text{DRAFT} = \frac{\text{DRAWBAR HP} \times 375}{\text{SPEED (MPH)}}$$

$$\text{DRAFT (for moldboard)} = \frac{270 \text{ HP} \times 375}{4.5 \text{ MPH}} = 22{,}500 \text{ lbs.}$$

$$\text{DRAFT (for chisel)} = \frac{270 \text{ HP} \times 375}{5.0 \text{ MPH}} = 20{,}250 \text{ lbs.}$$

$$\text{WIDTH IN FT.} = \frac{\text{TOTAL DRAFT}}{\text{DRAFT PER FOOT}}$$

$$\text{WIDTH IN FT. (moldboard)} = \frac{22{,}500 \text{ lbs.}}{950 \text{ lbs./ft. (at 8", 4.5 MPH)}} = 23 \text{ ft. } 8 \text{ in.}$$

CLOSEST MOLDBOARD 14-20" = 23 ft. 3 in.

$$\text{WIDTH IN FT. (chisel)} = \frac{20{,}250 \text{ lbs.}}{500 \text{ lbs./ft. (at 8", 5.0 MPH)}} = 40 \text{ ft. } 6 \text{ in.}$$

CLOSEST CHISEL = 40 ft.

Using a field efficiency of 85% for the moldboard and 90% for the chisel (4), the number of acres per hour can be computed by the formula:

EFFECTIVE FIELD CAPACITY (AC/HR) = $\frac{S \times W}{8.25} \times \frac{E}{100}$ where S = speed in MPH

W = width in feet

E = field efficiency (%)

$$\text{MOLDBOARD} = \frac{4.5 \text{ MPH} \times 23 \text{ ft. } 3 \text{ in.}}{8.25} \times \frac{85\%}{100} = 10.7 \text{ AC/HR}$$

$$\text{CHISEL PLOW} = \frac{5.0 \text{ MPH} \times 40 \text{ ft.}}{8.25} \times \frac{90\%}{100} = 21.8 \text{ AC/HR}$$

Results from this computation show that the moldboard works only 49% of the amount of ground that can be tilled with the chisel plow, using the same tractor for one hour. Another way to look at it is that the chisel plow can till over 2 times the area that can be plowed with a moldboard plow, with its same energy requirement in horsepower hours (HP hrs.). This is using a chisel equipped with straight 2" points.

In separate tests, using the same depth (9") and speed (4.5 MPH), Williams (5), from Iowa State, compares a moldboard plow with a chisel equipped with straight points, twisted points and coulters, and twisted points. Computed draft from this data for the moldboard is 971 lbs./ft., and 617 lbs./ft. for the chisel equipped with the coulters and twisted points. When these values are put into the formulas, it is found that the moldboard will work 62% of the area that can be tilled with the coulter-twist point chisel. Expressing it in another way, the chisel with coulters and twisted points will work 1.6 times the amount of area that can be moldboard plowed, using the same tractor.

This shows a significant reduction in time required for primary tillage when using a chisel plow. Fall work periods may be shortened by late harvests, early winter storms or a shortage of manpower which is an additional expense. Tractor engine hours can also be reduced when chiseling a given

number of acres instead of moldboard plowing. Also, the soil can be tilled at a more optimum moisture level since less time is needed to chisel a given number of acres.

Tillage at a proper moisture level is important for good soil management for several reasons. Tillage of soil that is dry on top is not a good practice if the tillage tool works to a depth where the moisture level exceeds 50% of the available moisture holding capacity (in plasticity range). Soil with this moisture level, at the depth of tillage, will compact and form new tillage pans (6). The reason is that moisture films between the soil particles act as a lubricant allowing them to slip over one another and thus compact (7). Compaction of soil reduces infiltration rates, enhances runoff, which therefore increases erosion and can limit the growth of roots (8).

Tillage of excessively dry soil can also create problems. When the soil is excessively dry, cohesive forces act between the soil particles and the soil becomes hard. Tillage at a low moisture level may produce a fine granular structure due to aggregate breakdown. This fine granular structure will crust easily when wetted, causing crop emergence and runoff problems (9). Another problem which can occur is that large hard clods are brought to the surface. This requires larger amounts of energy for primary tillage due to the increased draft which is a result of the hard cohesive soil (10). Also, greater amounts of energy are required for subsequent tillage operations necessary to pulverize the large clods (11). Still another problem is that tillage tools receive excessive wear when soil is tilled too dry due to the abrasive action of the dry soil particles.

Abuse to the soil and abuse to machinery in these cases can be elimi-

nated by tilling at a soil moisture level at which the soil is friable (just below the lower plastic limit). Here again the chisel plow has an advantage over the moldboard plow in being capable of working more acres at a time when tillage operations can best be performed. This may be immediately after harvest for good fall tillage or in the spring when every day may be crucial to crop yields.

II. Soil Maintenance and Improvement by Tillage

Proper tillage of soil is done for a beneficial purpose or purposes. Weed control; management of residues; modifications of soil structure to increase intake, storage, and transmission of water; and providing a good environment for seeding and rooting of a crop are the objectives of good tillage operations (9). Areas of the United States vary in regard to tillage requirements. It is not within the scope of this report to review all such data. Instead this will be limited specifically to the Corn Belt.

Compaction of a wet subsoil from tillage tools has already been mentioned, but this is only a part of the story. Soil compactibility for a given soil is also affected by the organic matter in the soil. Organic matter has a high water absorptive capacity and a low particle density, which allows it to combine with soil minerals to produce aggregates that are more stable and resist compaction. With the same soil and more organic matter in this soil, tillage without compaction can be done at a higher soil water content. For maintenance of good soil structure, it is desirable to maintain an optimum level of soil organic matter content. The exact level necessary depends on soil texture, type of clay and other factors (12). It is generally understood that with increasing amounts of tillage, soil organic

matter is oxidized more quickly and thus its content in the soil is reduced.

Two other major causes for soil compaction in the field are wheel traffic and worn tillage tools (11). Increasing wheel weight or wheel slip directly increases soil compaction. A drive wheel should be weighted to allow 8-15% slip under normal implement load conditions (13). Excessive wheel weight and/or wheel traffic can compact a tilled soil to a density that is higher than before tillage (14).

Soil compaction at the depth of tillage is commonly termed a "tillage pan." (Besides being caused by working the soil too wet, tillage pans are created by worn tillage tool edges.) It has long been known that worn plowshares smear and compact the layer of soil below them (12). Worn chisel points will also leave a compacted area, but not across the full width of tillage as will the moldboard plow. Not only do the worn tillage tool edges increase soil compaction, they also increase draft, thus requiring more energy to pull them.

Chisels are often used to break up tillage pans, and in much of the Corn Belt chiseling is done at a depth of 10-12 inches (15). Some believe that tillage at these depths and deeper with a chisel or subsoiler will greatly benefit crop production. This is true only for areas of the country where the soil has a natural hardpan or where the soil is easily compacted and not subject to freeze-thaw conditions (16).

In parts of the western Corn Belt, deep chiseling on the contour increases soil moisture storage where total rainfall is low, but highly intense (9). In Kansas, research has shown that chiseling to a depth of 8-15 inches improved permeability in soils with dense layers until further tillage operations were performed which virtually eliminated any benefits (17).

Other research in the Corn Belt area shows that where soils freeze to depths of 3 feet or more, or where dry weather causes shrinking and cracking of the subsoil, deep tillage has very little benefit (18). Corn yield studies in Missouri on Mexico silt loam and Sharon silt loam by McKibben and Whitaker show no significant advantage due to depth and degree of root zone tillage (19).

In many areas, deep tillage is not necessary to store soil water. The only requirement is a rough, porous surface that is ridged at right angles to the slope of the land (20). Pore space should not be excessively large, since this condition readily dries the soil out to the depth of tillage (21,22). Neither should the pores be small because this causes crusting and increased runoff (21).

Tillage at depths below 6-8" may shatter old tillage pans, but begin new problems. Compaction at the depth of tillage will not disappear. It will occur at the new depth of tillage where even better compacting conditions normally exist. Wheel traffic compaction from subsequent tillage will also go deeper due to the deeper layer of tilled soil that can be easily compressed. Energy requirements in gallons per acre are increased by more draft, due to increased depth. Poor use of machine and man hours also result from unnecessary operations, all of which increase the total cost per acre for crop production. Since deep tillage (8" or deeper) is costly, it should be used only in areas of the Corn Belt where rainfall is high in intensity and low in amount. Nature, by freezing and thawing and by drying and cracking, effectively breaks shallow tillage pans.

III. Infiltration

Water that infiltrates the soil adds to moisture storage when reserves are low, but drains through the soil profile after the soil reaches field capacity. Infiltration rates usually are higher when soil moisture is low (nearer the permanent wilting point) and decrease as the soil reaches field capacity. Mannering, Griffith, and Richey (21), point out that tillage can modify soils in several ways which will definitely affect the infiltration rate. These include contour tillage, surface roughness, crop residue placement and soil structure.

Contour tillage is done across the slope using ridges or rows to divert the water and is beneficial in slowing runoff water from the field. This gives the water more time to infiltrate and less erosive potential.

Aggregate size and surface roughness are also important in regards to infiltration of water into the soil. Large aggregates increase the infiltration rate of the soil, whereas the smaller aggregates have a tendency to break down upon soaking or raindrop impact and reduce the infiltration rate of the soil.

Tables 1 and 2 show the effect of tillage on soil aggregation for four soils with four tillage systems at the end of five years (21). Note the average for the till-plant and the chisel system were relatively close in the top 2" and virtually the same at the 2-6" depth. Conventional systems had the smallest aggregates and the coulter (no-till) system had the largest.

It should be noted that water stable aggregation is an index of the soil's resistance to compaction, dispersion, plant emergence, aeration, drainage, water intake and soil erosion. The results from the work of Mannering, Griffith and Richey (21) given in Tables 1 and 2 show that systems

with lesser amounts of tillage have advantages related to aggregate size over conventional tillage. They also state that for good crop emergence, a seedbed zone must have 20-30% aggregates that are less than 2 mm (21).

For a given soil type, bulk density is an indirect measure of permeability (as bulk density decreases, permeability and infiltration increases). Tillage that results in a decrease in bulk density would therefore produce a soil condition that has more permeability and infiltration. Figure 1 shows the average bulk densities for 5 soils for seven tillage systems three weeks after planting. Note the chisel plow produced the lowest bulk density and the coulter or no-till had the highest. Based on bulk density alone, the chisel should produce a soil condition which has a higher permeability and infiltration rate than any other system at this time (3 weeks after planting). But it should also be noted that by fall these differences largely disappear (21).

Surface roughness and infiltration rates in inches per hour were also compared by Mannering, Griffith, and Richey in Indiana using tillage treatments and simulated rainfall. Results from their work on Xenia silt loam with a 3% slope (Figure 2) show that a rough surface maintains a higher infiltration rate for a longer period of time (21). Conventional tillage practices leave soil surfaces smooth, which decrease infiltration rate (23).

Tillage which leaves residue on the surface and produces a rough surface is most beneficial to infiltration. Chisel and moldboard systems were compared on a Barnes loam soil by Burwell, Sloneker, and Nelson (1968). They concluded that spring infiltration before runoff was eight times greater for the chisel system than for the conventionally-tilled system (fall plow, spring disk, and harrow) (24).

Table 1. Tillage Effect on Soil Aggregation (0-2")*-a

	Aggregation Index**				
	Tracy S.L.	Runnymede L.	Bedford Si.L.	Blount Si.L.	Avg.
Conv.	.442	.336	.332	.227	.347
Chis.	.601	.470	.215	.543	.456
Till Plant	.708	.399	.305	.454	.467
Coulter	1.006	.786	.593	.687	.768

*Water stable aggregates determined by a modified Yoder technique, passed through an 8 mm. sieve while moist, air dried and then stability measurements were made by wet sieve method.

**Difference between the mean weight diameter of the original and dispersed samples expressed in mm.

[a]Mannering, J.V., D. R. Griffith, and C. B. Richey. 1976. Tillage for moisture conservation. Chicago, Illinois, ASAE Paper #75-2523.

Table 2. Tillage Effect on Soil Aggregation (2-6")*-[b]

	Aggregation Index**				
	Tracy S.L.	Runnymede L.	Bedford Si. L.	Blount Si. L.	Avg.
Conv.	.579	.548	.287	.458	
Chis.	.719	.483	.345	.695	.561
Till Plant	.787	.431	.370	.650	.560
Coulter	1.058	.622	.427	.687	.699

*Water stable aggregates determined by a modified Yoder technique, passed through an 8 mm. sieve while moist, air dried and then stability measurements were made by wet sieve method.

**Difference between the mean weight diameter of the original and dispersed samples expressed in mm.

[a]Mannering, J. V., D. R. Griffith, and C. B. Richey. 1976. Tillage for moisture conservation. Chicago, Illinois, ASAE Paper #75-2523.

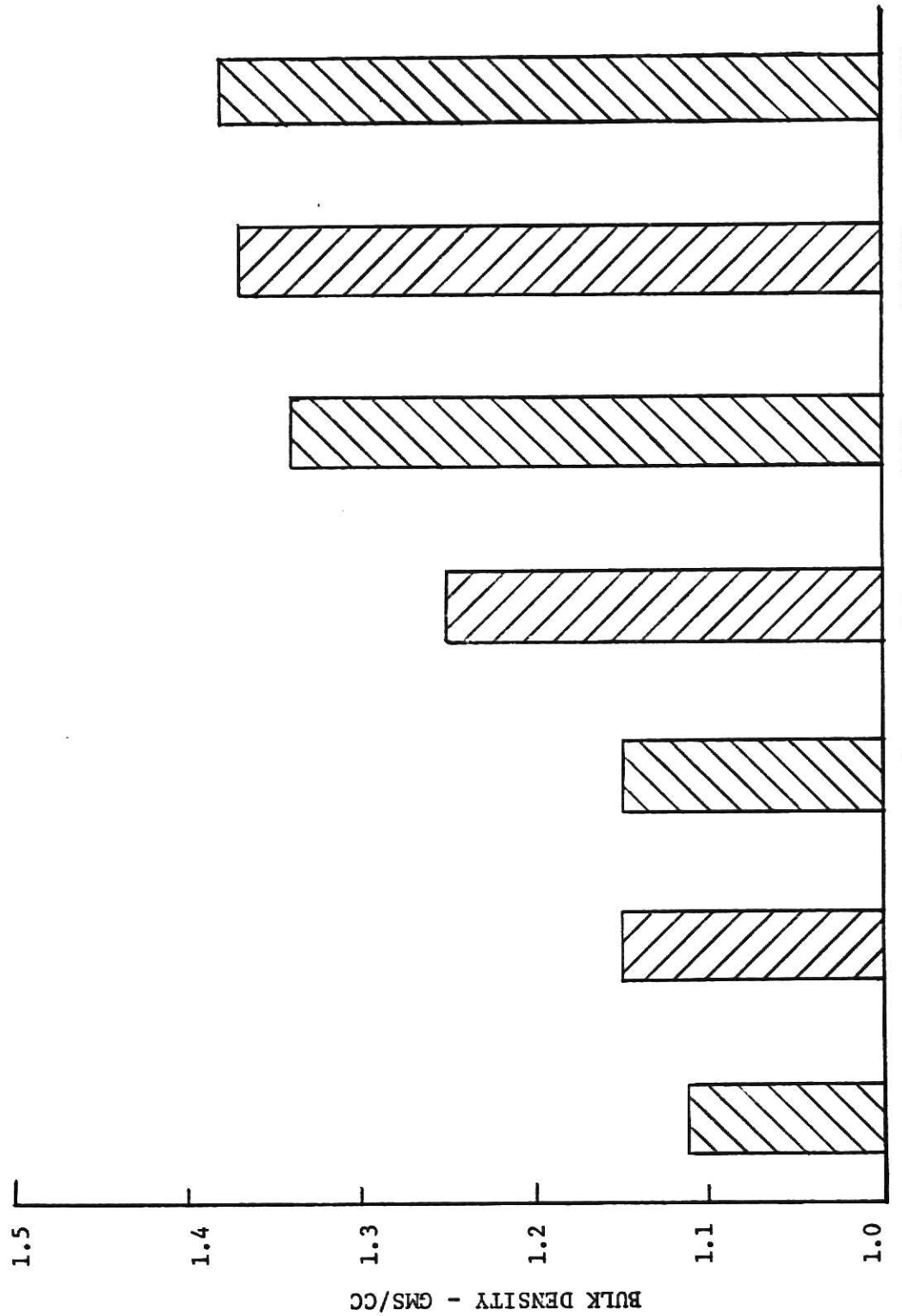


Figure 1. Tillage System Effect on Bulk Density 0-20 cm. Three Weeks after Plant. Average of 5 Soils.

[1]Mannering, J. V., D. R. Griffith and C. B. Richey. 1975. Tillage for moisture conservation. Chicago, Illinois, ASAE Paper #75-2523.

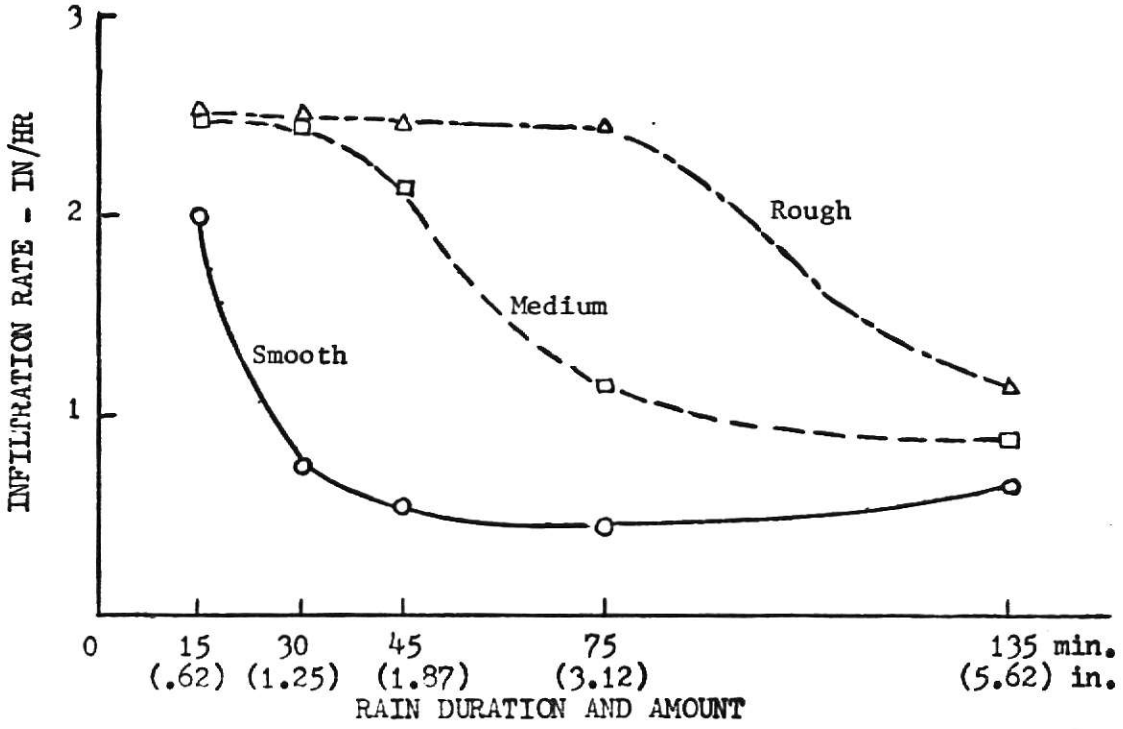


Figure 2. The Effect of Surface Roughness As Affected by Tillage on the Infiltration Rate, Xenia Silt Loam, 3% Slope.

[2]Mannering, J. V., D. R. Griffith and C. B. Richey, 1975. Tillage for moisture conservation. Chicago, Illinois, ASAE Paper #75-2523.

IV. Erosion

Erosion is greatly reduced when the amount of runoff is reduced, and the length of time for runoff to occur is increased. Not only will soil losses under these conditions be greatly decreased, but so will the nutrient loss that accompanies soil erosion.

Late spring tests run by Mannering, Griffith, and Johnson show that soil losses from fall chisel-plowed plots were one-half to three-fourths of the losses for fall moldboard plowing. They concluded that the amount of surface residue was inversely related to the amount of soil loss (25).

Oschwald and Siemens found that runoff was not only affected by the kind of fall tillage, but also by the previous crop grown on the soil (2). Results from their study on fall tillage with a moldboard plow or a disk-chisel and no-fall tillage is shown in Table 3. Notice that the disk-chisel system had less runoff and, except for one case, had less soil sediment loss than either the no-fall tillage or the moldboard-plowed plot.

Table 4 from Oschwald and Seimens (2) shows the effect of nutrient loss by runoff and sediment from six different tillage planting systems on Catlin silt loam. The fall plow system had the greatest amount of runoff water and the largest sediment loss, but had the least amount of nitrate in the runoff water. The coulter-chisel system had the least runoff water with the least amount of nitrate and soluble phosphorous. Sediment losses, however, were not as low as the disk or chop, plant plots. The chop, plant plot had the least amount of sediment losses, but the amount of runoff water was nearly as great as that of the moldboard-plowed test.

From their tests, Oschwald and Seimens (2) stated that total runoff quantity was the smallest when the chisel plow was used in soil preparation.

Table 3. Runoff and Soil Loss as Influenced by the Water Applied, Kind of Fall Tillage, and Crop or Year Catlin Silt Loam[a-c]

Minutes[b]	Water applied (in.)	Fall moldboard plow		Disk-chisel		No fall tillage	
		Corn (1974)	Soybeans (1975)	Corn (1974)	Soybeans (1975)	Corn (1974)	Soybeans (1975)
		Runoff (inches)					
60	2.5	1.19	1.53	.04	.83	.89	1.27
90	3.75	2.29	2.71	.31	2.00	1.81	2.37
120	5.0	3.37	3.78	1.13	3.25	2.79	3.47
		Soil loss (pounds per acre)					
60	2.5	3,751	9,751	56	2,464	373	1,232
90	3.75	7,689	16,111	360	4,613	681	2,310
120	5.0	11,321	22,885	1,294	6,656	1,003	3,445

[a]Simulated rainfall applied at intensity of 2.5 inches per hour after overwinter weathering but prior to any spring tillage.
[b]Time from start of water application.
[c]Oschwald, W. R. and J. C. Seimens. 1976. Conservation tillage: A perspective. U. of Illinois. Agronomy Facts. Sm-30

Table 4. Influence of Tillage-Planting System on Runoff and Sediment Loss. Urbana, Illinois, 1973 Catlin Silt Loam[a-d]

Tillage-planting system	Runoff			Sediment		
	Total (in.)	NO_3-N, (lb./A.)	Soluble P (lb./A.)	Total loss (1,000 lb./A.)	Total N (lb./A.)	Total P (lb./A.)
Fall plow	5.7	0.5	.11	16.5[b]	34.5[b]	11.5[b]
Disk-chisel	4.1	1.3	.11	4.5	10.6	3.5
Coulter-chisel.	3.7	0.6	.09	3.9	9.4	3.1
Chop, chisel.	4.0	0.7	.09	6.4	13.8	4.3
Disk.	4.0	1.2	.08	3.3	8.8	2.7
Chop, plant	5.1	0.6	.11	2.8	7.2	2.2

[a]Water applied at 2.5 inches per hour for 4 hours.
[b]Significantly higher at the .01 level.
[d]Oschwald, W. R. and J. C. Seimens. 1976. Conservation tillage: A perspective. U. of Illinois. Agronomy Facts. Sm-30

The rough surface left by the chisel provides more resistance to runoff, and thereby less erosive potential.

Crop residues also decrease erosion potential and evaporative moisture loss. Research from 1954-1973 by Heinemann and Whitaker, shows that with 50% of previous crop residue on the surface at planting time, soil losses were reduced to less than 50% of clean-tilled conventional seedbeds (26). This can be attributed to several factors. First the mulch will intercept the raindrop and slow its velocity before it reaches the soil. This reduces detachment of soil particles by raindrop impact; transportation by splash erosion; and crusting, which causes sealing and thus further surface erosion. Secondly, the surface mulch will reduce the velocity of the runoff water, giving it more time to infiltrate the soil. Greater infiltration with less runoff is associated with the amount of surface residue in tons per acre (Figure 3). Wind erosion is influenced by climate, soil type, field size, and the amount of residue on the surface and by the surface roughness of the soil. Standing residue is about twice as effective in controlling wind erosion as flattened residue. More large stubble residue is required to check wind erosion than small grain residue (27) (Table 5).

Evaporative losses which occur early in the crop season (mid-April to mid-June) when temperatures and solar radiation are high, continue until the crop shades the soil sufficiently to reduce losses. It is through periods such as these, that crop residue mulch not only helps control any erosion which may occur, but also greatly affects evaporative losses (22). Surface mulches also reduce evaporative losses which would normally be lost on bare fields, when small showers penetrate the residue cover. Moisture held on the residue is lost to the atmosphere due to evaporation, but the moisture

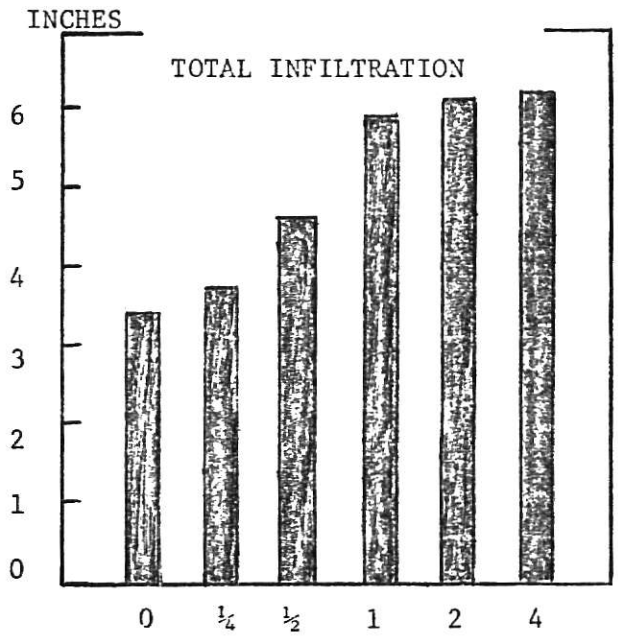


Figure 3. The Relationship of Varying Amounts of Crop Residue on the Surface of a Wea Silt Loam to Infiltration.[3]

[3]Mannering, J. V., D. R. Griffith and C. B. Richey, 1975. Tillage for moisture conservation. Chicago, Illinois, ASAE Paper #75-2523.

Table 5. Pounds of Residue Required Per Acre to Hold Wind Erosion to 5 Tons Per Acre Annually[e].

	Wheat Residue		Sorghum Residue	
Soil Texture*	Standing	Flattened	Standing	Flattened
	(lb/A)			
Silts	450	930	1,800	2,600
Clays and silty loams	800	1,600	3,300	4,750
Loamy fine sands	1,050	2,130	4,200	6,200

[e]Fenster, C. R. and C. A. Wicks. 1976. Minimum tillage systems reduce wind erosion. University of Nebraska, ASAE Paper #76-2032.

*Silts with 50% nonerodible fractions greater than 0.84 mm. in diameter; clay and silty clay with 25% and loamy sand with 10% nonerodible fractions.

at the soil surface is retained in the soil. This allows more moisture to be collected in dry times and is a definite benefit to a growing crop.

A tillage system must regulate the amount of residue left on the surface if it is to be beneficial for evaporative loss and erosion control purposes. Table 6 shows the percent reduction of surface residue for each tillage operation. Residue coverage varies with height, position, length, and amount of residue on the surface. It also varies with the speed of operation and soil condition at the time of tillage. Table 6 gives a general rule of thumb for the amount of residue, in percent, that remains after each tillage operation. This figure can be used when planning the tillage operations necessary to achieve a given amount of surface residue at planting time, when the initial amount of residue is known.

Surface roughness, aggregate size and stability, porosity, residue placement, and contour tillage all affect the soil's erosive potential. Tillage should be done at a time and in a manner which utilizes the benefits of each one. The following conditions describe the results of a tillage system that improves soil conditions and yet minimizes costs: large aggregates, low bulk density, high permeability, rough surface, residue in and on the surface, contour tillage, and tillage only to a depth necessary for existing climatic conditions.

Tillage at the proper soil moisture content, depth, and on the contour with a chisel will leave residue in and on a rough surface. This soil condition will have a high infiltration rate resulting in low runoff. The moldboard plow, even if used properly, cannot compete with the chisel in maintaining conditions necessary for good erosion control.

Table 6. Estimated* % Residue Remaining on the Surface After One Tillage Operation

TILLAGE TOOL	% RESIDUE REMAINING
Moldboard	0 - 10%
Chisel (straight points)	75 - 95%
(twisted points)	50 - 60%
Heavy tandem or offset	40 - 50%
Tandem disk	50 - 55%

*Based on data from operations on wheat stubble (1976).

An increasing number of states are proposing erosion control laws. Some states, such as Iowa, already have laws concerning erosion. As increased measures are put into effect to control non-point source erosion, more systems using the moldboard plow will be replaced by conservation tillage practices. The choice of the system used will depend on the climate, topography, and soil in the area; the crop or crops to be raised; and individual preferences.

V. Crop Yields

Crop yields are of great importance when comparing tillage systems. Some producers strive for the highest possible yields and neglect costs. Producers with better management realize that yields should be optimized, that is, the most return for the amount spent. Quality materials (fertilizer, seed, herbicides, and insecticides), combined with a properly managed tillage-planting system, results in the greatest possible returns.

Tillage affects virtually every aspect of crop production and crop yield. Soil-water storage will affect the amount of available moisture for the growing crop to reach top yield. Surface roughness and residue not only help store water, but also help reduce runoff, causing less soil loss and thus less nutrients lost. Less nutrients lost mean less applied fertilizer required to produce a crop with high yield.

Studies done in Indiana by Mannering, Griffith, and Johnson (21) show that fall chiseling produces corn yields equal to or greater than moldboard plowing. Illinois research (Table 7) shows yields for four years on a Catlin silt loam, using six different tillage systems (2). Notice the average corn yields for this study. The chisel plow had a higher yield

Table 7. Corn and Soybean Yields on the Erosion Plots, Urbana, Illinois

Catlin Silt Loam[g]

Tillage-planting system	Yields, bushels per acre				
	Corn, 1972	Corn, 1973	Soybeans, 1974	Corn, 1975	Corn, Average
Fall plow	126	167	43	142	145
Disk-chisel	127	159	40	142	143
Coulter-chisel. . . .	133	167	42	129	143
Chisel.	131	169	41	137	146
Chop-plant.	...	140	36	132	136
Disk.	130	160	48	135	142

[g]Oschwald, W. R. and J. C. Seimens. 1976. Conservation tillage: A perspective. U. of Illinois. Agronomy Facts. SM-30

than did the fall plow system for two of the three years shown.

This is not to say that using the chisel will increase yields. Other factors such as weather, weed and insect control, proper soil fertility, date of planting, and proper planting procedures all interact. Weather obviously cannot be controlled, but its effect on the soil and growing crop can be influenced by tillage. With the chisel, more rainfall can be stored in the soil profile, meaning less water erosion. Residue left on the surface not only slows water and wind erosion and reduces evaporation from the soil, but it slightly reduces the temperature of the soil.

A temperature reduction, especially in early spring, can have an effect on the rate of plant emergence and early growth. Research done in Indiana by Griffith, Mannering, and Richey (28), using six tillage systems, showed that as surface residue in the row increased, temperature in the row at a 4" depth tended to decrease. Although temperature may be lower and plant growth slower in the early spring due to increased amounts of surface residue, yields for a fall chisel system compared equal to or better than fall plowing when stands were equal. Secondary tillage that provides good seed to soil contact is a prerequisite for a good stand. On soils that drain poorly, a chisel-disk system should be used, and caution should be taken as the finer soil particles crust and erode easily as compared to larger soil particles (28).

Insects and weeds can also affect yields on any field no matter what tillage system has been used. Weeds require moisture and sunlight and use nutrients which would otherwise be available to the growing crop. Competition between weeds and the crops in the early crop growing season has the most detrimental effect on final yields (29).

Types of weed control include tillage, herbicides and crop rotations. One or combinations of these are used to control weeds, depending upon the weeds present and the type of tillage system. In tillage systems that leave residue on the soil surface, it has been shown that using a combination of tillage and preemergence herbicide will give season-long control of weeds (30). The amount of cornstalk residue on the surface has little effect on the control of weeds by preemergent herbicide when applied at the recommended rates (30). Rotations from summer to winter crops may be done in order to help control summer perennial weed problems (29). As further developments in herbicides become available, there promises to be less and less dependence on tillage and crop rotation for weed control.

Insect control is a must for all systems. Systems with lower amounts of tillage tend to have more insect problems than systems with conventional tillage (31). This is due to a change in the ecosystem brought about by more surface residue and lower amounts of tillage. No-tillage has the most potential for insect problems, but has been gaining acceptance as ways to control insects have become available (31). The fall chisel system does have more potential for insect problems than a fall plow system, but this may be eliminated by proper management and use of insecticides.

Crop yields for a chisel system with proper management of fertility, control of weeds and insects, and proper planting at an optimum time should result in comparable yields to those of a moldboard plow system. This may not be true for soils that are wet, if large amounts of residue (more than 4,000 lbs.) remain on the surface.

VI. Power Requirements

Power requirements for any tillage operation vary with the machine condition, soil type, moisture content, compaction, surface condition, and the speed and depth of operation. Soil surface conditions affect tractive efficiency, which directly affects the engine horsepower required for a specific operation. First to be considered is draft and some of the factors that make it vary for the same implement. Depth of operation affects draft in that the deeper the operation, the higher the draft requirement. Speed also affects draft as higher speeds increase the draft forces of an implement. Soil conditions which make the soil harder to break up (clay soils, dry soils, compacted soils and dispersed soils) also increase draft.

Results from actual field tests done in Brown County, Kansas (1976) on a Sharpsburg silt loam soil show the effect of speed and depth on chisel plow draft (Table 8). Notice, in this case, that as speed increased from 3.40 MPH to 3.93 MPH, draft per shank also increased from 425 to 463 pounds per shank, when depth remained the same. Notice too that when depth changes, so does draft per shank.

Draft for several tillage tools over a range of conditions are listed in Table 9. Lower values are for sandy soils whereas higher values are for heavy clay or compacted soils. Notice for these figures that the chisel has slightly more than half the draft and energy requirements of the moldboard, all conditions being equal.

Energy requirements for chiseling are much less than for moldboarding. At 5.5 MPH, moldboarding requires almost twice the energy of chisel plowing under the same conditions (32). Figure 4 shows the energy requirements of

Table 8. Chisel Plow Research Data from Brown County, Kansas 1976

20 Ft. Chisel Plow--Solid 26" Shank, Straight Points

Sharpsburg Silt Loam

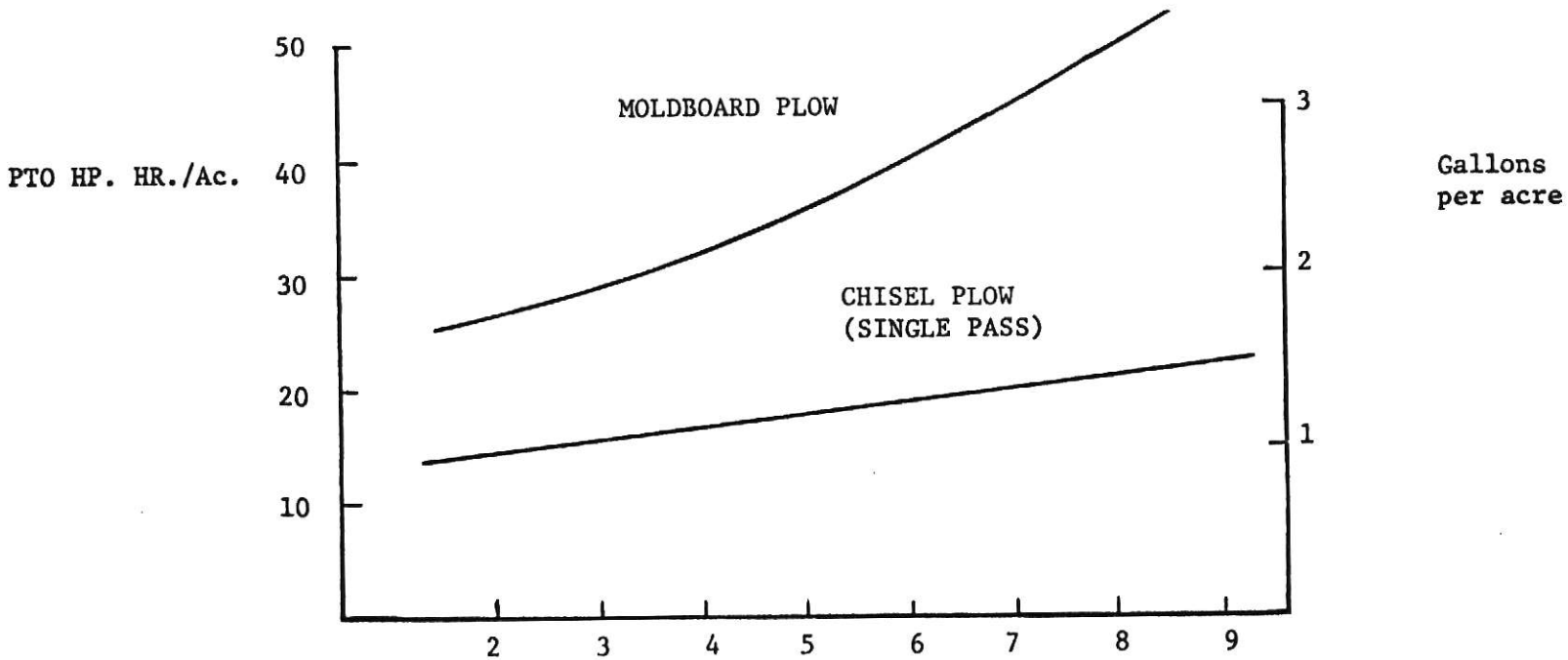
% DRIVE WHEEL SLIP	TRUE MPH	TOTAL DRAFT (lbs)	DEPTH IN INCHES	GPA	AC/HR	DRAFT (lbs.) PER SHANK
28	3.40	8500	6.5	1.16	8.22	425
21.1	3.63	9000	6.5	1.09	8.92	450
14.3	3.93	9250	6.5	.98	9.54	463
19.5	4.50	8000	5.0	.87	10.97	400
20.4	4.00	8500	5.5	.95	9.69	425

Table 9. Draft, Energy, and Diesel Fuel Requirements for Various Tillage Operations[h]

	Draft lbs./ft.	HP hrs./Ac.*	Diesel gal./Ac.
Moldboard	375-1300	13.8-43.8	1.1-3.5
Chisel	200-750	6.2-25.0	.5-2.0
Heavy Tandem or Offset	250-500	11.2-22.5	.9-1.8
Tandem Disk	100-280	5.0-12.5	.4-1.0
Springtooth	75-300	3.8-12.5	.3-1.0
Spiketooth	20-60	1.2- 2.5	.1- .2
Field Cultivator	150-400	6.2-17.5	.5-1.4

*12.5 HP--hr./gal. diesel

[h]Adapted from Table 1, Energy requirements of various tillage systems. S. J. Clark



8 in. depth, medium draft soil good tractive conditions

Figure 4. Moldboard and Chisel Plow Energy Requirements[4]

[4]Zoz, Frank M. 1974. Optimum width and speed for least cost tillage TRANSACTIONS of the ASAE, pps. 845-850.

a moldboard and chisel at different speeds with other conditions being the same.

Engine horsepower and thus energy required are not affected by draft alone, but secondly by tractive efficiency. Tractive efficiency (T.E.) depends on the soil surface conditions. A soil that is firm will have a greater tractive efficiency (T.E. = 0.70), than will a loose soil, (T.E. = 0.45). Tractive efficiency is a factor that accounts for the amount of power required to overcome the rolling resistance of the tractor wheels and energy lost due to slip. Its effect on the engine horsepower required to pull a certain load can be shown by the following equations:

$$\text{DRAWBAR HP/FT.} = \frac{\text{SPEED x DRAFT/FT.}}{375}$$

For this example a speed of 5.0 MPH and a draft of 500 lbs./ft. will be used.

$$\frac{\text{5.0 MPH x 500 LBS./FT.}}{375} = \text{6.7 DRAWBAR HP/FT.}$$

Next it is necessary to determine the engine horsepower required to produce the 6.7 HP/FT. at the drawbar. To do this, the following formula is used:

$$\text{ENGINE HP/FT.} = \frac{\text{DRAWBAR HP/FT.}}{.96 \text{ x T.E.}}$$

The .96 is for gear loss. Difference for engine horsepower required under different T.E. conditions (0.70 and 0.45) are:

$$\text{ENGINE HP/FT.}_1 = \frac{6.7 \text{ HP/FT.}}{.96 \times .70} = 9.9 \text{ ENGINE HP/FT.}_1$$

$$\text{ENGINE HP/FT.}_2 = \frac{6.7 \text{ HP/FT.}}{.96 \times .45} = 15.5 \text{ ENGINE HP/FT.}_2$$

Results from the two equations show that tractive efficiency definitely affects the amount of engine horsepower required to pull a given load on different surface conditions. Table 10 shows some common values for tractive efficiency as listed in a paper by Clark (33). These values should be varied when soft or extra firm surface conditions exist.

Using the above equations, it is possible to: size equipment to tractors, tractors to equipment, or determine the total system needed for obtaining a certain field capacity. Draft per foot requirements for the machine in a given soil, T.E., field efficiency, and speed in MPH should be selected that are reasonable for the conditions at hand. To complete the calculations, one of the following must also be known: acres/hour, machine width, or available engine (PTO) horsepower. The following basic formulas are used:

$$\text{EFFECTIVE FIELD CAPACITY (AC/HR)} = \frac{\text{WIDTH (FT)} \times \text{SPEED (MPH)} \times \text{FIELD EFFICIENCY (decimal)}}{8.25}$$

$$\text{DRAWBAR HP} = \frac{\text{DRAFT (LBS./FT.)} \times \text{WIDTH (FT.)} \times \text{SPEED (MPH)}}{375}$$

$$\text{ENGINE HP} = \frac{\text{DRAWBAR HP}}{.96 \times \text{TRACTIVE EFFICIENCY (T.E.)}}$$

VII. Machinery Costs

Costs are important to every producer because costs affect the net

Table 10. Common Tractive Efficiency Values for Various Tillage Operations[i]

TOOL	T. E.
Moldboard	.70
Chisel	.65
Heavy Tandem or Offset	.55
Tandem Disk	.55
Springtooth	.55
Spike Tooth	.55
Field Cultivator	.60

[i]Clark, S. J. Energy requirements of various tillage systems, Kansas State University

profit. Farm size, hours available for performing the operation on time, initial cost, maintenance and operating costs all influence the justification of ownership and the capacity of the machine. It is the purpose of this section to show some of the savings in cost of the chisel over the moldboard.

As indicated earlier, the chisel, when compared with a plow, shows a savings of time (increased acres per hour) and energy (less HP hours per acre). In addition the initial cost of a chisel is less than for a moldboard plow, when each is sized for a given horsepower tractor. Repair costs for the chisel are less than for the moldboard. Bowers (4) estimates the life of the chisel at 2,000 hours with a repair cost of 65.0% of initial price, and the moldboard with the same life, but with an 80.0% cost of the initial price for repair. This is a significant difference in itself. The farmer acceptance of the chisel is not surprising when the timeliness factor of the chisel over the moldboard plow, the amount of acres worked in 2,000 hours, and the difference in repair cost per acre are considered.

Moldboards have more replacement parts than chisels. The most often replaced parts on the two tillage machines are moldboard shares and chisel points. Kansas farmers, equipment dealers, and extension personnel at Kansas State University suggest that, in respect to wear and replacement, the chisel point will last at least twice as long per foot as the moldboard share, conditions being equal (34). The average price per foot was computed using 1976 net prices (35). Standard chisel points were $.04 (1.23%) per foot higher than a moldboard share per foot, based on a 16" moldboard. Even with a higher price per foot, the chisel point costs less

per acre because it will work at least twice as many acres as a foot of moldboard share. For northeast Kansas, Schlender and Figurski (36) reported an average custom rate of $7.23 per acre for moldboarding and $6.20 per acre for chiseling. These figures are representative of the initial cost, fixed cost, and variable costs per acre of the machine.

Machinery related costs in dollars per acre for tillage systems were compiled by Siemens at the University of Illinois (37). Some of the results are listed in Table 11. Notice that conventional tillage always has the highest cost per acre for machinery, with the chisel system being the next highest cost.

Chisels, when compared to moldboards, not only reduce machinery costs and energy costs, but also increase the amount of acres that can be worked in a given amount of time. With less costs than a moldboard plow system and comparable yields, the chisel system will allow the producer more potential for net profit.

Table 11. Costs Related to Machinery for Different Tillage Systems[j]

TILLAGE SYSTEM	# OF TRACTORS AND HORSEPOWER	COMBINE SIZE	MACHINERY	TIMELINESS	LABOR*	TOTAL
	500 Acres--170 acres in soybeans and 330 acres in corn					
Conventional	1 - 125	4-row	30.75	0.66	6.79	38.20
Chisel	1 - 125	4-row	29.64	0.66	6.39	36.69
Chisel (Disk 1X)	1 - 125	4-row	28.87	0.00	5.90	34.77
Disk Plant	1 - 100	3-row	25.20	0.66	7.23	33.09
No-Till	1 - 80	3-row	29.81	0.00	6.76	31.57
	750 Acres--250 acres in soybeans and 500 acres in corn					
Conventional	2 - 125	6-row	28.58	0.06	6.29	34.93
Chisel	2 - 125	6-row	27.63	0.06	5.80	33.49
Chisel (Disk 1X)	1 - 150	6-row	23.15	0.69	4.43	28.27
Disk Plant	1 - 125	4-row	20.62	1.68	4.68	27.16
No-Till	1 - 80	4-row	19.28	0.00	4.86	24.14

[j]Siemens, John C. 1975. Machinery related costs for tillage alternatives, p. 14

*Labor = $5.00 per hour

CHISEL PLOW ATTACHMENTS

Many combinations of accessories can be used with the chisel to accomplish many jobs. Anhydrous ammonia (NH_3) is applied with the chisel when a regulator, distributor head and tube behind the chisel point is used. Special chisel plow knives are also available for applying NH_3.

Tine harrows may accompany the chisel for sealing in NH_3, incorporating chemicals, leveling the soil, breaking up clods, distributing trash evenly on and in the soil surface, conserving moisture, and controlling weeds by leaving them uprooted on the surface.

Non-powered rotating rods, much like a rod weeder can also be mounted behind the chisel plow. Claims for its use are similar to those of the tine harrow.

Three or four inch wide twisted points can also be used on the chisel plow. They provide more inversion action than a standard point, cover more residue and leave a rougher surface for better infiltration and erosion control. Twisted points require more power because they do more work to the soil.

In heavy residue, or weeds and vines, a set of coulters may be used to chop up and allow residue to pass through the chisel that would otherwise wrap around the shanks and cause clogging problems. These also require additional power.

For shallow weed control (2-4" deep), 16-18" sweeps can be mounted on the shanks. With a tine harrow mounted behind, seedbed preparation may be completed in one trip.

NO-TILLAGE

No-tillage seems to be gaining in popularity as more chemicals become available for efficient weed, insect, and disease control. Reduced machinery costs and reduced erosion are other reasons for its growing popularity among both new and old farmers. The purpose of this section is to briefly discuss the effects of no-tillage and determine whether or not the chisel plow should be used in rotation with no-tillage.

Soil physical properties are affected by the use of no-till. Mannering, Griffith, and Richey (21) showed that at the end of five years, the aggregates in no-till were significantly larger than for other tillage systems (Table 1, page 12 and Table 2, page 13). They also noted a higher bulk density for no-till than for other tillage systems (Figure 1, page 14). An increase in bulk density generally denotes a decrease in porosity and infiltration. Research by Oschwald and Seimens (2) shows that runoff of water is greater for the no-till system than for the chisel or disk systems (Table 4, page 17). However, note that sediment and nutrient losses for the no-till system, even with more runoff, were much less than other systems which have less runoff. Certainly in a case such as this, no-tillage would be the system to use to minimize pollutants in runoff.

Crop yields on corn in Illinois (2) for no-tillage compared to yields for conventional, chisel, and disk systems are shown on Table 7, page 24. Note the average corn yield in this case is less than for all other systems. However, other reports show that yields are equal to conventional tillage systems and, in some cases, even greater (28).

Potential for insect problems is greatest in no-till due to the larger amount of residue on the surface (31). New chemical controls are reducing

the hazards in this area and bringing about more acceptance of no-till.

Machinery cost is another advantage to the system of no-till. An 80 horsepower tractor is all that is necessary to farm 1,000 acres (36). Time spent in the field is also reduced, which reduces labor costs. Machinery and labor costs for 500- and 750-acre farms are given in Table 11, page 36.

Herbicides are costly in the no-till system--effectively, they make total costs per acre comparable to the costs of a chisel system (37). The disadvantage of depending totally on herbicides is that they must be managed properly--there is only one chance to do it right. Improper herbicide application costs money!

Research in no-till for small grains is currently in progress at the K. S. U. Fort Hays Experiment Station. It may well be that some day no-till will be as standard as the moldboard plow once was in the past. At present, however, there is still a need for some form of primary and secondary tillage when rotating to small grain or meadow crops. Crop rotations from row crop to small grains or meadow require that the soil be tilled and a seedbed prepared. Lime and some fertilizers must be periodically worked into the soil for good soil maintenance. Here is the place for a chisel and a disk in a primarily otherwise no-till system.

SUMMARY OF THE BENEFITS FOR USING A CHISEL PLOW VS. THE MOLDBOARD

The chisel plow has several advantages over the moldboard plow. With the chisel, 1.6 to 2 times the amount of acres can be prepared in a given time as with the moldboard, all conditions being equal. This means that less hours are required from the tractor engine and the operator for chiseling. More acres per hour with a chisel allows for more acres to be worked at an optimum soil moisture content; less energy in horsepower hours per acre; and a savings of fuel and dollars.

Chisel plowed fields have rougher soil surfaces and more surface residue which increases infiltration and reduces runoff, soil loss, and nutrient loss. Not only are these good conservation aspects, but they also reduce costs by reducing the amount of fertilizer required to maintain soil fertility and by storing more water in the soil profile for optimum yields.

Chisel plows have a lower initial cost and a lower repair cost than the moldboard. With lower fixed and variable costs and comparable yields, a system using the chisel plow will have higher potential for net profit than one using a moldboard plow.

Chisel plows, like moldboards, can be equipped with several attachments to accomplish different objectives. One benefit of a chisel over a moldboard is that a chisel may be used for secondary tillage. This may be accomplished by using sweeps and a tine harrow.

Chisels are simple to set and easy to maintain. They require no setting of tractor wheels and need no headlands. Fields can be chiseled in any direction when slope is negligible. This often saves time, especially in odd-shaped fields.

The use of the chisel plow is favored in many areas of the Corn Belt by providing reduced erosion potential, reduced costs and comparable yields with the moldboard plow. With proper management, producers can benefit from the use of a chisel plow.

SUGGESTIONS FOR FUTURE RESEARCH

Further research needs to be done to determine the proper depth of tillage for various soil and climatic conditions. In conjunction with this, the effect of tillage, tillage depth, soil organic matter and soil moisture content on soil compaction, and the depth of compaction, should be resolved.

Another area that needs further research is the use of the chisel vs. the moldboard plow. In this area, data for a chisel equipped with straight or twisted points, with and without coulters, should be taken in the same soil, as with a moldboard plow. The following information should be collected and analyzed on an initial and long-term basis: draft, depth, surface roughness, residue coverage, infiltration, runoff water, sediment loss, organic matter, soil strength, soil oxygen content, compaction of the soil, depth of compaction, acres per hour, and gallons of fuel per acre.

REFERENCES

1. Wittmuss, H. D., G. B. Triplett, Jr., and B. W. Greb. 1976. Concepts of conservation tillage systems using surface mulches. Conservation Tillage: The Proc. of a Nat. Conf., Soil Conservation Soc. of America, Ankeny, Iowa.

2. Oschwald, W. R. and J. C. Seimens. 1976. Conservation tillage: A perspective. University of Illinois. Agronomy Facts. SM-30.

3. Terminology and definitions for soil tillage and soil-tool relationships. 1975. ASAE Yearbook.

4. Bowers, Wendell. 1975. Machinery management. Fundamentals of machine operation. Deer & Co., Moline, Ill., pp. 28, 44, 46, 91.

5. Williams, D. L. 1976. Data for primary tillage tools used at a tillage field day, April 28, 1976, Joice, Iowa.

6. Oschwald, William R. Chisel plow and strip tillage systems. Conservation Tillage: The Proc. of a Nat. Conf., Soil Conservation Society of America, 1973, Ankeny, Iowa.

7. Gerard, C. J. and W. R. Cowley. Nov. 1964. Hidden hardpans steal profits. Crops and Soils, pp. 11-12.

8. Larson, W. E. Dec. 1972. Tillage during the past 25 years. Crops and Soils, pp. 5-6.

9. Raney, W. A. and A. W. Zingg. 1957. Principles of tillage. Soil: the yearbook of agriculture. U. S. Dept. of Agr., pp. 277-281.

10. Larson, W. E. and James Swan. March, 1970. Tillage of wet and dry soils. Crops and Soils, March '70, pp. 8-9.

11. Gill, William R. 1971. Economic assessment of soil compaction. Compaction of agricultural soils. St. Joseph, Michigan, American Soc. of Agricultural Engineers, pp. 431-458.

12. Thompson, Louis M. and Fredrick R. Troeh. 1973. Land use and soil management. Soils and soil fertility, 3rd ed., pp. 416-418.

13. Schrock, Mark D. and Stanley J. Clark. 1976. Getting the most from your tractor. Coop. Ext. Ser., Kansas State University. FM-14.

14. Cooper, A. W. 1971. Effects of tillage on soil compaction. Compaction of agricultural soils. St. Joseph, Michigan, American Soc. of Agricultural Engineers, pp. 315-367.

15. Tillage and Energy Survey. 1975. State of Illinois.

16. Reicosky, D. C., R. B. Campbell and C. W. Doty. 1976. Corn plant water stress as influenced by chiseling, irrigation, and water table depth. Agron. J. 68: 499-503.

17. Hobbs, J. A., R. B. Herring, D. E. Peaslee, W. W. Harris, and G. E. Fairbanks. 1961. Deep tillage effects on soils and crops. Agron. J. 53: 313-316.

18. Larson, W. E., W. G. Lovely and V. C. Jamison. 1961. Subsoiling doesn't pay in the midwest. Iowa Farm Science. College of Agr. Exp. Station Ext. Service, Iowa State University of Sci. and Tech., 15 (7): 5-6.

19. McKibben, J. S. and F. D. Whitaker. 1973. Tilling various soil zones affects corn yields. Transactions of the ASAE 16 (3): 404-406.

20. Larson, W. E. April-May 1967. Tillage: enough is enough. Crops and Soils, pp. 12-13.

21. Mannering, J. V., D. R. Griffith and C. B. Richey. 1975. Tillage for moisture conservation. Chicago, Illinois, ASAE Paper #75-2523.

22. Willis, W. O. and J. J. Bond. 1971. Soil water evaporation: reduced by simulated tillage. Soil Sci. Soc. Amer. Proc. 35: 526-529.

23. Larson, W. E. 1964. Soil parameters for evaluating tillage needs and operations. Soil Sci. Soc. Proc., pp. 118-122.

24. Burwell, R. E., L. L. Sloneker and W. W. Nelson. 1968. Tillage influences water intake. Journal of Soil and Water Cons., 23 (5).

25. Mannering, J. V., D. R. Griffith and C. B. Johnson. Tillage and simulated rainfall studies. Supplied by author, J. V. Mannering.

26. Heinemann, H. G. and F. D. Whitaker. 1974. Soil cover governs soil loss on United States claypan soil. Proc. of the Paris Symposium. Sept., 1974, AISH Publ. No. 113.

27. Fenster, C. R. and C. A. Wicks. 1976. Minimum tillage systems reduce wind erosion. University of Nebraska, ASAE Paper #76-2032.

28. Griffith, D. R., J. V. Mannering, C. B. Richey. 1976. Energy requirements and areas of adaptation for eight tillage-planting systems for corn. Paper supplied by J. V. Mannering.

29. Wiese, A. F. and D. W. Staniforth. 1973. Weed control in conservation tillage. Conservation Tillage: The Proc. of a Nat. Conf., pp. 108-114.

30. Erbach, Donald C., W. G. Lovely. 1974. Weed control with conservation tillage production of corn and soybeans. J. Soil and Water Cons., Jan.-Feb., 1974, pp. 44-45.

31. Musick, G. J. and H. B. Petty. 1973. Insect control in conservation tillage systems. Conservation Tillage: The Proc. of a Nat. Conf., pp. 120-125.

32. Zoz, Frank M. 1974. Optimum width and speed for least cost tillage. Transactions of the ASAE, pp. 845-850.

33. Clark, Stanley Jr. Energy requirements for various tillage systems.

34. Schrock, Mark and various Kansas farmer and dealers, 1976. Information on the life of chisel points and moldboard shares. (Private communications).

35. Plow shares and related items net price list and Wiese chisel spikes and related items net price list. 1976. Wiese Corporation. 1501 Fifth St. Perry, Iowa.

36. Schlender, John R. and Leo Figurski. 1976. Custom rates for tillage and planting operations and fertilizer and pesticide applications. Farm Management Guide. July 1976. MF-253. Coop. Ext. Ser., K. S. U.

37. Siemens, John C. 1975. Machinery related costs for tillage alternatives. Paper supplied by author.

APPENDICES

Appendix A. Provisions for Internship

SUBJECT: Krause Plow Corporation and Kansas State University Cooperative Graduate Thesis Program

Student: John Ferdinand, Graduate Student
Agricultural Mechanization

Professor in Charge: Stanley Clark, Agricultural Engineering Department

Krause Directors: Virgil Smith, Sales Manager
Floyd Barkman, Merchandising Coordinator

Project:

Determine the benefits of chisel plowing versus moldboard plowing, with emphasis on use in the Corn Belt area. This should be written with the goal of using it as a special sales booklet for Krause customers and dealers.

1. The following is a sample of information to be included and should be the latest information available.

   a. Residue coverage comparison.

   b. Soil sediment loss comparison. (water and wind erosion)

   c. Power consumption comparison.

   d. Soil compaction comparison.

   e. Crop yields comparison.

   f. What other tillage tools would be used in conjunction with the chisel plow and why. (Disc Harrows, Field Cultivators, etc.)

   g. Chisel attachments to be used in specific areas and why. (Stalk-slicer, tine harrow, etc.)

   h. Cost or investment and upkeep comparisons.

   i. Depth of operation comparisons.

   j. Define the meanings of conservation tillage, minimum tillage and no-tillage.

   k. etc.

2. This project will be carried out during the months of June and August of 1976. A written report and all materials used for reference are to be delivered to Krause no later than September 24, 1976.

3. Krause will pay Mr. Ferdinand $500.00 per month for a total of $1,000.00 to complete the project. Krause will also pay travel expenses as directed by the company. This will include mileage, meals, and lodging. Special supplies would also be paid by the Company such as film for pictures and xeroxing of material for the Krause files.

4. Mr. Ferdinand will coordinate his efforts by staying in contact with Floyd Barkman at Krause Plow Corporation and Professor Stanley Clark at Kansas State University.

5. Mr. Ferdinand will be expected to derive information from the Agricultural Department at Kansas State University and other land grant universities. He may also be asked to personally contact farmers, dealers, or companies that have information that would be helpful in this special project.

6. Krause Plow Corporation is under no future obligation to Mr. Ferdinand beyond this project; likewise, neither is Mr. Ferdinand under any obligation to Krause Plow Corporation beyond this project.

Krause Plow Corporation

KANSAS STATE UNIVERSITY

Department of Agricultural Engineering
Seaton Hall
Manhattan, Kansas 66506
Phone: 913 532-5580

August 3, 1976

Dear Mr.

I would appreciate your help! I am doing research at Kansas State University, Manhattan, Kansas on tillage systems in the cornbelt. I would appreciate your answers and comments to the questions below and on the following page. A self-addressed, postpaid envelope has been enclosed for your convenience. I'll be waiting to hear your comments.

Respectfully yours,

John Ferdinand
Agricultural Mechanization Student
Kansas State University

Name (Optional)_____ State_____ County_____

Farm Size: ☐ up to 250 ☐ 250-500 ☐ 500 up

Largest Tractor: PTO H.P._____ or Make and Model_____

What do you consider being the major primary tillage tool on your farm?

(moldboard plow, chisel plow, heavy disk, etc.)_____

Description of your major primary tillage tool:

MAKE (J-D, IHC, etc.)	SIZE (6-16, 15 ft., etc.)	FOR DISKS Tandem, Offset	Blade Dia. (20-28)	Notched or Smooth

Depth of operation of your major primary tillage tool: ____ inches

Reason(s) for this depth: Shallow or deep:_____

List in order the field operations you normally like to do from harvest to harvest. If any operations are combined, please show them that way. When using a chisel plow or a field cultivator, indicate what is mounted to the shank (straight points, twisted points, sweeps, etc.). Please list any attachments used with a tool--example: disk harrow with tine harrow.

1. _____
2. _____
3. _____
4. _____
5. _____
6. _____
7. _____
8. _____
9. _____
10. _____
11. _____
12. _____

When compared to a moldboard plow system in corn, do you think that a ☐ chisel system or a ☐ disk system (please check either chisel system or disk system) does the following:

	YES	NO	
1. Saves time?	___	___	
2. Saves fuel?	___	___	
3. Reduces costs?	___	___	
4. Affects yields?	___	___	If YES, increases or decreases? _____
5. Reduces erosion?	___	___	
6. Increases weed control problems?	___	___	

OTHER COMMENTS: (Please feel free to write any or all changes that you would like to see made in tillage machinery and any reasons for that change. Use back of sheet if necessary.)

Appendix B. (continued)

Summary of the Results of the Survey

The surveys were sent at random from a list of producers' names obtained from the county extension agent in their county. 88% of the 83 surveys sent were completed and returned. The majority of the persons completing the survey (90%) reported using a chisel and disk system for their primary tillage. The remaining 10% reported using a moldboard plow. Those using the chisel or disk system agreed that they saved time, fuel and reduced costs. Most felt that there was no significant difference in yields over the moldboard system, but that there was an increased need for better weed control.

Those reporting the use of a moldboard used it mainly on corn ground to plow down stalks and fertilizer. Often they used only a chisel or a disk on soybean ground.

Most farmers reported tilling deep with the idea that it was necessary to break hardpans or to optimize soil water content (storage in dry years and drainage in wet years).

99% of those reporting used reduced amounts of tillage as compared to conventional tillage systems. This is a good indication that producers realize that they can produce an equal crop yield with lesser amounts of energy and labor than formerly thought necessary.

USE OF A CHISEL PLOW IN THE CORN BELT VS. THE MOLDBOARD

by

JOHN E. FERDINAND

B. S., Emporia Kansas State College, 1974

AN ABSTRACT OF A MASTER'S REPORT

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE
AGRICULTURAL MECHANIZATION

Department of Agricultural Engineering

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1977

ABSTRACT

The purpose of this report is to provide information to farm managers and machinery manufacturers on tillage in the Corn Belt. Basic principles of this information are applicable to other areas.

Tillage should provide for good infiltration of water, minimize and slow runoff, and decrease erosive potential by: maintaining soil organic matter; providing a rough porous surface at right angles to the slope; and leaving residue anchored in and lying on the soil surface. Moldboards leave little residue in and on the soil surface, allowing more raindrop erosion and aggregate breakdown, which results in crusting, decreased infiltration, and increased erosion from excessive runoff. Runoff, soil losses, and nutrient losses are greater for moldboard plowed fields than for the chisel plowed fields when soil and slope conditions are the same. The major difference is that the chisel leaves a rougher soil surface and more surface residue.

In most areas of the Corn Belt, depth of tillage is not as critical to the increase of infiltration and reduction of runoff and erosion as residue placement and surface roughness. In areas where the annual rainfall is not low and highly intense, deep tillage (below 10" deep) will improve permeability of soils, only if there is a dense layer present and only as long as the surface is left undisturbed. Further tillage operations on deep-tilled soil eliminate any previous benefits and may compact the soil to the deepest depth of tillage. In most of the Corn Belt, it is felt that deep tillage does not pay and is not necessary to break tillage pans because the soil freezes and thaws and also dries and cracks, breaking up most shallow tillage pans.

Tillage operations should be done when the soil is in the friable range (below the lower plastic limit and above the dry hard region). There are several reasons for this: first, compaction of the soil is eliminated; second, aggregate stability is good so that a fine granular structure does not result; third, dry hard clods are not produced; fourth, less abrasive wear occurs to the tillage tool because the soil is less abrasive than when dry; and fifth, less energy is required due to reduced draft (wetter soil is more adhesive, making it plastic or sticky, while dryer soil has a high cohesive force acting on its particles, making it hard).

With good management, crop yields on chisel plowed fields compare equally to or better than fields prepared by a moldboard. It is recognized that when using the chisel plow in place of the moldboard, there will be more insect and weed control problems. However, good pest control can be maintained by proper use of perticides. Water storage resulting from reduced runoff and evaporation and less nutrients lost by erosion are other benefits of using the chisel plow for optimum yield potential.

Initial machinery costs for the chisel are much lower than for a moldboard. Repair costs for the moldboard are much higher--80% of the initial cost for a moldboard versus 65% of the initial cost for repair of a chisel plow.

Chisels, when compared to moldboards, reduce machinery and energy costs and have a higher capacity in acres per hour, thereby reducing costs for tillage per acre. With less costs than for a moldboard plow and comparable yields, the chisel system will allow the producer more potential for net profit.

The chisel is a versatile tillage tool; many different attachments may be used with it to accomplish many different objectives. The use of

the chisel plow is favored in many areas of the Corn Belt by providing reduced erosion potential, reduced costs and comparable yields with the moldboard plow.