

1976

EC76-714 Conservation Production Systems for Row-Crops

D. E. Lane

Ron Gaddis

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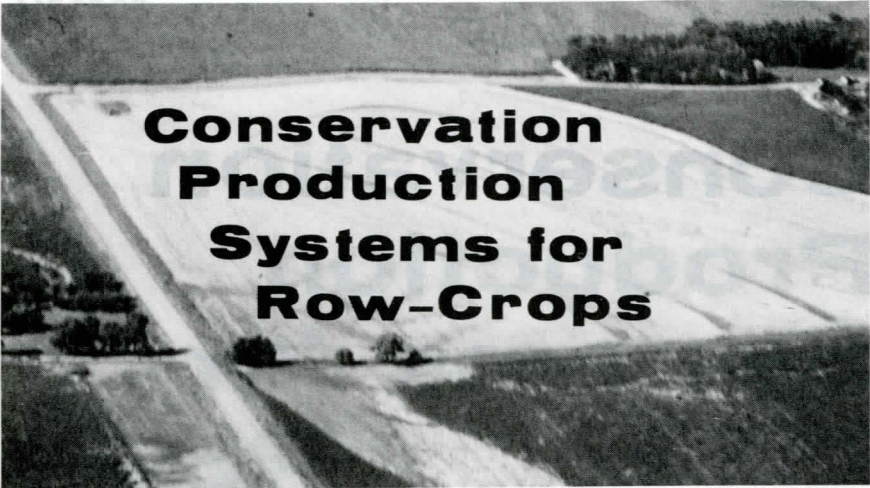
EC 76-714

Conservation Production Systems for Row- Crops



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Conservation Production Systems for Row-Crops

D. E. Lane
Extension Engineer (Power Machinery)
Ron Gaddis
Extension Engineer (Conservation)

INTRODUCTION

Conservation production systems involve managing surface residue to minimize soil erosion and water loss while maintaining or improving yields. Such systems feature:

1. Reduced number of tillage or soil stirring operations to protect the soil from wind and water erosion, conserve moisture from natural rainfall, improve soil physical properties through less soil compaction, save energy, and lower labor requirements.
2. More flexibility in timing field operations.
3. Lower production costs.

Reduction of tillage is the key feature of conservation production systems because disadvantages of tillage frequently exceed benefits. Many studies have shown that the main benefit from tillage has been weed control. Herbicides now give the farmer other choices.

Tillage is sometimes effective for breaking crusts to let seedlings emerge. In areas of surplus spring rainfall, farmers till the soil to dry out the surface and permit more timely planting.

CONSERVATION PRODUCTION SYSTEMS

Crop production systems and their variations in tillage requirements are shown in Table 1. One extreme is the maximum tillage conventional system involving plowing and several other tillage operations. The other extreme is a "no tillage" or absolute minimum tillage system which involves slot planting into a non-tilled surface or sod where a herbicide has been used to kill or set back competitive vegetation. Between these two extremes are several "reduced tillage methods."

Table 1. Crop production systems.

<i>Maximum tillage</i>	<i>Conservation production systems</i>				
	<i>Reduced Tillage</i>				<i>"No tillage" or absolute minimum tillage</i>
<i>Conventional</i>	<i>Chisel plant</i>	<i>Disk plant</i>	<i>Disk-list</i>	<i>Till plant</i>	<i>Slot or sod plant</i>
Disk Plow Disk Harrow Plant	Chisel Disk Plant	Disk twice Plant	Disk twice List	Chop or disk Till plant or List	Till plant or List Spray and plant or Spray plant

There are few areas where Nebraska farmers still practice maximum tillage. Most Nebraska farmers are included somewhere in the "reduced tillage" systems.

Till Plant System

Till planting can be accomplished with a lister if the lister is properly used.

In Nebraska the till plant system has been studied more than most conservation tillage and planting methods. It is used here as the basis of comparison for other systems.

The till plant system includes a sequence of field operations so that each operation makes the next easier and, at the same time, prepares for the next season. Till plant requires four operations:

Stalk cutting — Stalks are chopped in the spring two to three weeks before planting (Figure 1). Residue is moved into furrows between the rows.



Fig. 1

Planting — The seedbed is opened in the old row by a sweep (Figure 2). Seed, fertilizer, herbicide, and insecticide are placed with same machine. Residue is lightly covered with soil moved off the ridge.



Fig. 2

Cultivating — A cultivator is used as necessary to control weeds (Figure 3).



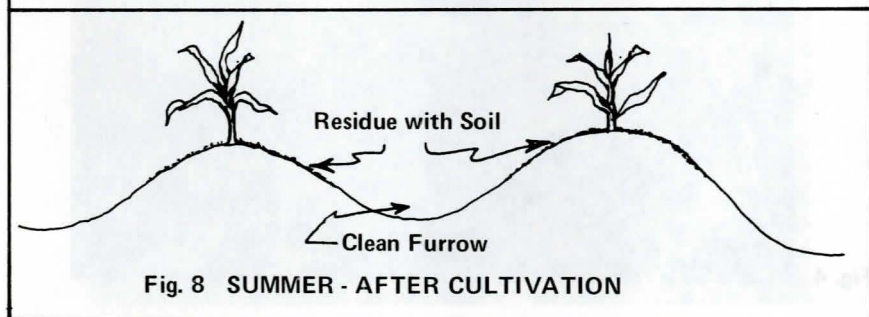
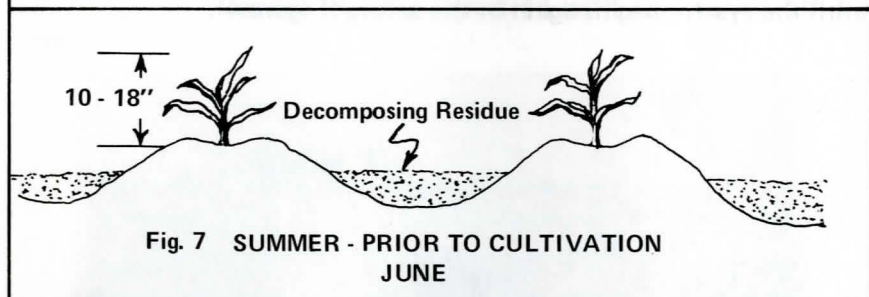
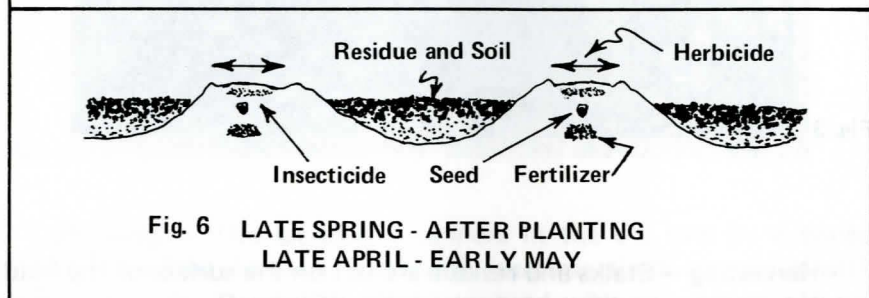
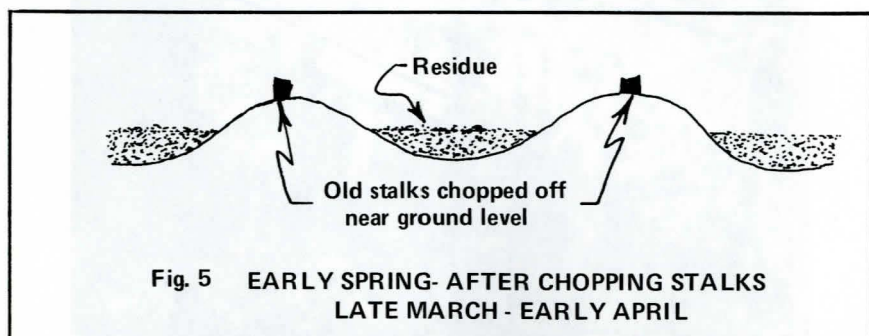
Fig. 3

Harvesting — Stalks and residue are left on the surface of the field until the system begins again in the spring (Figure 4).



Fig. 4

Since till planting, for best management, is a bed plant system, the rebuilding of seedbeds during the season is necessary. Figures 5-8 show the effects of the four operations on the seedbed.



Development of Till-plant System

Nebraska research on the till-plant system started in 1955. The first machine utilized a 36" sweep running 2-3 inches deep and a 20" sweep running 6-7 inches deep. The sweeps were followed by a treader and packer ahead of a conventional surface planter. From this evolved a compact machine with a sweep, trash guard, runner and planter unit, all mounted on a tool bar. The first machines had no flexibility between planter units which were run by gauge wheels. The present machine uses individually flexed unit planters, each driven by a coulter (Figures 9, 10). The coulter is also used for depth control and to cut through residue.



Fig. 9



Fig. 10

Certain basic principles evolved from the till plant research. They fall into three categories.

Reduced Tillage System Principles

1. Number of operations needed for crop production can be minimized with good management.
2. Minimum soil compaction in crop rows is achieved since tractor wheels follow the same track for each operation and never run over the row where the seed is planted.
3. Decayed organic matter (including the old plant root system), and freezing and thawing combined with wetting and drying keeps the soil granulated and friable.

Planting Principles

1. Planting seed on a residue free ridge (bed) provides a warm, well-drained seedbed.
2. Seed is pressed into firm, moist soil and is covered with loose soil.

Conservation Principles

1. Crop residues left on the surface control wind and water erosion.
2. Water intake and infiltration are improved because of an "open" soil surface.
3. An economic and energy advantage occurs as fewer operations and pieces of equipment are used. There is the possibility of using a smaller tractor (70 Hp max PTO).
4. Less labor is needed with more flexibility in use of labor.

Other Systems

Other relatively effective and successful systems, some utilizing conventional tillage equipment, are:

Disk and Plant System

Usually more disking is done than is necessary. A light disking on the same day of planting and use of herbicide pre-plant or pre-emergence would do as well as several diskings. The best seedbed in this system is in the old row.

Chisel and Plant System

Many farmers chisel in the fall as chiseling roughens the soil surface. They disk in the spring before planting. Shallow chiseling in the spring also leaves the soil roughened, but seed can still be placed on firm soil below. Residues are mostly on the surface and may reduce effectiveness of herbicides.

Bed Planting System

Bed forming and planting are done in one operation. Residues are in the bed and the seed rows are placed on the side of the bed in firm soil. Herbicides are broadcast for weed control (assuming herbicide control). No cultivation or hilling is needed as irrigation furrows are formed in the planting operation.

Listing System

Listing forms ridges between the planted rows. Deep listing places seed in cooler soil. All water is channeled into the seed row. Residues are placed in the ridge and covered.

Slot Planting System

Slot planting is similar to conventional planting in the type of planter used. The slot planter is heavier so it will penetrate in grass, legumes, or old stalk residues (Figures 11, 12).

Slot planting in grass or legume places the seed in a slot opened in the growing cover crop which is killed by spraying either before planting time or at planting time.

Slot planting in old stalk residues places the seed in the zone of the root system of the previous crop. A preplant chopping or disking operation, if necessary, is used to reduce residues in the old row and break up the crown of the old plant.

Slot planting can be used to plant in grass or residues of the previous crop on either irrigated or non-irrigated land. On dryland, all of the grass must be killed for a successful crop. With either type of farming, the grass competition must be stopped at planting time so plants can become established.

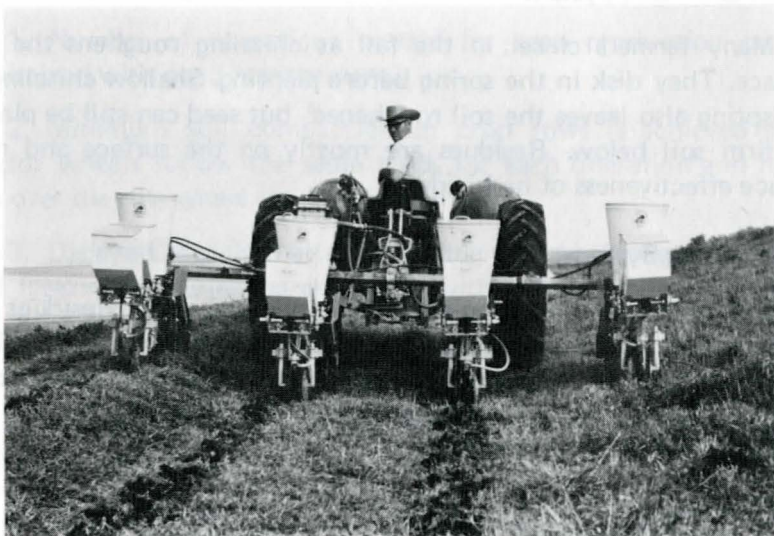


Fig. 11

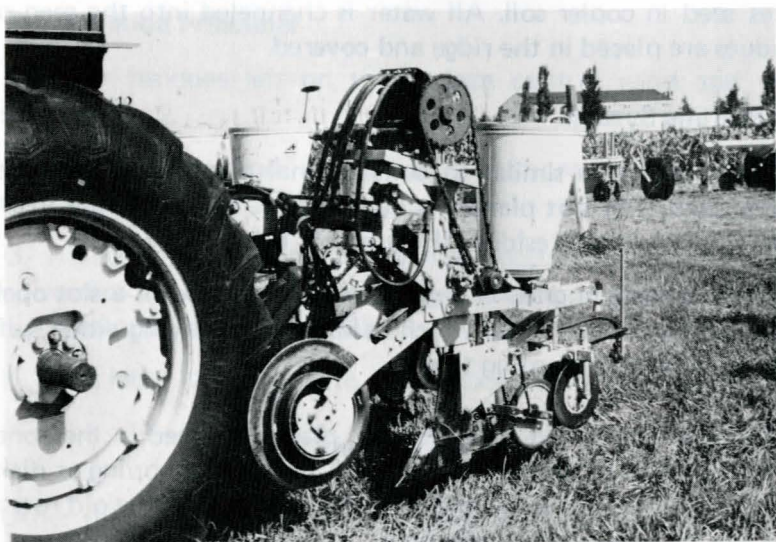


Fig. 12

Each of these systems can reduce the number of operations used in raising a crop. Those that bury the greatest amount of residue will result in the most soil erosion both by wind and water. Planting through surface residues or deeper as in listing will place seed in cooler soil and reduce the rate of germination and early growth.

CONSERVATION TILLAGE BENEFITS

Conservation tillage has advantages in net returns from yield, labor and time saving, energy saving, soil and water conservation, and water retention and use.

Yield

Yield data from plots through the state are similar to yield data from other states. Long term yields of maximum (conventional) tillage and till planting are not significantly different. In Nebraska, the 10-year average yield is 119 bushels per acre for maximum tillage and 121 bushels per acre for till plant.

Yields, when compared on a yearly basis, may not be the same. In moderately dry years, conservation tillage has produced more and in wet years maximum tillage has produced more.

Energy Requirements

Elimination of any trip across the field will save energy. Some tillage operations (Table 2) require much energy. These are the best ones to eliminate. One of the highest energy field operations is use of the moldboard plow. The use of a plow must be supplemented by other operations such as disking and harrowing to prepare the seedbed for the surface planter. The overall effects on energy requirements are seen in Figure 13, which compares the methods of till-plant and slot-plant with the maximum tillage method.

Table 2. Energy requirements for various tillage operations.

<i>Machinery data</i>			
	<i>hp/hr/ac</i>		<i>hp/hr/ac</i>
Chop stalks	10.0	Harrow	5.5
One-way	8.7	Drill	4.5
Sweep plow	4.6	Plant, surface	4.0
Chisel plow	14.5	Till plant	4.0
Moldboard plow	19.0	List	6.7
Disk	5.5	Cultivate	3.3
Field cultivate	9.5	Spray	1.0
Rodweed	2.6	Combine	8.6

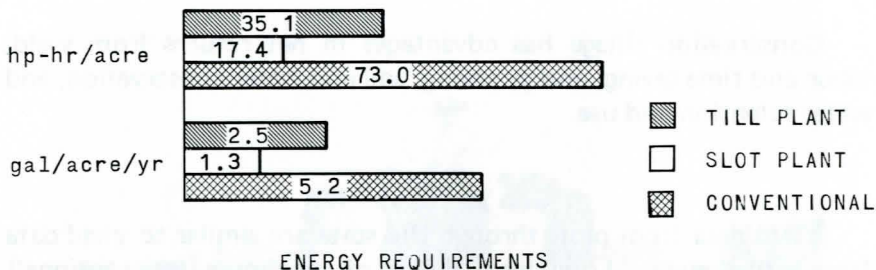


Fig. 13

Included in the till plant and slot plant systems is the high energy operation of stalk shredding. Many times stalk shredding can be eliminated by using a disk, about one inch deep, traveling along the rows. This cleans the top of the ridge for planting.

Cultivation that does not break a crust or kill weeds wastes energy. As long as the soil is open to air and water, there is no need to cultivate to break a crust. Unnecessary cultivation stirs the soil uselessly and causes loss of soil moisture.

Labor Requirements and Labor Use

The fewer trips across a field the fewer hours of labor are required unless more time is required to do the operations retained or substituted. Conservation tillage operations are not slower. Since fewer are performed, much labor is saved in field operations (Figure 14).

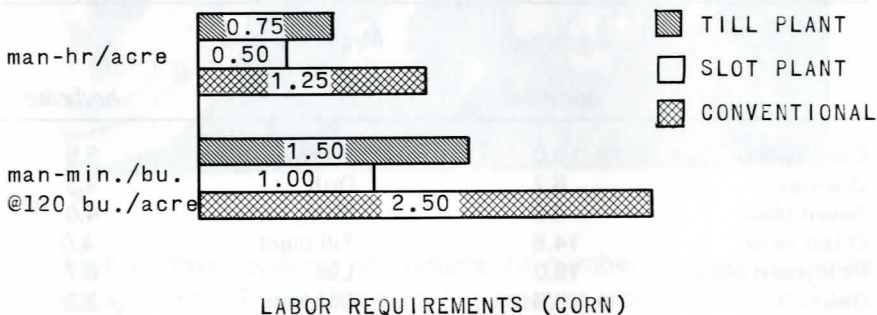


Fig. 14

Scheduling

For any given tillage and planting system the field operations should not interfere with following operations. If this does occur, there can be production losses. Planning and scheduling the operations can eliminate much of the interference.

Many factors affect the timing of operations but weather and type of tillage and planting system are the major considerations.

Weather is one factor that causes the time required to plant a given number of acres to vary from year to year. Figure 15 shows that some years, because of weather, the time required to plant with a particular planter is about three times longer than in other years.

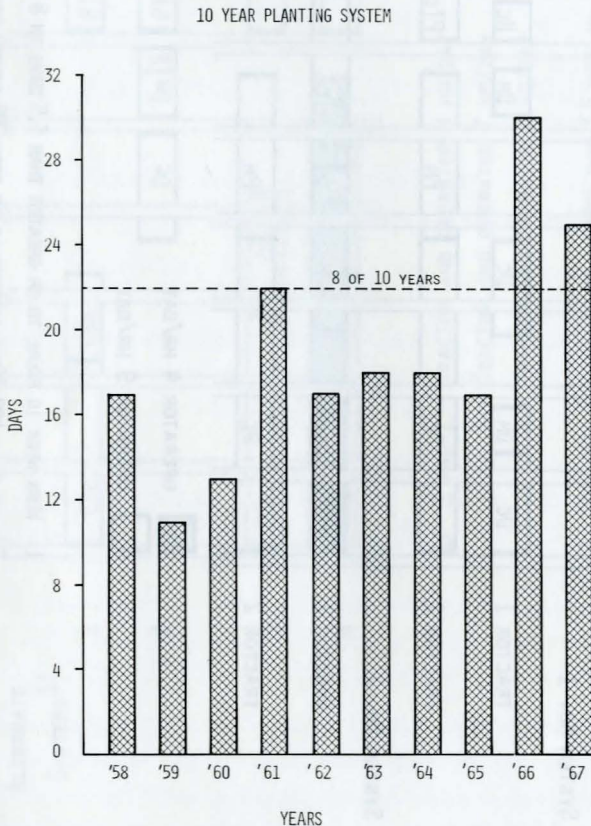
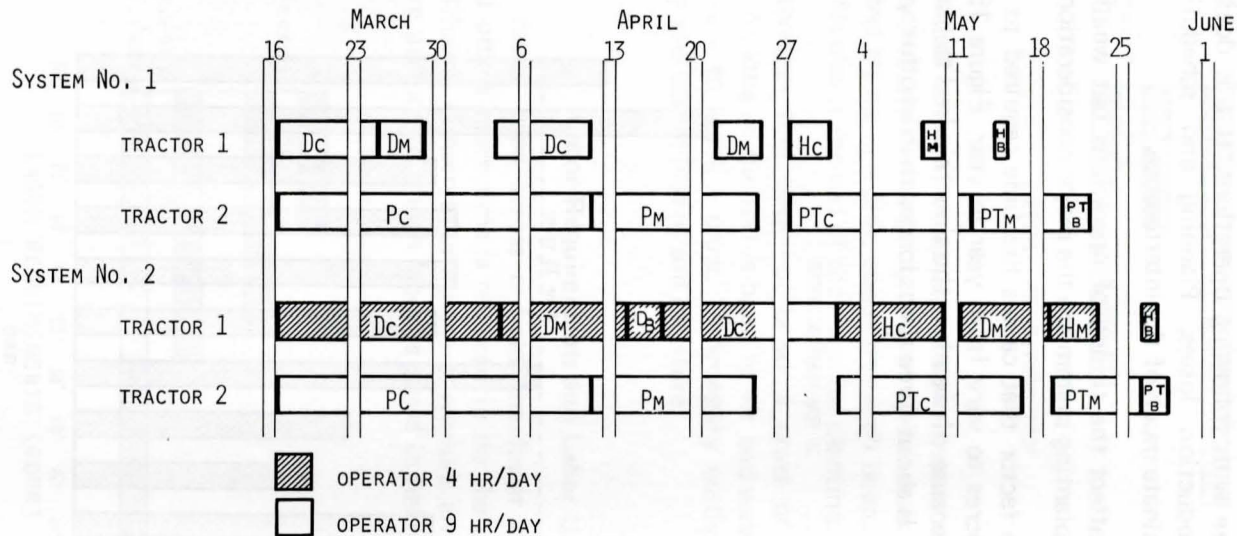


Fig. 15

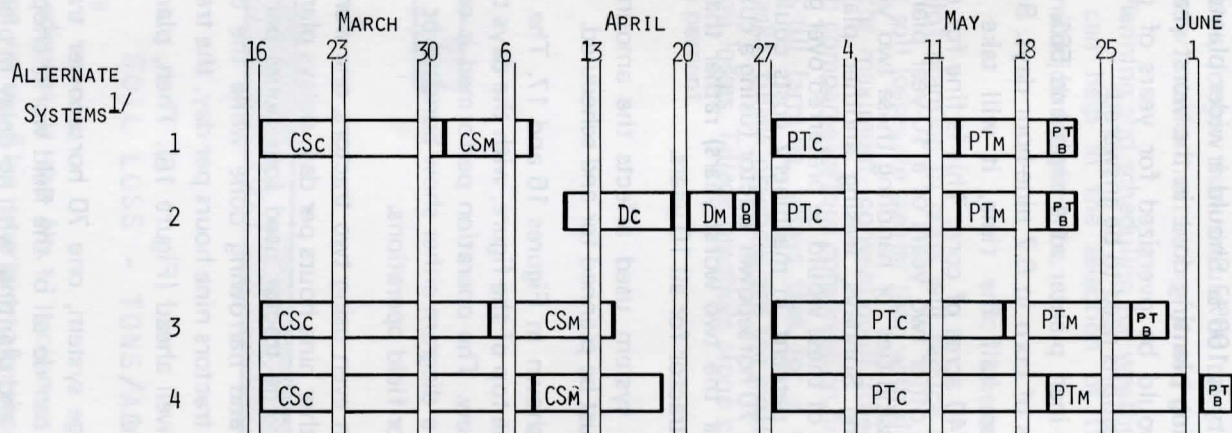
CLEAN TILLAGE SPRING MACHINERY SCHEDULING



1. WORK WEEK IS EQUAL TO OR GREATER THAN 3.5 DAYS IN 8 OF 10 YEARS,
BASED ON 480 ACRES CONSISTING OF CORN-240 ACRES, MILO-120 ACRES,
SOYBEANS-40 ACRES, AND HAY-80 ACRES.

D - DISK C - CORN
P - PLOW M - MILO
H - HARROW B - BEANS
PT - PLANT

CONSERVATION TILLAGE SPRING MACHINERY SCHEDULING



- ^{1/} 1 AND 2 - TRACTOR AND OPERATOR 9 HR/DAY
3 - TRACTOR AND OPERATOR 7 HR/DAY
4 - TRACTOR AND OPERATOR 6 HR/DAY

1. WORK WEEK IS EQUAL TO OR GREATER THAN 3.5 DAYS IN 8 OF 10 YEARS, BASED ON 480 ACRES CONSISTING OF CORN-240 ACRES, MILO-120 ACRES, SOYBEANS-40 ACRES, AND HAY-80 ACRES,

D - DISK
CS - CHOP STALKS
PT - PLANT
C - CORN
M - MILO
B - BEANS

Considering the variation in time required to plant, how many days should be scheduled for planting? Will the schedule be set so that the completion probability is 100%? Should a wider planter be used so the certainty of getting planting done in the worst years is 100%? If so, the planter would be oversized for years of good planting conditions. These questions need to be answered.

For example, a 6-row 30-inch planter at 4 mph and 56% field efficiency can plant 240 acres of corn in 6.7 nine-hour days. But if weather delays the operation half the time, it will take 13.4 nine-hour days to plant the 240 acres of corn. This is fine for eight years but is too long for the other two years of a 10-year planting system. There are several possibilities for handling these two years: working longer days, working Sundays, leasing another planter, hiring a custom operator. Any of these would be preferred over going to an 8-row planter. Eleven percent in machinery costs could be saved by using a 6-row with a 70 horsepower tractor (using a custom operator for half the corn for the two worst years) rather than an 8-row with a 100 horsepower tractor for all 10 years.

The tillage and planting system used affects the amount of equipment used and how it must be planned for and scheduled.

Scheduling diagrams are shown in Figures 16 and 17. The days and weeks are shown across the top of the figure, with the days to do an operation blocked out below. The operation performed is coded in the block. Blank spaces in a diagram either show Sundays or days when the tractor is not used for field operations.

A maximum tillage system even using two tractors, one working four hours per day and the other nine hours per day, delays planting by several days (Figure 16). The tractor used four hours per day can't get all of the disking and harrowing done while the other tractor is plowing. Using two tractors nine hours per day, the tractor disking and harrowing keeps well ahead (Figure 16). Then, planting can start on the scheduled date.

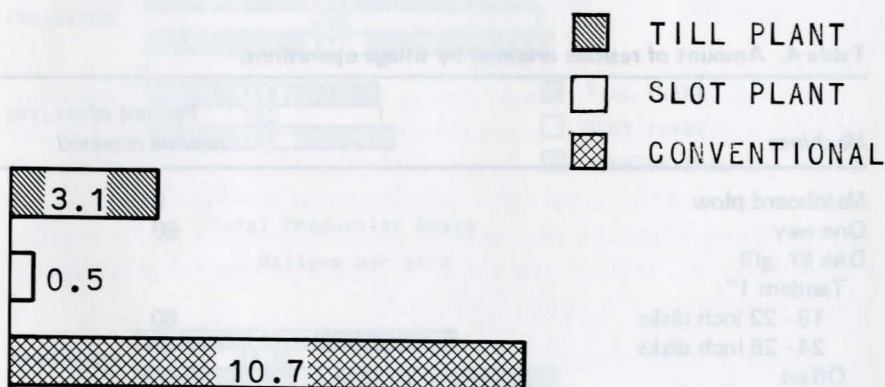
With a conservation tillage system, one 70 horsepower tractor working nine hours per day can do all of the field work; chopping stalks and planting, or disking and planting, with no delay in planting dates (Figure 17). With this system there is time for other farm chores. The tractor could be used fewer hours per day, still without a

delay in planting date, but planting would take longer. Working 7 hours per day, it takes 17 days to plant corn and for 6 hours per day, 22 days, longer than should be taken but perhaps more feasible if other farm tasks must be performed during the planting season.

Planning and scheduling for weather is a good management tool that can help in the selection of the cropping system and can minimize job interference.

Soil Losses

Slot planting in grass will reduce soil losses to a minimum. Till plant soil losses are greater than with slot plant but are about 1/3 the loss for maximum (conventional) tilled fields (Figure 18). Table 3, which compares various conservation practices to "up and down hill" clean till farming, shows that for a typical corn farm in eastern Nebraska, tillage practices are the most influential factor in eliminating soil losses. Tillage practices alone can reduce soil losses as much as 90 percent.



SOIL LOSS - TONS/ACRE

Fig. 18

Sediment is the No. 1 pollutant (by volume) of Nebraska's surface waters. This is certain to be the object of increased attention. Often overlooked is the fact that soil loss usually means fertilizer dollars lost as well.

Table 3. Typical potential reductions in soil losses.

Terracing	50%
Contour farming	50%
Terracing & contour farming	75%
Tillage practices	90%
All	97.5%

The moldboard plow, in turning the soil completely, also buries the residue (Table 4). The amount of residue buried by other tillage operations is also shown. A single disking retains 60%. Double disking leaves 36% of the original residue.

Table 4. Amount of residue retained by tillage operations.

<i>Machines</i>	<i>Percent of residue retained</i>
Moldboard plow	0
One way	60
Disk	
Tandem 1"	
18 - 22 inch disks	60
24 - 26 inch disks	50
Offset	
18 - 22 inch disks	60
24 - 26 inch disks	50
Chisel plow	75
Mulch treader	75 - 80
Sweep 30 inch or larger	90
Rodweeder	90 - 95
Slot planter	100
Till planter, 3 inches deep on ridge	80

Water Intake and Infiltration

Water intake rate of till plant fields is increased. More rainfall or irrigation water can enter the soil in less time. Water moves more easily into the soil where it can be retained for plant use. With reduced stirring of the soil and better intake, more of the rainfall before planting time is stored.

Economic Returns

Costs of agricultural production have been increasing rapidly. When land, water, seed, fertilizer, insecticide, hauling, drying and storage costs are included, about \$10 per acre on dryland or irrigated corn can be saved with conservation tillage (Figure 19). This is a small percent of production cost but on 400 acres can amount to \$4,000 per year. Operational costs are shown (Figure 20), for comparison of various tillage and planting systems. Herbicide costs are on the basis of the same rates per acre but broadcast for conventional tillage and banded for till plant.

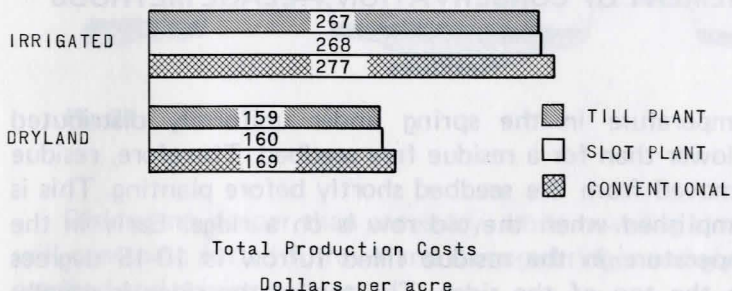


Fig. 19

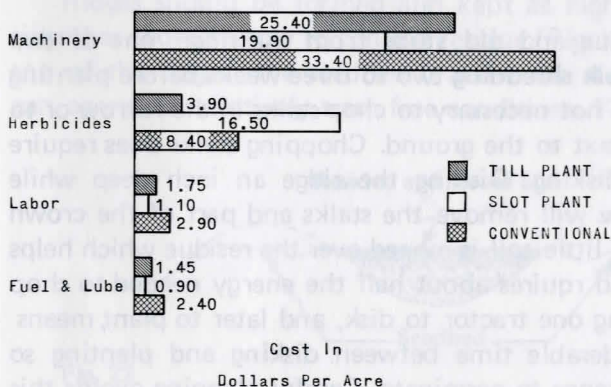


Fig. 20

CROPS AND CONSERVATION TILLAGE

Conservation tillage methods can be adapted to corn, milo, soybeans, and sugar beets. Also, with proper management, the methods can be used in crop rotations.

Corn and milo have been planted directly in legumes and native grasses. The legume or grass is killed with a herbicide either before or as the field is planted with either the slot planter, the no-till planter or the till planter. After the crop has been established, in following years, either the slot plant or no-till with no cultivation or till plant with cultivation can be used.

Care must be taken with slot, no-till or till plant systems so that herbicide residues do not affect the next crop in the rotation. The till plant system is fine for row crops in the rotation but some tillage may be needed to level the seedbed when converting from row crop to legumes or small grain.

MANAGEMENT OF CONSERVATION TILLAGE METHODS

Residues

Soil temperature in the spring under uniformly distributed residues is lower than for a residue free seedbed. Therefore, residue should be moved from the seedbed shortly before planting. This is easily accomplished when the old row is on a ridge. Early in the spring, temperature in the residue filled furrow is 10-15 degrees cooler than the top of the ridge. The top of the ridge is usually within one degree of a clean tilled seedbed.

To remove residue and old stubs from the ridge, one of two methods are used; stalk shredding two to three weeks before planting or *light* disking. It is not necessary to chop stalks in the furrow or to chop the stubs off next to the ground. Chopping stalks does require more energy than disking. Disking the ridge an inch deep while driving in the furrow will remove the stalks and part of the crown from the seedbed. A little soil is moved over the residue which helps it decay. This method requires about half the energy needed to chop stalks. However, using one tractor to disk, and later to plant, means there will be considerable time between disking and planting so weeds will have a chance to germinate. Careful planning avoids this problem.

Ridges or Beds

The ridges for row crop culture with till plant or bed plant are built and rebuilt by the operations during the season. With normal fall conditions ridges will be in good shape for the next season. Certain practices and field conditions cause damage to the ridges so some off season maintenance may be required. Combining or forage harvesting under wet conditions can tear down the ridges or ruin the contour of the furrow. Cattle trails across ridges can cause depressions in the ridges and planter skips can result. When these situations occur, it is necessary to either rebuild the ridge or knock it down a little so the seedbed is uniform.

Ridges can be rebuilt before planting with the cultivator. A cultivator may be set to give a contour as shown in Figure 21. The seedbed has not been disturbed but soil has been moved from the side of the ridge to cover residue and to give a uniform surface on which to drive.



Fig. 21

Disking no deeper than necessary, while traveling along the rows, will overcome rutted furrows and damaged ridges and give a uniform seedbed and driving surface.

Ridges should be formed and kept as high as possible. A high ridge has more furrow to contain residue (Figure 22). By planting on top of the ridges, the seedbed is above the residue and the planter can operate in relatively trash free conditions. The seedbed should be

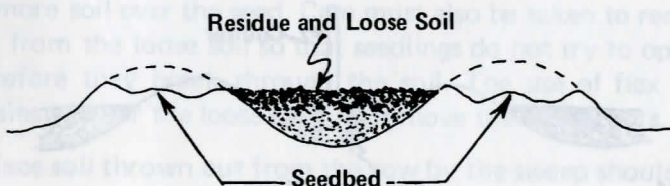


Fig. 22

high enough that a slight depression is left between the rows after planting so water from hard rains is not channeled into the seedbed. In wet, heavy soil, high ridges offer a better possibility of having a well-drained seedbed.

Fertilization

Fertilizers may be applied preplant, during planting, postplant, or sidedress. The total amount of fertilizer applied need be no greater for conservation tillage systems than for conventional tillage. However, a starter is more necessary with conservation tillage as nitrogen fertilizer may be tied up in residue decomposition during the early part of the season.

Anhydrous ammonia applied preplant may be placed on the side of the ridge or in the furrow.

When placed on the side of the ridge, the knife runs in a fairly clean area so coulters are not necessary to cut through the residue. The knives do need to be placed on opposite sides of the ridges to keep the machine balanced (Figure 23).

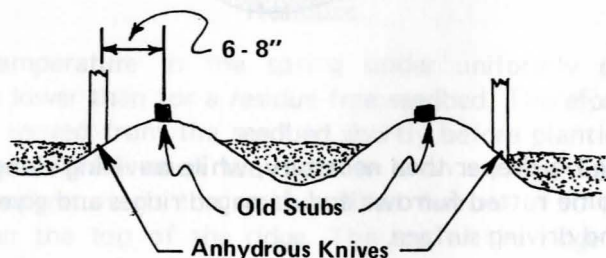


Fig. 23

When placed in the bottom of the furrow, a coulters is needed to cut through the residue ahead of the anhydrous knife (Figure 24).

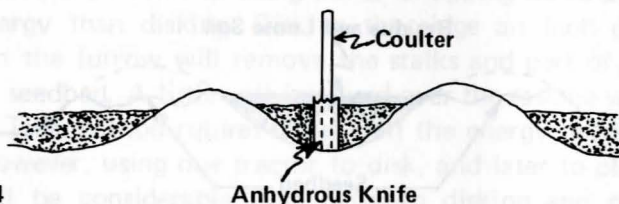


Fig. 24

Liquid starter fertilizer works well. Place the liquid $\frac{3}{4}$ to 1 inch deeper than the seed. Up to 20 pounds per acre of soluble nutrients that absorb water have been placed below the seed without stand reduction. A high concentration of these nutrients below the seed can cause germination problems. For example, 100 pounds of 10-20-0 is equivalent to 100 pounds of 5-20-5 in soluble nutrients which can dehydrate the seed.

Fertilizers applied as sidedress are handled much the same as when applied on a clean tilled field.

Planting

The till planter is designed to make a flat-bottomed seedbed. The seed is dropped on this flat, firm surface directly ahead of a seed press wheel which presses it into the firm moist soil. The seed is covered with loose soil.

The sweep should run deep enough to get into moist soil and allow the seed to be covered with moist soil. As a result, the depth of the sweep will vary from year to year. In dry years planting would be deeper than in normal or wet years.

The planter should run level from front to rear for uniform seed placement as well as good operation of press wheels and covering disks. If tipped forward, the press wheel will pull some seed to the surface and the rest of the seed is poorly placed. If tipped back, planter rides on the heel of the runner and will not run at a uniform depth.

The seed press wheel should have good pressure on the soil. The rubber tire must flex in wet sticky conditions or it will carry seed up to the surface.

Without press wheels on the planter, covering disks should be set to put more soil over the seed. Care must also be taken to remove air pockets from the loose soil so that seedlings do not try to open their leaves before they break through the soil. The use of flex tines or drag chains will stir the loose soil and remove the air pockets.

Surface soil thrown out from the row by the sweep should not be pulled back to cover the seeds as this soil contains germinating weed

seeds. In wet heavy soil, moving soil out can be a problem as well as getting enough soil to cover the seed. Usually this can be handled by adjusting the covering disks. The use of a soil agitator on the bottom of the planter runner (Figure 25) will help loosen soil which fills the runner mark after the liquid fertilizer is dropped, but ahead of the seed tube. This loose soil helps separate the seed from the liquid fertilizer.

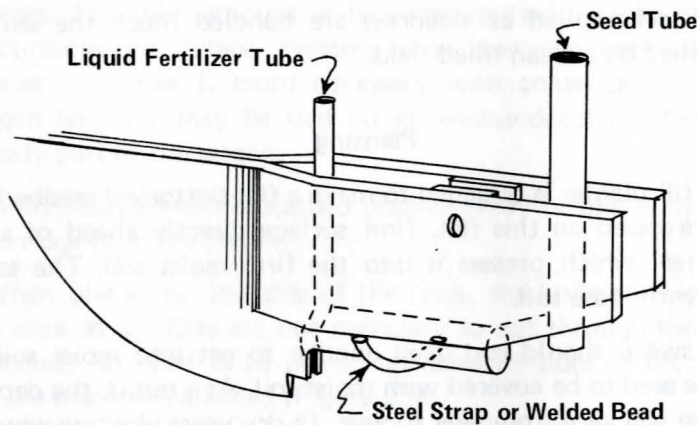


Fig. 25 SOIL AGITATOR ON PLANTER RUNNER

The soil agitator can be arc welded beads or $1/4 \times 1/8 \times 3$ inch strips welded on the half round bottom of the runner.

The till planter is a heavy machine that can sink too much in soft soils that do not settle. Excessive sinkage causes poor seed drop and poor seed placement, seed soil contact, and covering. For these soils it would be better to use a light tillage for weed and residue control, or to keep weeds under control with herbicides then using a light surface planter.

Compaction

Compaction from wheels is kept to a minimum as wheels run in the furrow and never over the row. The compaction caused in the furrow is not critical to plant root development. Freezing and thawing, wetting and drying, plant root development and plant decomposition maintain the surface soil in a well granulated friable condition.

Weed Control

The most critical operation in planting is weed control. With the till-planter, the sweeps must move some soil and the weed seeds out of the row. Covering disks must be set so this same soil isn't pulled back onto the row. This leaves the row itself clean. Weed germination between the rows is well suppressed by the residue. In addition, weeds in the furrow are easily controlled by later cultivation.

The use of herbicides banded over the row is more necessary with soybeans or milo than corn (for more on herbicides, see EC 76-130, Herbicide Use in Nebraska).

Broadcast spraying of herbicides is not necessary. Weeds between the row can be controlled by cultivation. Low pressure nozzles with a uniform pattern and operating close to the soil are recommended for banding. The low pressure gives good droplet size so these nozzles can be used in moderate winds.

Three things determine the proper time for cultivation.

1. Soil crusting that prevents air and water movement into the soil.
2. The number and size of weeds in the row and between the rows.
3. The height of the plants in relation to the amount of acres to be cultivated.

If weeds don't dictate an early cultivation, the crop should get a good growth before cultivation. Many times a single layby cultivation is all that is needed to control weeds and throw up the ridge for the next year's seedbed.

Set the cultivator to throw soil higher than weeds in the row. If the soil comes down on the weeds in the row there is a much better chance of getting them completely covered and killed. The sweep should run no deeper than necessary to get under the residue but still have enough resistance to shear off weed roots. Shallow cultivation with large sweeps will kill more weeds than deep cultivation as the shallow operation with sweeps agitates and breaks the soil loose from weed roots.

Heavy duty cultivators are of two types: rear mounted tool bar and rolling--both work well in conservation tillage.

The rear mounted tool bar type may employ alternate tool setups. One uses two large half sweeps in front with a smaller sweep in the center of the furrow (Figure 26). This setup will go through heavy residue with less disturbance and will undercut the weeds.

The other setup uses disk hillers in front with a large sweep in the rear (Figure 27). The disk moves the soil to cover weeds in the row and sweeps undercut the weeds between the rows. Disks should be set at a shallow angle so soil is thrown up and back instead of directly into the row. A higher travel speed can be maintained this way.

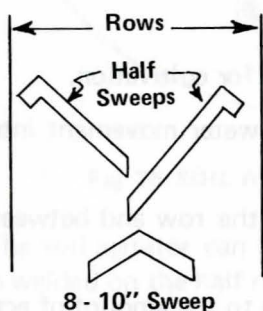


Fig. 26

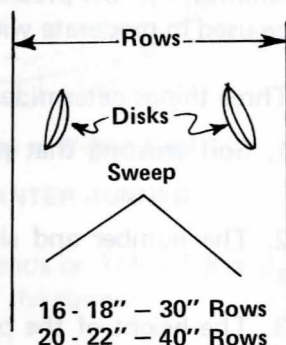


Fig. 27

In some conservation production systems--till plant--weed seeds from the previous year are swept out of the row. Weeds between the rows can be handled with the cultivator. However, weed seed in the soil profile can cause problems. Good management and timely operation are required for weed control in and between the rows. Any time the soil profile is stirred, weed seeds from the profile may germinate.

Some annual and winter annual weeds can be troublesome. Others, cocklebur and sunflower, if not turned up in the profile, are usually not a difficult problem. Shattercane can be partially controlled by using a wider sweep, 16 inch, to move seed out further

between the rows, then cultivation can be more effective. Timing is important as cultivation must cover any cane that comes in the row. Any stray plants or patches of shattercane may be rogued which helps in control for the next year. Hemp dogbane and milkweed are the most troublesome weeds in reduced tillage as the sweeps or shallow cultivation does little to control them.

As in any cropping system weed control requires good management, especially in timing of weed control operations.

Weeds will not prove to be as great a problem as anticipated with conservation tillage. Conservation tillage methods delay the good conditions for weed seed germination.

Insects and Diseases

In comparison trials, the incidence of insect populations and disease organisms have been no greater with till plant than with clean tillage. Although the environment in surface residue would seem more ideal for disease organisms and for over-wintering of insects, these problems have **not** proved to be more serious in comparison trials. The same insecticides that are needed to control pests, such as corn rootworms, are needed with till plant also.

Operation

The care taken in the layby cultivation determines to a great extent how straight next year's rows will be. A kink in a till plant row is almost impossible to remove during planting. In this case, some tillage will be required to knock down part of the ridge, giving a better driving surface and better control when planting.

The new types of planters work well on terraced fields as disks or coulters act as stabilizers causing the machine to tend to go in one direction until the tractor pulls it around. In this way, the planter will follow contours quite well. The same is true of a cultivator that has stabilizers and flexibility between the row units.

Management of any conservation production system is the most critical part. Timing is extremely important for planting, weed control operations, and fertilizer application. None of these are greatly different than clean tillage decisions but an error is more obvious and is harder to correct.

Successful Crop Production Systems

The following are requirements of a successful crop production system:

1. Timely establishment and proper distribution of the desired population of plants of the selected, adapted crop variety.
2. Providing an environment that meets the growth and reproduction requirements of the crop in terms of temperature, light, moisture, and plant nutrients.
3. Adequate protection from hazards such as competition from weeds and damage from insects and diseases.
4. Harvest of high yields with retention of crop quality.
5. Competitive in cost.

A *conservation* production system is a successful crop production system that also adequately protects the soil from wind and water erosion and, in Nebraska, provides maximum conservation and use of natural rainfall in producing high and stable crop yields.