Equipment for No-Tillage Crop Production

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The first planter system designed specifically for no-tillage farming was introduced in the commercial market almost two decades ago (Agrichemical Age, 1982). Since then, an impressive variety of machines and component options have been developed and manufactured. Illustrating this extensive evolution is the fact that there are currently commercially available more than 4,000 different combinations of coulters, openers, covering disks, presswheels, and other components for row planters alone (Successful Farming, 1983b). In spite of this proliferation of available machinery, many of the perceived problems associated with no-tillage production are equipment related. In a survey conducted by Pioneer Hi-Bred International, the three most important reasons farmers gave for opposing conservation tillage were (1) inadequate weed control, (2) high chemical costs, and (3) lack of proper equipment (Agrichemical Age, 1983). Better equipment was listed by 34 percent of the respondents to that same survey as a technological factor that could influence farmers to increase conservation tillage practices.

A 1982 survey of 509 West Tennessee farmers was conducted to identify the crop producers' views of the advantages and disadvantages of no-tillage production techniques (Leuthold and Hart, 1984). Farmer response to eight listed disadvantages are summarized by user category in Table 1. Note that several of the major disadvantages of no-tillage as perceived by farmers are either directly or indirectly related to machinery.

Table 1. Proportion of West Tennessee farmer survey respondents who perceived various problems of no-tillage as major disadvantages

		User Category		
Disadvantages of No-tillage	All Farmers (N-509)	Former Users (N-54)	Nonusers (N-156)	Continued Users (N-223)
	percentage			
1. Increased chemical costs	60.5	64.8	57.1	57.9
2. Weed control problems	49.5	59.3	60.3	40.4
3. Cost of no-till equipment	37.5	42.6	48.7	27.4
4. More difficult to manage	29.9	35.2	37.2	25.1
5. More precise planting needed	19.3	27.8	18.6	17.4
6. Necessity of also keeping conventional planters	19.3	27.8	27.6	13.5
7. Spray residues	13.6	24.1	20.5	7.6
8. Yield variability	13.0	22.2	18.0	6.7

Long regarded as vital to the success of any no-tillage crop production system is the ability to (1) establish adequate plant stands and (2) effectively control the crop pests, most notably weeds. Neither of these tasks is easily accomplished in a practical sense without proper equipment and good machinery management. Consequently, both researchers and manufacturers have continually sought to develop more effective planting and chemical application equipment and to identify widely reliable operating procedures for that equipment. In the past few years, considerable attention has been given to developing fertilizer application equipment to meet the unique requirements of no-tillage cultural practices. An overview of the available equipment and recommended operating procedures in the general areas of planting, spraying, and fertilizer application for no-tillage is presented below.

PLANTING EQUIPMENT

No-tillage planters generally feature more rugged construction, have more soil-contacting components or assemblies, and consequently cost 15 to 25 percent more than conventional planters (Mowitz, 1985). The principal functions of a no-tillage planter are to prepare a seed zone in previously untilled soil and to place crop seeds such that an adequate stand of plants in an acceptable pattern is established. General preparation of the seed zone is the function of the primary furrow opener which may be a passive rolling coulter, a powered coulter, a powered tiller, a rigid blade or shank, or some combination of these. Passive rolling coulters (smooth, serrated, ripple, or fluted) are by far the most widely used primary furrow openers. The coulter should cleanly cut through surface residue without pushing portions of the residue down into the opened slot. Studies have indicated that plant residue pressed into the furrow results in reduced seedling emergence because the residue prevents the seed-soil contact necessary for germination (Sanford, 1982). Thus, coulter edges should be kept sharp. Some research suggests that clearing the residue from a narrow strip in front of the furrow opener can be advantageous in enhancing germination (Mangold, 1985). Attachments featuring tines or disks designed for clearing away residue in the path of the furrow opener are widely available but may be more useful in reduced tillage planting than in no-tillage environments.

The coulter should uniformly penetrate the soil to a depth somewhat greater than the depth of desired seed placement. When the soil is especially hard, achieving this penetration may require the addition of a substantial quantity of ballast, perhaps 400 to 500 pounds per row.

Debate over which type of coulter is best for a particular planting situation continues. Smooth coulters require less force to cut heavy residue and to penetrate hard, dry soil than do wider ripple and fluted coulters (Erbach and Choi, 1983). Smooth coulters, on the other hand, open a very narrow slot and perform little tillage within the slot. Wider fluted and ripple coulters perform more tillage and produce more loose soil but tend to be more speed sensitive than smooth coulters. At high operating speeds and with certain soil moisture conditions, wider coulters tend to throw soil out of the furrow. This soil displacement is undesirable for at least two reasons: (1) loose soil needed to cover the seed is effectively lost, and (2) soil thrown out of the furrow makes maintaining a uniform seeding depth more difficult. The general trend is toward the narrower coulter design (smooth, ripple, or fluted) because research indicates that a narrow slot results in more precision in seed placement and that the narrow coulters function better over a wider range of planting conditions (Successful Farming, 1983b). Multiple coulters are sometimes used for opening and conditioning the furrow. In the usual scheme, a smooth coulter in front cuts the residue and creates a slot in the soil while a following ripple or fluted coulter provides additionial tillage within the slot. The overall distance from the leading furrow opening device to the rear-most soil-contacting component on the planter should be as short as possible to insure proper tracking when planting on the contour.

The primary furrow opening assembly may include a shank to provide deep tillage directly under the crop row. Studies have shown that in-row subsoiling may be necessary to obtain no-till crop yields comparable to conventional tillage yields in soils particularly susceptible to compaction and plow pan formation (Touchton arid Johnson, 1982). A smooth coulter is usually mounted in front of the shank to cut the surface residue, initiate slot formation, and prevent collection of trash on the shank. Attachments behind the shank are necessary to insure that the deep slot is completely refilled with moderately compacted soil; otherwise, uniformity of seeding depth is likely to be difficult to achieve.

Disk-type planter openers are typically used on no-tillage units, although runner openers are successfully employed on some models. Double-disk planter openers are generally preferred behind rolling coulters because they disturb relatively little soil and cut through the residue well. At least one commercial planter model employs an offset double-disk opener designed to penetrate the untilled soil directly without benefit of a leading coulter for opening a slot. Depth control at the planter opener is important in assuring uniformity in the depth of seed placement. Best results are obtained when depth' is controlled for each planter unit independently and when the depth control device is located very near the planter opener.

Furrow closing devices and press wheels are used to insure that the deposited seed are covered with soil and that the soil is brought firmly in contact with the seed. The difficulty in closing the furrow behind the planter opener depends upon the characteristics of the soil, especially the moisture content. To vividly illustrate the importance of the operating conditions, consider the results of Tennessee tests evaluating commercial no-tillage planter performance in seeding soybeans in wheat stubble. A planter equipped with a pneumatic center-rib press wheel operated in Calloway silt loam at 21 percent moisture (db) failed to adequately close the furrows leaving an average of 28 percent of the seeds exposed while a similarly equipped planter operated in Memphis silt loam at 20 percent moisture achieved complete furrow closure and excellent seed coverage. In these same tests, aggressive covering devices (multiple press wheels and furrow closure disks) tended to cover a greater percentage of metered seed under dry soil conditions than a single press wheel design (Bell, 1984). The press wheel should assure that the soil is firmed around the seed to establish seed-soil contact without excessively compacting the soil through which the seedling must emerge.

SPRAYING EQUIPMENT

Herbicide formulations applied for no-tillage planting should be delivered so as to accomplish two things: (1) thorough coverage of the foliage of existing vegetation to effect post emergence control and (2) uniform penetration of surface residue enroute to the soil surface to establish preemergence weed control. Specific studies with metribuzin and atrazine indicated that less than 50 percent of the chemicals penetrated the straw and stubble and reached the soil surface (Ghadiri et al., 1984; Banks and Robinson, 1982). Results of a study examining straw and stubble penetration using flat fan nozzles to apply 10 to 30 gallons per acre showed that the percentage of chemical reaching the soil increased as application rate increased (Gerling and Solie, 1984). While the operating pressure did not affect the percentage penetration, the quantity of surface residue did have a pronounced effect. Some sources suggest application rates as high as 60 gallons per acre where vegetation is heavy or growth is rank (Successful Farming, 1983a). Yet there is tremendous interest in and considerable research related to the use of relatively low volume application in no-tillage. Centrifugal-type droplet forming devices known as controlled droplet applicators (CDA), which generate small droplets relatively uniform in size, are currently being widely marketed as low volume applicators. Several studies, including one in Tennessee, where soybeans were no-till seeded in wheat stubble, showed that weed control obtained with 4 gallons per acre was equal to that obtained with applications of 20 gallons per acre. Furthermore, low volume applications with flat fan nozzles were just as effective as those made with CDA. Among the disadvantages cited by critics of CDA are poor canopy or stubble penetration and enhanced drift potential naturally associated with small droplets. Perhaps Gordon Berg (1985) in a recent article summarized the question of CDA versus conventional spray application best by noting that "the jury is still out."

Experimental air-assist nozzles which employ a stream of compressed air to aid in formation and delivery of droplets to the target surface have been introduced as low volume application units. The droplets are delivered from a modified flood tip in a tapered edge flat spray pattern for broadcast application. Design modifications to the prototype nozzles continue to be made based upon the results of field and laboratory tests.

Renewed interest has been shown in postemergence directed sprayers for use in no-tillage crops. While effective over-the-top postemergence herbicides have been made widely available, postemergent directed spraying may still offer an economically attractive alternative from the standpoint of total cost of herbicides required to produce a crop. However, many row crops currently grown no-tillage are seeded in rows spaced 20 inches or less. In a Tennessee study, six commercial and experimental directed spray applicators were evaluated for effectiveness of operation in soybeans planted with 20-inch row spacing. Each of the sprayers featured devices for shielding the soybean plants from the spray being applied between the crop rows. Recommended nozzle tips ranged from flood-type to flat fan and even spray. Study results indicated that with careful management directed spraying is a feasible alternative in 20-inch rows and that a good selection of appropriate equipment is commercially available.

New equipment for injecting chemical concentrate into the fluid circuit near the point of spray discharge from the machine is being introduced in the marketplace. The overwhelming advantage of this technology is that an operator can put a bulk container of chemical on the sprayer and inject the material right in the field, eliminating the necessity for tank mixing and disposal of excess liquid. Some experts suggest that there remain several problems to resolve before direct chemical injection systems become commomplace. However, most agree that such systems offer tremendous potential for increasing the efficiency and safety of chemical application generally.

While there are presently available radar speed detectors, sprayer monitors, and electronic control systems designed to enhance the precision of chemical application, a recent study in Nebraska revealed that 60 percent of the applicators surveyed missed their estimated application rate by more than 10 percent. About a third overapplied by more than 10 percent with an average error of 30 percent (Agrichemical Age, 1985). While farmers must stay abreast of changes in technology, this and similar studies indicate that attention should be given to maintaining chemical application equipment in good working condition and to proper calibration and operation of the equipment.

FERTILIZER APPLICATION EQUIPMENT

Fertilizer application on the soil surface has been the general practice in no-tillage historically. Certain nitrogenous fertilizers were not used because of the significant nutrient loss due to volatilization. There was also the suggestion that the presence of crop residues on the soil surface made the nitrogen less available for crop use. Some studies indicate that nutrients can become stratified in the soil if the soil is continuously no-tilled and not stirred and mixed through tillage. Considerable research suggests potential performance advantages associated with injecting fertilizer materials into the soil at a particular time in the plant growth cycle or in a strategic location relative to the plant. Fertilizer injection units used in conventional cultivation generally consisted of a shank or blade with a fertilizer delivery tube on the back side. Such a device was not directly applicable to no-tillage cropping practices. But with the addition of a smooth coulter in front of the blade to cut the residue and to start forming the slit in the soil, the device worked quite well in no-tillage environments. Consequently, several brands of such liquid or dry fertilizer injectors are currently available commercially. They are designed as either planter toolbar attachments or for use with separate fertilizer applicators. Use of a depth control device for the coulter is generally recommended so that fertilizer placement can be maintained at the desired depth.

A new machine which uses high pressure to force a stream of liquid fertilizer through crop stubble and into the soil has been developed specifically for no-tillage applications (Richardson, 1984). Fertilizer at pressures of up to 2,000 psi flows through a solid stream nozzle mounted on a shoe which slides over the ground surface. Depth of fertilizer penetration depends on the soil condition including moisture content, the height of the nozzle relative to the ground surface, and the liquid pressure. Application rate depends upon the orifice size selected.

A CLOSING COMMENT

The survey mentioned near the beginning of this paper suggested that several of the perceived problems associated with conservation tillage were related to the production equipment used (Agrichemical Age, 1983). However, 96 percent of the conservation tillage practioners surveyed in that study indicated at least a moderate level of satisfaction with the practice and the results obtained. Continued innovative developments in equipment and operational methodology for no-tillage will farther alleviate perceived shortcomings of the practice. At a 1984 national conference on conservation tillage, industry representatives indicated that they were anxious and ready to design, manufacture, and market new equipment for conservation farming (Lindemann et al., 1984).

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