INFLUENCE OF NO-TILL ON SOYBEAN CULTURAL PRACTICES'

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Conservation Provisions of the 1985 Farm Bill required farmers who want to continue participating in government programs to control erosion on land with high erosion rates. Farmers had to begin implementing conservation plans for the 1990 cropping season. Plans must be fully implemented by January 1, 1995. No-till became a significant part of these conservation plans, because current erosion models give little credit for full-width tillage systems that leave residue on the soil surface (Alberts et al., 1985). A rapid rise in the proportion of U.S. crop acres planted to no-till began with implementation of conservation plans (Figure 1). Growth in no-till has been more rapid in soybeans that other crops. At least part of the reason for this is that soybeans produce a soil condition that is more erosive than other crops (Alberts et al., 1985).

Acreage not designated as highly erosive is also increasingly being planted to no-till. The desire to use similar machinery systems on a farm unit accounts for a portion of this adoption. Lower herbicide costs, a greater array of herbicides, improved seeding equipment, and aggressive marketing by pesticide manufacturers have also contributed to growth of no-till.

"Musts" With No-Till

Growing soybeans without tillage requires a couple obvious changes compared to using full-width tillage prior to planting. First, either a burndown or early preplant herbicide program must be used before planting. This will kill established weeds normally eliminated with tillage and should be designed to control the particular weed species present.

A second change involves equipment choices. Most important is the need for a planter or drill capable of penetrating and preparing a seedbed under the higher residue and firmer conditions associated with no-till. Combine attachments that uniformly spread residue aid chemical performance and ease of seeding. With headers less than 15 to 17 feet wide, a simple straw spreader is often adequate. With wider headers, chaff spreaders and straw choppers greatly improve residue spreading. If row crop cultivation is planned, a heavier-duty cultivator is also required for no-till.

Beyond these obvious changes, other changes in culture often involve fine tuning the system. Considerable research suggests that soybean production practices used to maximize yields in conventional tillage systems are often the same practices needed to maximize yields in mulch-till or no-till systems (Oplinger and Philbrook, 1992; Lueschen et al., 1992). This is not to imply that no-till is an easier system to use or best in all situations. In fact, there is often a higher risk with no-till, and it is not the system of choice for all situations. The remainder of the discussion will focus on these "finer points" of no-till.

Seed-Related Considerations

The best yielding varieties in no-till systems are generally the same varieties giving highest yields in tilled systems. Elmore (1987 and 1991) has confirmed this relationship in 30-inch row widths. Philbrook et al. (1991) have confirmed this relationship in drill row widths. In a few instances, no-till has caused unique changes in pest levels, creating significant variety interactions. For example, during one year Vasilis et al. (1988) observed greater Phytopthora root rot *(Phytopthora megasperma)* under no-till. Using a variety with lower resistance caused a 44% loss in final stand and an associated yield loss. In Tennessee, cyst nematode *(Heterodera glycines* Ichinohe) populations were lower in no-till than in systems using tillage (Tyler et al., 1987). Varieties with single and multirace resistance produced similar yields in no-till, but with tillage the variety with single race resistance yielded less if cyst counts were high. The clear message is to choose varieties with the best resistance to pests known to be present.

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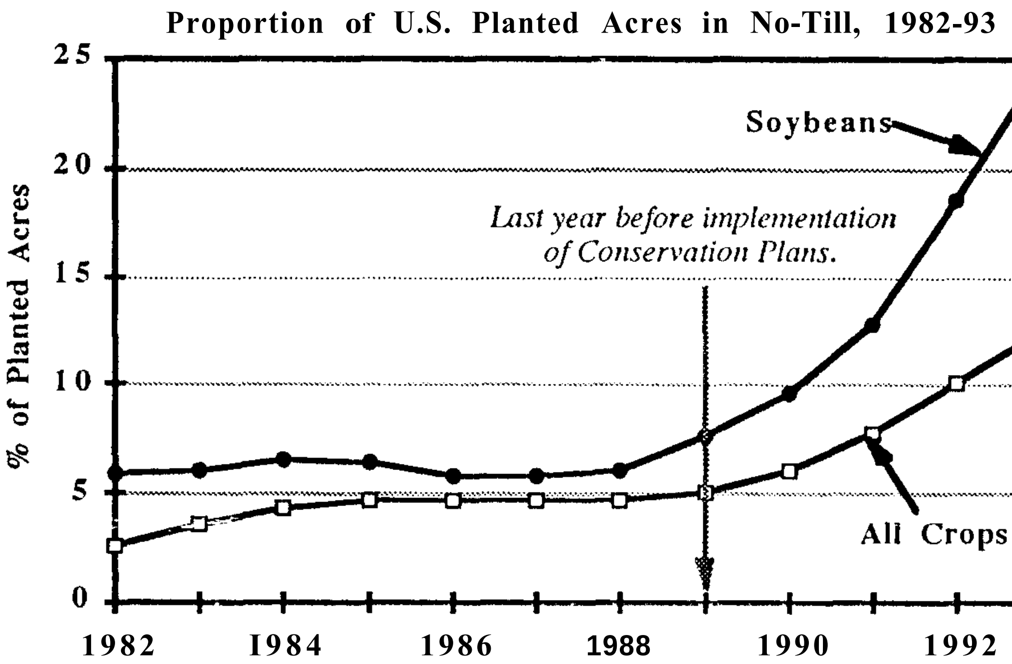

Figure 1. Use of no-till in soybeans and all planted crops (CTIC, 1993).

Cooler and moist seedbeds associated with no-till encourage many to promote greater use of seed treatment pesticides (Grooms, 1993). Phytopthora and pythium are two common pathogens more prevalent in no-till soils. In Wisconsin, Guy and Oplinger I19891evaluated two seed treatments on six varieties grown in moldboard, mulch- and no-till seedbeds at two locations over 2 years. Moldboard plow soybeans averaged 8 bu/acre higher than no-till. Apron seed treatment tended to increase yield in no-till, but not in other tillage systems. Vitavax 200 seed treatment caused both yield enhancement and reduction for some varieties. The authors concluded that seed treatments should be especially considered in no-till. In contrast, Lueschen et al. (1991) found that seed treatments were not necessary to obtain adequate stands, even in no-till seedbeds. Thus, where high vigor seed is used there is not strong research evidence supporting the need for seed treatment, but many consider it a cheap insurance to help assure adequate stands.

Between 140,000 to 200,000 seeds per acre is sufficient to maximize yields where tillage has been used (Johnson. 1987). Using 30-inch row widths in Nebraska, Elmore (1991) found this same range of seeding rates to be effective in both conventional and no-till. Using solid seeded rows in Wisconsin, Oplinger and Philbrook (1992) found that 176,000 seeds per acre maximized yields with tillage whereas 15 to 32% higher seeding rates were required with no-till (up to 232,000 seeds per acre). Pioneer Hi-Bred (1992) recommends a seeding rate of 200,000 to 225,000 viable seeds per acre where soybeans are drilled into corn residue. There is little evidence that higher final stands are required in no-till. However, given cooler seedbeds, higher residue conditions, and a greater likelihood of pests, it seems logical to increase seeding rates by 10 to 25% with no-till. especially in drill row widths.

Fertilizer Placement

Phosphorus and potassium are relatively immobile nutrients. They remain near the soil surface if not band-injected or mixed into the soil with tillage. Band and broadcast applications of potassium resulted in similar yields on two Illinois soils with relatively high exchangeable rates of potassium (Vasilas et al., 19881. In contrast, Mississippi researchers found band placement of P and K was better than broadcast placement on two of three soils testing low in these elements (Hairston et al., 1990). Benefits of band placement occurred with no-till but were not evident where full-width tillage had been used. In both of these studies, no-till yields were lower than where full-width tillage had been used, but band placement could not overcome yield reductions associated with no-till.

Where no-till is used, it would seem advisable to either include occasional tillage to incorporate nutrients or consider deep band injection of P and K, especially if soil tests are low to medium for these elements. Getting P and K into the surface soil will prevent them from being positionally unavailable if dry conditions occur for extended periods. Occasional tillage would have the added benefit of mixing lime into the surface layer. Several herbicides can cause significant injury if pH becomes too high.

Planting Dates and Row Width

Optimum planting dates and row widths do not generally change with tillage system. Where narrow rows yield more with tillage, no-till beans also yield more in narrower rows (Oplinger and Philbrook, 1992; Lueschen et al., 1992). Likewise, environments not showing any advantage to narrow rows do not seem to respond differently if no-till is used (McIsaac et al., 1990). Use of row widths less than 30 inches has grown steadily and now accounts for nearly 50% of the planted acreage (Fig. 2). During the past 4 years adoption of drill row widths has been greater than intermediate row widths. This may be at least partially due to greater use of no-till. Soybeans planted no-till grow slower after emergence and tend to provide better early season weed competition if planted in narrow row widths.

Crop Rotations and Soil Types

Over half of U.S. soybeans are grown in rotation with corn. A majority of the remainder are rotated after wheat or cotton. A few acres of continuous soybeans are grown, mainly in the south. Although some research fails to show a yield advantage for crop rotation (Wagger and Denton, 19921, most studies show 5 to 15% increases in yield where crops are grown in rotation (Dick et al., 1986a. 1986b; Johnson, 1987; Lund et al. 1993). If a soil is not well adapted to limited tillage, crop rotation often helps bring reduced- or

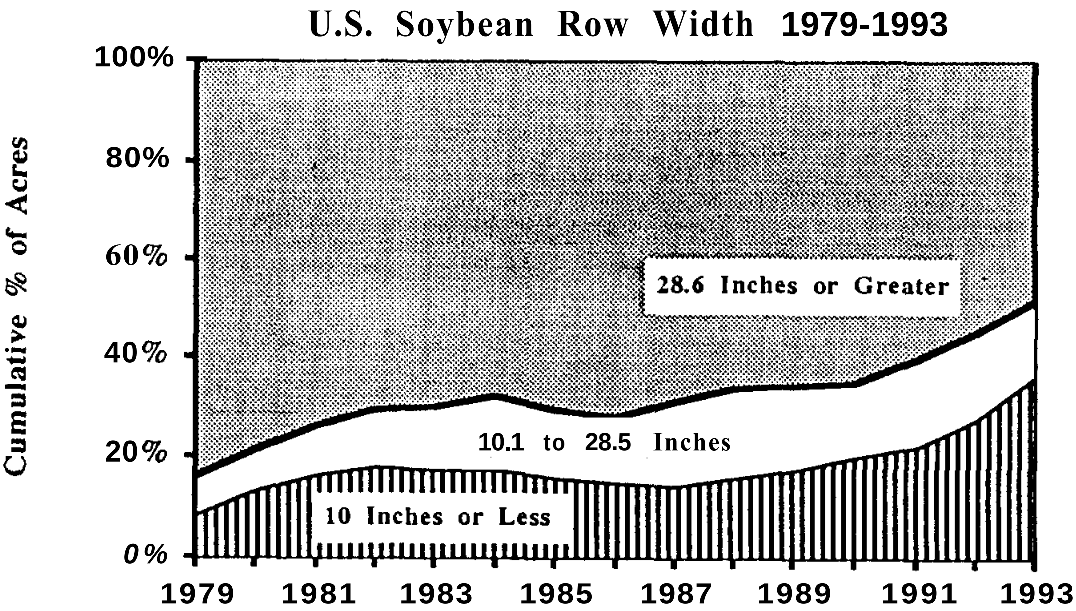

Figure 2. Proportion of U.S. soybean acreage planted in different row widths (Crop Reporting Board, 1981-1993).

Table 1. Effect of tillage system on soybean yields when grown in a cornlsoybean rotation. Summarizes 18 research reports published in the last decade (see appendix for sources).

Tillage System	Favorable Soils	DroughtylPan Soils
	---Bu/Acre---	
Moldboard plow	44.0	'33.2
Reduced-Till	43.1	35.6
No-till	41.1	38.1
Locations	11	7
Location-years	86	53

• The moldboard yield is based on only four locations, but if the number of locations is restricted to four for all tillage systems, mean yields are essentially the same as shown.

no-till yields closer to those of more conventional tillage systems.

From the earliest days of reduced tillage research, it has been obvious that optimum tillage systems are site specific. Droughty soils that are well drained tend to produce the highest yields with limited tillage or no-till systems. In contrast, moderate to poorly drained productive soils tend to yield most with some type of full-width tillage system. As shown in Table 1, modern research continues to validate this lesson. To avoid variations due to crop rotations, Table 1 considers only corn-soybean rotation studies that included a no-till, moldboard plow, and some form of reduced-till treatment–usually a disk or chisel system. An attempt has been made to include published studies from throughout the major soybean producing areas, somewhat in proportion to planted acres. Many more studies could be cited, particularly on favorable soils–for example, an additional five research locations in both Iowa and Illinois with 6 years or more of data showing similar results.

No-till produced yields 2.5 bushels/acre higher than reduced-till and nearly 5 bushels higher than moldboard plow on sandy soils or soils having a restrictive pan near the soil surface (Table 1). These soils can easily cause crop drought stress early in the growing season. The protective mulch of no-till surface cover reduces early season moisture loss. After a crop canopy develops, a surface mulch is of little help in moisture conservation, but higher yields often result from the greater early season moisture. On deep soils that are moderate to poorly drained, moisture conservation from a surface mulch is seldom of benefit. These soils are generally not subject to early season moisture stress, and surface mulch is detrimental because it delays early-season field operations and slows early crop growth. On deep soils no-till yields averaged about 3 bushels/acre below moldboard and 2 bushels below reduced-till.

Enthusiasts who promote no-till use for all situations often suggest that it takes 3 or 4 years for soils to adapt to no-till. They state that, given patience, no-till yields will approach or exceed those of where tillage is practiced. Table 1 includes only research conducted for 4 or more years–two sites included more than 20 years. In none of these 18 locations did yield response to tillage improve significantly with advancement of time, with either corn or soybeans. Thus, widespread experimental evidence does not support soils "adapting" to no-till. Small plot research places no-till in its best "light" because large combines, chemical trucks, and other transport vehicles are generally not used. These machines cause deeper compaction and provide farmers with a major incentive to use tillage.

Weed Control

In small plot research, as tillage is reduced or eliminated, small seeded annual grass species and perennials become more difficult to control. In contrast, large seeded broadleaf weeds are less

Table 2. Weed density in southwestern Ontario fields managed with various tillage systems (Frick and Thomas, 1992).

Weed life cycle	Tillage System		
	Moldboard	Reduced-till	No-till
	---number of weeds per m^{2}---		
Annual broad-leaved	4.7	9.4	9.9
Annual grass	4.5	8.2	8.3
Perennial	5.1	3.9	7.4
Total density	17.0	24.7	31.7

affected by tillage or become easier to control as tillage is eliminated. Overall number of weed species and weed densities tend to increase as tillage intensity is reduced (Buhler et al., 1990; Cardina et al., 1991). These conclusions are largely confirmed with on-farm experience. Frick and Thomas (1992) surveyed 593 soybean, corn, and winter wheat fields in southwestern Ontario during 1988 and 1989. They confirmed that weeds were present at highest densities in fields with no-till (Table 2). Both annual grass and broad-leaved weeds were at about equal population in reduced and no-till systems, but were double the density of those found in moldboard plowed fields. Perennial weed densities were highest in no-till and lowest in reduced-till systems. Thus, in spite of intense herbicide use, weeds continue to present a significant problem to modern soybean producers. If the trend continues toward less intense tillage, weed problems are likely to become greater.

Economics

I would like to illustrate the economics of no-till with a personal anecdote. Benefits of no-till have often been summarized with the catchy phrase of "saving soil, oil and toil." I'm not sure who first coined this phrase, but I first heard it in speeches given by John Block when he was Secretary of Agriculture. Last summer I visited Block Farms in Knox County, Illinois. After several years of trying no-till on a sizable acreage, they had settled on a reduced-till system for most of their acreage. In visiting with Jack's son Hans, I reminded him of his father's statements. Hans stated that they did experience reduced erosion, less use of diesel fuel and fewer hours in the field when they used no-till practices. He then went on to point out that tradeoffs included spraying more herbicides, paying additional costs for other chemicals and seeds, and accepting lower/more variable crop yields. Simply put, we might say the benefits of "saving soil, oil, and toil" were offset by more "spraying, paying, and praying."

The Block Farms have settled on reduced-till as the best compromise for conservation, management, and profits. No-till will be used only where mandated in their conservation plans. The Block's experience is not unique. Many who initially tried no-till enthusiastically have now altered their approach using a variety of modifications. This experience is given because it summarizes most of the recent research analyzing economic returns of various soybean tillage systems.

McIsaac et al. (1990) and Chase and Duffy (1991 calculated economic returns for small-plot research trials using similar chemical treatments for each tillage system, with the exception of additional burn down herbicides used for no-till. Brown et al. (1989) analyzed large field scale research plots using chemical treatments for each tillage system that were selected by a farm manager. Chemical treatments varied from field to field and year to year. Martin et al. (1991) used small, research tillage plots to evaluate several alternative weed control systems. Stephens et al. (1992) used a machinery selection program to evaluate several alternative herbicide and fertilizer systems commonly used with alternative tillage systems.

All of the above research analysis found no-till to result in the lowest machine and fuel costs as well as the lowest labor requirements. However, no-till was never the most profitable system because herbicides and other variable costs increased enough to offset machine-related savings. In some cases yields also decreased enough with no-till to significantly reduce profits. The most profitable systems involved full-width tillage of reduced-till and/or moldboard systems.

Most of the above studies involved soils classified as favorable in Table 1. If no-till were to result in several bushel/acre yield increases. it could easily be the most profitable system. The research also showed that where soil conservation is necessary, many of the reduce-till systems give profits similar to moldboard. If no-till is mandated, careful selection of fertilizer and herbicide options can help minimize costs making no-till cheaper than adopting unusual crop rotations or terraces.

The Chemical Issue

An opinion poll conducted by the Center for Communication Dynamics showed that, nationwide, nearly 60% of respondents (80% of college-educated respondents) agreed with the statement that "farmers use too many pesticides." Only 23% were willing to accept that drinking water was safe if it met government standards but still contained small amounts of chemicals (Batie et al.. 1986). Public sentiment continues to be strongly in favor of agriculture using fewer farm chemicals that stay on fields, and out of food and drinking water supplies. Recent legislation such as endangered species. safe drinking water, and coastal zones are all aimed at addressing this public sentiment.

The economic research papers cited above document that greater amounts of herbicides are used in no-till. Tillage can also affect use of other pesticides such as insecticides and rodenticides. One measure of pesticide use is annual sales. From the late 1970s through 1988, pesticide sales were either stable or declining, depending on whether measured in current or 1987 dollars (Fig. 3). Beginning in 1989 pesticide sales began a steady trend upward. This corresponds with the rapid growth in no-till acreage (Fig. 1) and implementation of conservation plans.

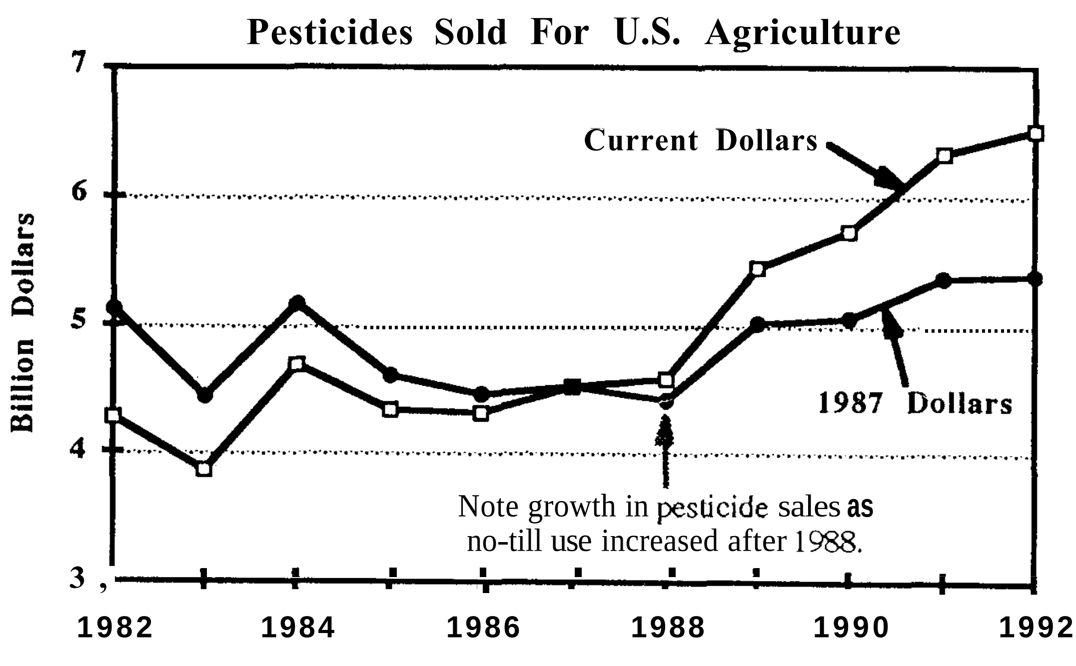

Figure 3. Pesticide sales in current and 1987 dollars (USDA. ERS, 1993b).

Table 3. Average number of pesticide treatments used with different tillage systems (USDA/ERS RTD Updates, 1992 and 1993a).

Tillage System	Soybeans	Corn	Cotton
	-Number of Treatments-		
1991:			
Conv. w Moldboard	1.41	1.37	3.70
Conv. wo Moldboard	1.48	1.63	5.48
Mulch-Till (>30% cover)	1.54	1.76	4.68
No/Ridge-Till	1.67	1.75	7.46
1992:			
Conv. w Moldboard	1.50	1.57	3.72
Conv. wo Moldboard	1.61	1.70	6.25
Mulch-Till (>30% cover)	1.57	1.85	•
No/Ridge-Till	1.73	1.71	*

• Insufficient data.

The number of pesticide treatments for soybeans and crops commonly grown in rotation with soybeans is shown in Table 3. As tillage systems progress from moldboard plow to no-till, about 10 to 30% greater number of pesticide applications are used in corn and soybeans. In cotton the number of applications nearly double. Thus, one of the major challenges facing agriculture is to learn how to use fewer pesticides as the intensity of tillage is reduced.

A second challenge is to keep agricultural chemicals in place. During the severe flooding in 1993, extraordinarily large amounts of herbicides and nitrate were flushed into the Mississippi River. Even though extremely high streamflows were recorded during the flood, concentration of herbicides such as atrazine, alachlor, cyanazine, and metolachlor were similar to maximum concentrations measured during much lower streamflows in 1991 and 1992 (Goolsby et al., 1993). The total atrazine load transported to the Gulf of Mexico from April through August 1993 was 1.2 million pounds or about *80%* higher that the same period in 1991 and 235% higher than in 1992. The total load of nitrate transported to the Gulf during the same 1993 period was over 900,000 tons, 37% larger than in 1991 and 112% larger than in 1992.

Reduced amounts of application are one of the most effective methods available to reduce chemical contamination. Several alternatives exist to use pesticides more efficiently. Long-term, the seed industry will play an important role in reducing need for insecticides. Initial success has already occurred by incorporating some genetic insect resistance into crops such as cotton and corn. However, genetics can play only a minor role in controlling weeds because they do not feed on the crop. Yet, herbicides alone account for about 80% of the tonnage of US. pesticides sold.

Pesticides can be reduced by scouting and applying only where needed. Recent research is showing that small amounts of mechanical cultivation will allow greatly reduced herbicide application. During a two-year study in Minnesota, herbicide rates were reduced 50 to 75% by banding or using a broadcast application at half labeled rates (Fig. 4). A single cultivation following a reduced herbicide application was generally sufficient to produce yields equal to or greater than those obtained for the full-rate broadcast application without cultivation. Similar results have been obtained at three Missouri locations (Steckel et al., 1990). Herbicide cost savings more than offset the cost of cultivation, and improved weed

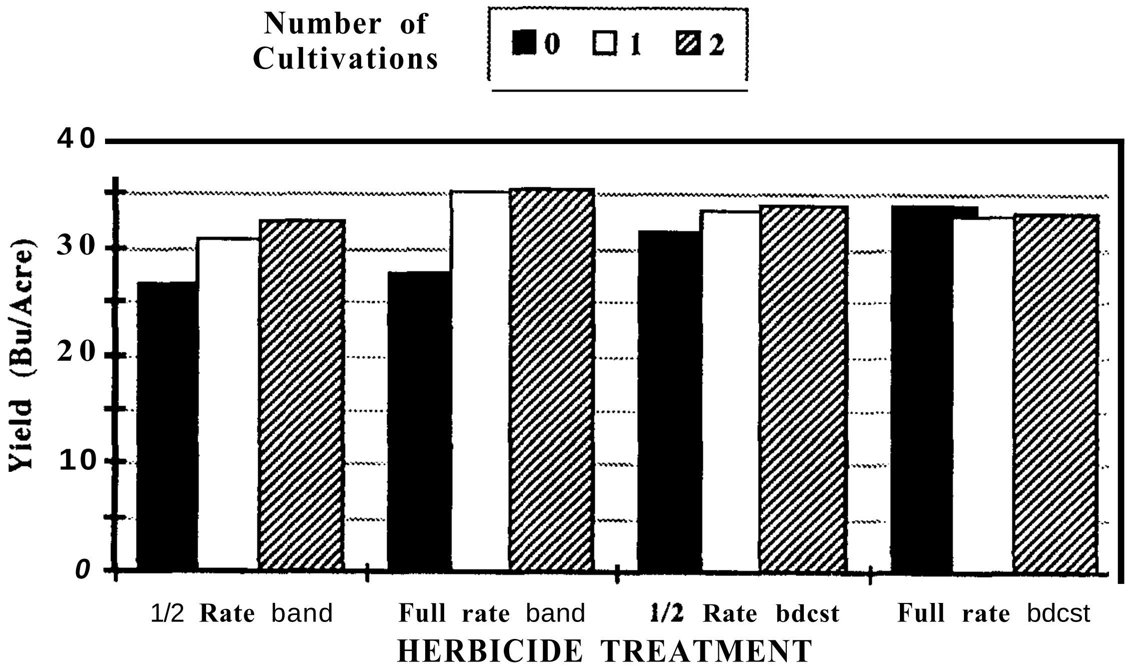

Figure 4. Two-year average soybean yields obtained with herbicide treatments of full-rate broadcast, half-rate broadcast, full-rate band, and half-rate band treatment. All were used with 0. 1 or 2 cultivations (Buhler et al. 1992).

control or yield gains add to profits. Environmental benefits include less chemical use.

A few pesticides are strongly adsorbed onto soil particles, while most developed since 1960 are only weakly to moderately adsorbed (Baker. 1992). Soil erosion control will reduce loss of strongly adsorbed pesticides. In contrast, erosion control will only have a limited effect on those weakly or moderately adsorbed to soil since they move primarily in runoff water (Baker, 1992). Christensen et al. (1992) summarized several different experiments using various Best Management Practices (BMPs) to reduce herbicide movement off fields (Fig. 5).

The reference line in Figure 5 (100% runoff1 used surface herbicide application in a moldboard plow system. Surface herbicide application in three forms of conservation tillage (no-till, ridge-till and chisel plow) reduced average herbicide runoff to about 30 to 50% that measured with surface application in moldboard tillage. The incorporation treatment was done with moldboard plow tillage and compared surface herbicide application with preplant incorporation. Incorporating herbicides in moldboard tillage was as effective at reducing herbicide runoff as was surface application in conservation tillage.

In no-till, no option exists other than surface herbicide application. Much of the chemical is applied to surface residue or growing weeds. If the first rain after application is intense, herbicide never gets a chance to move into or attach to the soil making it vulnerable to high rates of runoff. This is why no-till has such a large range in herbicide runoff and can exceed loss experienced with surface application in moldboard plow tillage (Figure 51. Combining preplant incorporation with surface preserving tillage provides an opportunity to reduce herbicide runoff, but the challenge becomes obtaining good incorporation while maintaining surface residue (Baker, 1992; Christensen et al., 1992). Many newer secondary tillage machines, especially field cultivators and combination machines, have been redesigned with more residue handling capability. A new tillage concept specifically designed for incorporation in high residue is also available (Johnson et al., 1992). These new machines provide producers the capability of incorporating herbicides for reduced runoff while retaining surface cover for erosion

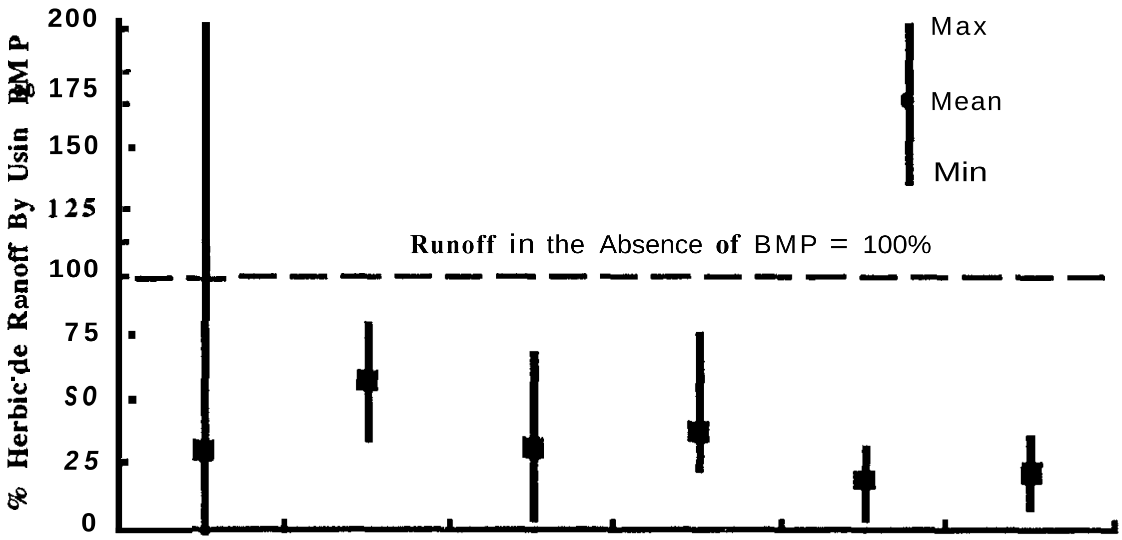

Figure 5. Herbicide runoff with various Best Management Practices (BMP), Christensen et al., 1992. The dashed line represents runoff relative to surface applications with moldboard.

control. These water quality advantages of tillage are important to weigh against soil erosion benefits of no-till.

Summary

Soybean no-till culture has greatly expanded with implementation of conservation provisions of the 1985 Farm Bill. Compared to other tillage systems, no-till requires burndown or early preplant herbicides to control weed growth occurring before planting. Combine attachments to uniformly spread residue and a rugged enough planter to provide precise seed placement are other unique requirements. Most other cultural practices are similar to those used with full-width tillage systems. No-till does have some tendency to require higher seeding rates and a greater need for seed treatment pesticides. Injection of nutrients or occasional use of tillage can also make no-till nutrient management much easier.

No-till often yields highest on soils prone to early season drought, while it generally yields less on more favorable soils. If a yield advantage does not occur with no-till, economics favor use of tillage. No-till is also often the least-cost system where highly erosive lands mandate extreme erosion control. A downside of no-till has been use of greater amounts of pesticides that are more vulnerable to surface runoff. Integrated weed management systems offer potential to greatly reduce herbicide use if combined with small amounts of row cultivation. Incorporation of herbicides while maintaining surface cover offers much of no-till's soil erosion control, yet provides potential for reduced herbicide runoff.

Appendix

Favorable soils in Table 1 are at Morris and Waseca, MN (Lueschen et al., 1992), Arlington, WI (Oplinger and Philbrook, 1992). Champaign, Perry, and Monmouth, IL (Univ. of Illinois, 1992), Custer, OH (Dick et al., 1986a). Lafayette, IN (Kladivko et al., 1986). Burlington, IA (Brown et al., 1989). Nashua, IA (Chase and Duffy, 1991), and Ames, IA (Erbach, 1982). The droughty soils include results from Northeast, AL (Edwards, et al., 1988), Brownstown and Kilborne, IL (Univ. of Illinois, 1992), Wooster, OH (Dick et al., 1986b). Reidsville and Rocky Mount, NC (Wagger and Denton, 1992), and Southeast, IN (Kladivko et al., 1986).

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