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Conservation tillage obstacles on dryland

By T. W. Massee

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PIONEER farmers lacked equipment to till and plant dryland wheat adequately. Poor crops after weedy fallow or from volunteer stands emphasized the need for better mechanization.

Between 1950 and 1960 there was only casual interest in the use of herbicides for chemical fallow. Yield results from chemical fallow trials did not signal a need to redirect farm management toward this practice because yield increases resulting from mechanization overshadowed the advantages of using herbicides. More problems seemingly were created than solved when herbicides were substituted for tillage—plant diseases, nutrient deficiencies, phytotoxic effects, and so forth.

The recent concern that conservation tillage controls soil erosion has renewed interest in the use of conservation tillage in dryland farming.

The problems

Several factors are involved when attempts to use conservation tillage result in lower crop yields. These include problems with soil moisture, soil structure, soil temperature, soil fertility, phytotoxic effects, weed control, plant pathogens, and other pests (rodents, insects).

Some of these problems are not real, while others need to be recognized and dealt with.

Soil moisture. Two physical aspects associated with no-till systems cause moisture differences. These are the residue and the resulting soil pore size, especially with regard to the capillary continuity provided by the pores to the evaporating (and infiltrating) soil surface.

Residue retards soil drying. On a bare, moist soil, about 90 percent of available (net) radiation is used to evaporate water (*15*); an adequate amount of residue reflects light, insulates the topsoil, and reduces air mixing by wind so that evaporation is reduced 50 percent. However, this reduction has its price. The bare soil, by losing sufficient surface water and becoming dry, develops a barrier against upward capillary movement. The evaporation rate drops abruptly to a rate lower than in the mulched soil, which remains moist at the surface. This prompts the question: Does mulch actually help the fallow retain more moisture at a critical time, as at fall seeding or for crop use?

Earlier research indicated that mulches effectively conserve moisture for short intervals between frequent rains, but in drier climates, the mulches are neither beneficial nor detrimental (*18*). Most recent laboratory work, which has been substantiated by theoretical diffusion mathematics, shows that where residue reduces moisture loss initially there will continue to be more moisture saved at all future times into the fallow period (*3*). The ineffectiveness of mulches in drier climates may relate to the limited residue produced in these areas. By averaging 16 experimental years of more recent work at three dry Great Plains locations and using a full 6.7 metric tons of residue per hectare (3 tons/acre), researchers showed that 50 percent more precipitation can be saved during summer fallow than had been thought possible (*10*).

Tilling to break the continuity of smaller capillary pores and thereby slow moisture movement to the surface will reduce evaporation during long-term drying periods (*2, 12*). Tillage will cause the surface layer above the implement working depth to be drier and the zone below to contain more moisture than an untilled soil. Untilled soil will have comparatively uniform moisture distribution throughout its profile.

This approach to summer fallow is important in the Pacific Northwest and Intermountain areas, where summers are dry and soil moisture at fall seeding varies (*12, 16, 23*). Using sweep tillage after summer fallow maximizes moisture control. Also, soil-active herbicides need to be decaying on fields seeded to winter wheat then; thus, weeds require alternative control.

T. W. Massee is a soil scientist at the Snake River Conservation Research Center, Agricultural Research Service, U.S. Department of Agriculture, Kimberly, Idaho 83341.

University of Idaho Extension

Soil structure. There are few circumstances in agriculture when tillage is needed to reduce soil bulk density. An example is where beets or potatoes are grown on fine-textured soils (*1*).

Occasionally, pans may be created by tillage. In these cases, chiselling or a similar operation is often beneficial. But within normal wheat growing situations, root penetration remains an important concern. Penetration depends primarily on soil moisture content and secondarily on structure. Both can be improved with conservation tillage. Where shallow rooting sometimes exists in association with no-till, there is usually a problem of residue phytotoxicity.

Reduced soil temperature. Surface residue will reduce early spring and summer soil temperatures at the wheat crown depth as much as 6°C (10.8°F) (*14*). While yield reductions with mulching have been attributed to such temperature changes (*25*), the relationship is probably coincidental. Workers using inert plastic mulching material have simulated the temperature reduction without yield loss (*23*).

If wheat were sensitive to minor temperature changes, it could not be grown successfully from Canada to Mexico. In practice, wheat planting dates must be selected to take advantage of the most suitable temperatures for its growth.

Plant nutrition problems. Conservation tillage may reduce the available nitrogen, sulfur, and, sometimes, phosphorus (*1, 24, 28*). Yield versus nitrogen-applied curves, comparing conventional tillage with conservation tillage, indicate that extra nitrogen is required to obtain equal yields with conservation tillage. The high-yield plateau from either tillage system is similar where sufficient N is applied (*1*). Some workers speculate that conservation tillage might contribute to denitrification of surface nitrogen applications because the associated residue provides a more moist, microbiologically active soil surface layer.

Recent experimental use of tracer material incorporated into fertilizer shows that denitrification losses may indeed be economically significant whether the residue is surface-mixed or on the surface as in a no-till system. However, even larger amounts of nitrogen fertilizer are immobilized by the soil microbes than are denitrified in either mentioned tillage type. As a result, less than 50 percent of applied nitrogen is recovered by the crop (*9, 20*).

In contrast, deep plowing stubble buries this immobilizing and denitrifying sink for applied nitrogen (*26*) and burning stubble destroys it so that in either case soil nitrogen cycling may progress at a faster rate. Burning stubble for 18 years caused yields to decline from an initial 105 percent to a final 88 percent of yields on unburned plots (*17*), presumably because of destruction of nitrogen in the system.

As an alternative to removing residue, surface banding or shank application of nitrogen fertilizer helps to keep this fertilizer concentrated and separated from residue sinks. This will provide quicker recovery. The need for these alternative methods should be less with no-till than with the much-used shallow disking of stubble, which leaves the residue at a broad and suitable site for intercepting broadcast nitrogen fertilizer. Therefore, continued basic and economic studies are needed to determine the immediate and long-term effects of nitrogen fertilization methods. Because sulfur behaves somewhat similar to nitrogen, it needs to be studied and considered in a similar light.

Phosphorus fertilizer application needs to incorporate the material at a depth where roots, especially roots of young plants, are active. Phosphorus is relatively immobile in the soil. Banding below or placing fertilizer with the seed are both efficient methods with conservation tillage.

Phytotoxic effects of residue. Phytotoxic effects are a deterrent to residue use (*6*). The effects resemble a nitrogen deficiency in some ways because wheat plants are generally unthrifty, perhaps yellowed, and have limited tillering. Their crowns may develop higher than normal, sometimes to the extent that adventitious roots will develop above the soil surface (*6*). Yield reductions of 20 to 25 percent have been associated with these effects.

Wheat and barley residue induce the most toxic effects during their initial two-to-three-week decomposition. Therefore, soil conditions and management may alter phytotoxicity at a given time. For example, where straw was incorporated by spring disking just before seeding in Montana, the subsequent wheat crop displayed phytotoxicity, but this was not the case where wheat was drilled into standing stubble (James Krall, personal communication).

As expected, such effects are most evident in climatic areas where residue yields are greatest. Although an earlier summary of mulching effects did not point to phytotoxins per se, it did correlate greater yield reductions from mulching with more humid climates according to a "precipitation: evaporation" index (*29*).

Several approaches can be used to avert the toxic effects of residue in conservation tillage.

Maintaining residue above ground so that it does not decompose uses the conservation tillage system to advantage. Removing the residue from the immediate area where seed is to be planted also has been proposed (*6*), although initial attempts to accomplish this with a modified planter were not entirely satisfactory. Another method involves seeding where the previous crop's residue does not exist, but this requires having that residue isolated, for example, in wide rows. Traditional use of narrow row spacings reflects the ideas that a more complete canopy provides better weed control and optimum yields. But unpublished yield results obtained by experiment station workers using new wheat and barley varieties in wide rows were surprisingly high. Montana experiments have shown that maximum yields can still be obtained when winter or spring wheat is seeded in rows 61 and 86 centimeters wide (24 and 34 inches) wide (James Krall, personal communication). Succeeding crops were planted in the between-row area, while the stubble was left standing.

Adopting a wide-row culture to circumvent the phytotoxic effects of residue appears to have merit. The practice's main weakness may be that grasstype weeds are or will become a problem in the crop. Having to cultivate as a result would defeat the purpose of conservation tillage.

Weed control. Despite the long list of herbicides that can be used in chemical fallow, none will maintain a weed-free condition needed for moisture conservation until wheat planting and then suddenly be noninhibiting to wheat growth. Contact herbicides depend upon the presence of actively growing weeds. Their use, except during rainy periods or at harvest, may indicate the loss of controlled management. Post-harvest use of a contact type is beneficial in areas where weeds continue to grow and deplete moisture after wheat harvest. In Colorado, for example, the success of conservation tillage resulted primarily from this fact (*11*).

Choice and timing of herbicides for fallow is critical. Lack of excellence in weed control will forfeit enough soil moisture and yield that conventional tillage will become more economical. Early experimental work undoubtedly suffered from slow-acting herbicides that allowed weeds to transpire for long periods after application. Some weed species may have even recovered. These aspects probably contributed to mediocre results when chemical fallow was first tried at Pendleton, Oregon (*21*). However, ongoing, unpublished work there now shows a substantial saving in soil moisture and yield increases with better chemicals and timing (Donald Rydrych, personal communication).

Plant pathogens. The influence of conservation tillage on plant diseases is a complex subject. Many undefined factors remain. Residue, soil temperature, moisture, and fertility differences with conservation tillage may all cause differences in disease activity, even if only from the resulting thriftiness of the host plant, wheat. The fact that deep plowing has been a standard recommendation for many diseases indicates that much still needs to be learned about alternative remedies.

Adequate nitrogen fertilizer, especially in the ammonium form rather than the nitrate form, has helped control take-all disease, but excessive nitrogen increases cercosperella, rhizoctonia (*13*), or fusarium (*22*). Perhaps where excessive nitrogen increased disease it was because nitrogen caused moisture stress (*7*).

Chloride forms of fertilizer have produced surprisingly beneficial results for take-all suppression and improved yield (*5*). This may relate to the effect of chlorides on moisture stress in wheat, for example, by reducing osmotic water potentials. Chlorides may also increase the florescent pseudomonads, which themselves are antogonistic to the take-all organism. Fusarium footrot can be fairly effectively controlled by planting in wide rows. Again, moisture stress was alleviated, which may have been the dominating factor (*7*).

Direct drilling in standing stubble benefited control of take-all and eyespot (*4*).

Other pests. Because residue harbors many insects that lay eggs in the soil, serious problems could exist with conservation tillage. But nothing serious has been reported yet (*19*). Extra mice have been noted, for example, in the Pacific Northwest. With conventional tillage they are confined to protected areas, such as fence rows and roadsides. Ordinarily, they tend to migrate only a few meters (*27*). Once conservation tillage is initiated, offspring spread into these fields as a second choice. Realizing this, control should be undertaken in the original breeding area before the spread occurs (James Harris, personal communication). Zinc phosphide bait is especially effective for control in these restricted areas (*27*).

Conclusions

In contrast to initial tests, use of conservation tillage in dryland wheat has produced positive results of late. Modern herbicides are more effective, and perhaps workers have become more knowledgeable about how to manage their operations within the bounds of a herbicide's capabilities. Limited sweep tillage may still be prudent to finish the summer fallow, especially in dry summers and for winter wheat. This tillage should be gauged to break the soil's capillary continuity just above planting depth to suppress evaporation and to help ensure moisture for seed germination.

Among the deterrents to use of conservation tillage are the phytotoxic effects from residue decomposition, plant diseases in localized areas, and limitations of implements for seeding and fertilization. The economic impact of disease and insects, if any, will not be known until there have been more years of experience, particularly with nitrogen fertilizer forms and rates that are chosen to control disease as well as supply the crop. Delayed soil nitrogen cycling from immobilization and denitrification should be no greater, or even less, than with stubble mulch tillage. Mice can be most economically controlled in noncrop breeding areas prior to field infestation.

Growing wheat in widely spaced rows, 61 to 86 centimeters (24 to 34 inches), must be evaluated further because it may offer several advantages in conservation tillage systems. Nitrogen fertilization and planting may be done between stubble rows with less immobilization of nitrogen. The practice may also eliminate phytotoxic effects, improve disease control, simplify planting operations, and still permit maximum crop yields. The practice may take on some of the precarious facets of row cropping, however. Tillage must thus be limited and used only during fallow.

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