Adopting Conservation Tillage in Irrigated Cropping Systems

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Introduction

Tillage in most crop rotations has been used to prepare seed-beds, control weeds and other pests, manage crop residues, reduce soil compaction, and incorporate fertilizer and pesticides. However, excessive tillage increases soil erosion, reduces soil carbon, increases fuel and labor needs, and reduces soil moisture.

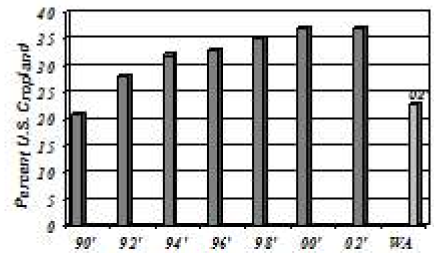
Reduced tillage practices in agronomic crops such as cereal grains, corn, soybeans, cotton, and sorghum were introduced over 50 years ago to conserve soil and water.

Conservation tillage systems are designed to manage crop residues on the soil surface with minimum or no-tillage. Systems are commonly referred to as stubble mulching, eco-fallow, reduced tillage, minimum tillage, no-tillage, and direct seed.

The goal of these systems is to maintain sufficient residue on the soil surface to reduce wind and water erosion, reduce energy use, conserve soil and water resources, reduce costly inputs, and improve profits.

These systems are used throughout the United States and can be applied to all kinds of crop residues and many cropping systems. Adoption in Washington State has been slow compared to the rest of the nation and implementation in irrigated counties is currently small (Figure 1).

Limited adoption of reduced tillage in many cropping systems, wether these are irrigated or dryland, has been due to a perception of poor crop stands or delayed emergence due to cool soils, disease and pest problems, poor soil-seed contact, poor weed control, inability to manage crop residues, inability to incorporate fertilizers and pesticides, and the higher cost to replace equipment.



County	Total (ac)	Conservation Till. (ac)	%
Adams	345,880	10,000	3
Benton	228,880	6,823	3
Franklin	190,000	13,700	7
Grant	415,600	42,000	10

Figure 1. Percent of U.S. crop land under conservation tillage for the period of 1990-2002 and Washington State for 2002. From the 2002 Crop Management Survey, CTIC, Purdue University, West Lafayette, IN.

Developments such as reduced tillage or no-tillage seeding equipment and field implements that handle crop residues and improved herbicide and fertilizer formulations are now available making it feasible for growers to implement reduced tillage.

In vegetable crops, the difficulty of controlling weeds and the need for custom-built equipment continues to slow the acceptance of reduced tillage practices. Commercial seeders which plant into stubble have been developed for most agronomic crops, but are only now becoming available for vegetable crops.

Increasing concern about the sustainability of irrigated crop production systems and environmental quality has emphasized the need to develop and implement management strategies that maintain and protect soil, water and air resources.

Production in irrigated regions typically occurs on soils low in organic matter that are highly susceptible to agri-chemical leaching under poor irrigation scheduling, and wind erosion when soils are left fallow. Adopting conservation tillage to reduce erosion, increase N use efficiency, and build organic matter would improve soil and environmental quality under irrigated farming systems.

The purpose of this review is to present a discussion of conservation tillage and identify where conservation tillage may fit into irrigated cropping systems.

Conservation Tillage Systems

Conservation tillage systems by definition manage crop residues at the soil surface and distribution in the soil profile to significantly reduce water and wind erosion (Figure 2). As a result, the equipment used for conservation tillage must deal with two important issues – crop residues and soil tilth. This is true of all agricultural equipment that engages the soil in some way including tillage implements, cultivators, chemical injection/applicators, and planters.

Figure 2. Corn growing through previous season's residues.

To handle crop residues, equipment has been modified to cut, lift, separate, and/or push crop residues to accommodate an implement or to keep residues away from seeds or plants.

To handle firmer soils often encountered in conservation tillage systems, either equipment weight was increased and/or devices added to increase down-pressure forces of the tillage implement or planting equipment.

Over time, equipment to manage high residue and high soil strength conditions became very efficient although some cropping situations remain a problem today.

The most complete conservation tillage system, no-tillage, leaves the maximum amount of crop residues on the soil surface and produces the least amount of soil disturbance. Because residue or plant material cover is the key to erosion control, the no-tillage system can reduce soil erosion to near natural levels.

Conservation tillage systems that use the chisel plow as a primary tillage operation often achieve only the minimum residue coverage on the soil surface to meet the conservation requirements and impose the most soil disturbance.

Conservation tillage systems are also available that vary in the amount and nature of soil disturbance and their management of crop residues. For example, residue cleaners of various sorts have been placed ahead of planter units to clear crop residues from the row to improve the conditions in the row for germination, emergence, and plant growth.

Adding implements to till a zone in the planter row has also been used to loosen soil and/or create a narrow width seed bed. These adaptations to no-tillage planters create what's called zone or strip tillage systems. The zone or strip tillage operation has been moved to a tool bar so that strips can be prepared prior to planting.

Some have added subsoiling implements to these zone and strip tillage systems to achieve deep tillage in the plant row in efforts to alleviate soil compaction and/or to place nutrients or fungicides deeper into the root zone.

Strip or zone tillage systems leave the inter-row untilled and residue covered for erosion control while creating soil conditions in the row more conducive to seed germination, plant growth and development.

Subsoiling tools were developed that can loosen soil to significant depths with minimal disturbance to crop residues on the soil surface and can be set up to do this in zones or for complete soil loosening.

Compared to conventional tilled systems that leave little crop residue on the soil surface, conservation tillage systems require fewer trips across the field and often a smaller machinery set, thereby saving time, labor, capital, and energy. To many, these benefits led to their decision to adopt conservation tillage, even when soil erosion rates were not excessive.

Today, conservation tillage systems are used in a wide range of cropping systems. Some farmers are dedicated to a particular conservation tillage system while others use a variety of tillage systems within their crop rotation or in an effort to match tillage systems to different soil conditions on their farms.

From an equipment standpoint, growers should focus on how they need to manage crop residues or live plant materials like cover crops and what their soils need in terms of loosening to optimize conditions for plant growth and development. It should not be surprising that the amount of tillage you thought you needed may be in excess of what is actually needed to optimize crop productivity.

In strip-till, crop residues are cleared from a 6-8 inch wide band and a 4-6 inch mound of soil is created using mole knives and ridging disks (Figure 3). Fertilizers (P and K) can be applied through the knife at the same time as tillage and in some states, like Indiana, fall applications of N are made during the strip-till operation.

The strip-till principle enhances emergence and early growth of corn in the spring via a loose, bare soil and to keep the inter-row area firm and residue covered for erosion control and wheel traffic, retaining the traditional benefits of a no-tillage system.

Figure 3. Strip tiller.

The common practice has been to perform strip-till in the fall but there is potential to perform strip-till in the spring if done prior to planting and without the mole-knife to avoid excessive loosening of the soil in the row.

Recent reports indicate considerable success in the use of fall strip-till for corn production, yielding better than no-tillage and comparable to conventional tillage (CTIC Partners, Vol. 17, No. 4, September, 1999).

Reduced Tillage in Potato Rotations

Modifications to equipment and cultural practices that maintain residue cover by reduced tillage are feasible for such crops as potatoes.

Reduced tillage has had limited testing in potato production. Tillage is primarily used in potato production to control weeds, facilitate planting, and increase the ease of later cultivation and harvest. Commercial potato planters, hilling equipment, and reservoir tillage equipment are not currently designed to handle large amounts of crop residues.

Potatoes planted using strip tillage produced yields comparable to potato planted with conventional tillage in North Carolina. Potatoes did not produce well when grown no-till or subsurface-tilled in a sandy soil with low organic matter in North Carolina. Researchers in Maine found no differences in potato yields among six tillage systems, but weeds were more difficult to control with minimum tillage.

Yields were increased by planting potatoes with no-till into preformed beds of ryegrass sod and into cereal rye residues in New York and Washington State**.**

Planting potato with reduced tillage into cereal rye residues reduced potato yield 1 of 4 years and had no effect on yield the other 3 years in New York. Weed pressure also increased in the reduced tillage systems without herbicide applications compared to conventional systems without herbicide applications.

In the 1970's, a team of Washington State University researchers (R. Thornton, R. Kunkel, N. Holstad and G. Hyde) modified a potato planter capable of handling large amounts of residue that resulted in less soil disturbance during planting.

Their modifications equipped a 4-row Lockwood planter with 8-10 inch lister shovels placed in front of the planter shoes, set to run deep enough to spit the residue and clear it to the side (Figures 4, 5). In addition, a 16 inch sweep ran behind the lister at a depth of 6 - 8 inches, to loosen the soil and undercut the residue 6-8 inches on each side of the seed row. Twelve inch covering disks were set to pull soil only from the area cleared by the shovels.

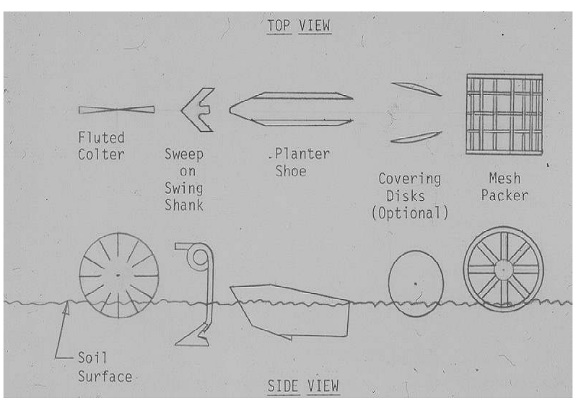


Figure 4. Tool bar design on a Lockwood reduced till potato planter.

They reported that problems encountered during harvest ranged from none to severe depending on the amount of residue, and the time between harvest and planting. Early harvests had enough undecomposed residue to cause a problem, while there were few problems with late harvested potatoes.


Figure 5. Potatoes planted into wheat residue at a Royal slope field site.

Yields of reduced tillage potatoes equaled or exceeded yields of conventionally planted potatoes, ranging from 24-39 T/acre.

Soil Structure and Physical Properties

The benefits of conservation tillage to soil structure and aggregation are well documented. A reduction in tillage changes the distribution of crop residues, reduces soil disturbance, and alters the decomposition rate resulting in increased biological activity and increased soil organic matter. All these lead to increased soil aggregation and therefore improved soil structure.

Compaction is a downside to reduced tillage at least in the short term. This can be especially true of no-tillage which by definition does not allow any tillage other than that needed to place and cover the seed. If a soil is compacted before the start of no-tillage, there is nothing mechanical that can alleviate the compact soil condition.

Roots and increased biological activity, including earth worm activity, can alter compacted layers. However, this is a gradual process that occurs over a number of years. The best way to start no-tillage is to alleviate compact layers by mechanical means prior to starting no-tillage and then to control wheel traffic to reduce the incidence of compaction.

Sub-soiling with minimal residue disturbance and zone tillage have performed well in compacted soils and should be considered if compaction is identified.

It can be stated with certainty that conservation tillage improves soil structure and aggregation over the long term. There are likely to be some short term issues in regards to soil structure during the transition from conventional tillage systems to conservation tillage systems particularly with the strictest forms of no-tillage. With these systems, you are in fact changing the ecology of soils and you will have to be patient as you learn how to optimize the management in your farming operation.

Crops grown without tillage use water more efficiently. The water-holding capacity of the soil increases, and water losses from runoff and evaporation are reduced. For crops grown without irrigation in drought-prone soils, this more efficient water use can translate into higher yields.

Weed Control

The difficulty of weed control without cultivation is one of the most important limits on the use of reduced tillage practices for crop production. Tillage or cultivation buries many weed seeds and brings previous buried seed closer to the soil surface.

Weed seeds accumulate in greater numbers at or near the soil surface in no till systems, which often provide excellent conditions for germination. However, weed seed left near the soil surface is also subject to greater fluctuation in water and temperature, is exposed to seed predators and pathogens, and has a shorter longevity than seed buried deeper.

The general practice in reduced tillage systems is to replace cultivation with herbicides, mowing, or flaming to kill the existing vegetation before the crop is planted, but few options exist for weeds that germinate after the crop is planted. Effective herbicide materials for pre-emergence weed control are currently available for beans, cabbage, potatoes, corn, sweet corn, and tomatoes.

Since herbicides cannot be mechanically incorporated into the soil except in strip-tillage systems, herbicides must be applied over the residue and moved into the soil by rainfall or irrigation (Figure 6). More water is necessary to activate the herbicide in no-till systems because the residues intercept some of the herbicide before it reaches the soil. For this reason, higher herbicide rates may be necessary.

Eliminating or reducing tillage affects weed species differently. Some annual weeds such as horseweed, prickly lettuce, common groundsel, and salsify tend to increase in reduced tillage systems as there are more safe sites for seedlings to become established with increased crop residues and little soil disturbance. Other annual weeds such as hairy and black nightshade are favored by soil disturbance.

Figure 6. Corn planted into wheat stubble.

Changes in herbicide selection, timing of application, and interactions of herbicides with crop residues can also result in specific weed species shifts under various tillage systems. Crop residues left on the soil surface can adsorb herbicides reducing the amount reaching the soil surface. Changes in soil micro-environment due to crop residues can also affect persistence of herbicides in the soil and length of residual weed control.

Crop residues can impact the establishment and growth of weed seedlings. Heavy residues shade the soil creating a moist and cool micro-site, which can delay or prevent germination of weed species that require warmer temperatures, greater fluctuation in temperatures, or light for germination.

Establishment of some weed species is favored by these conditions and weed species shifts can result. Decaying crop residues may tie up soil nitrogen in the top several centimeters of soil where most weed seeds germinate and may release allelochemicals that delay or prevent weed seed germination. Decaying cover crop residues of cereal rye, white mustard, and hairy vetch have all been shown to reduce weed density in the following crop. How various weed species respond to reduced nitrogen or allelochemicals results in weed species shifts. Many studies have measured increases in annual grass weeds in reduced or no till systems.

Change in the amount of crop residues left on the soil surface also affects survival of small rodents and arthropods, which can be both beneficial and detrimental. Arthropods that feed on weed seed or weed seedlings can reduce weed populations and impact weed species dominance. In general, arthropods and rodents that feed on weed seeds are increased with reduced tillage.

Perennial weeds generally increase or are more difficult to control in reduced tillage systems. In reduced tillage systems, root systems of perennial weeds are not disturbed by tillage. Timing of herbicide applications (early spring) may not coincide with the most susceptible stage of weed growth. Common milkweed, dandelion, Canada thistle and field bindweed have increased under reduced tillage in numerous studies. With the advent of genetically engineered crops that are resistant to the herbicide glyphosate, some difficult to control perennial weeds may now be managed more effectively in reduced tillage systems.

Annual weed control can be accomplished in reduced till corn and wheat using numerous herbicides registered on these two major crops. However, annual grass and perennial weeds have tended to increase under many reduced tillage systems.

Sweet corn seed, having a higher sugar and lower starch content and a less vigorous seedling than field corn, is more susceptible to diseases, insect feeding, and herbicide injury than field corn. These problems can sometimes be exacerbated using reduced tillage, which can result in lower soil temperatures and higher soil water content than conventional tillage systems. Sweet corn has been grown successfully in the PNW using strip tillage or modified no-till planters that remove some crop residue from the seed row and ensure good seed-soil contact and a warmer soil environment.

Figure 7. Harrowing to reduce weeds after planting.

Weed control in potatoes is accomplished primarily with a combination of herbicides and cultivation. A common weed control system in potato production in the Western United States is a combination of a timely harrow (drag off, Figure 7) and hilling operation plus a herbicide application.

Potato seed pieces are planted deeper than most annual crops and can withstand several aggressive cultivations to remove weeds before potato plants emerge. Cultivation and hilling may increase soil erosion, injure potatoes, increase soil compaction, and bring weed seeds to the soil surface. Despite these undesirable effects of cultivation, 86% of U.S.

potato acreage is cultivated for weed control.

Herbicides are available that reduce the need for cultivation to control annual weeds after planting. Yield of potato was increased by eliminating post plant cultivation and controlling weeds with herbicides alone in North Dakota.

Volunteer potato is the most common perennial weed problem in Pacific Northwest potato rotations. Unharvested tuber density following a commercial potato harvest ranges from 1.5 to10 times the number of potato tubers typically planted for a potato crop.

In most potato growing regions, potato tubers left in the ground freeze and do not present a problem in the following crop. However, in the mild winter climate of the Columbia Basin of Washington, soil temperatures at the 10 cm depth reach -2.4 C, required to kill tubers, only 4 in 10 years, and only 1 in 10 years at the 20 cm depth.

Volunteer potato can be suppressed in corn with a combination of herbicides and cultivation. Herbicides alone are able to suppress vegetative growth of volunteer potato and tuber mass in corn, but do not often reduce the number of new tubers produced. Cultivation one week following post-emergence applied herbicides greatly reduces the number of new tubers produced.

Mesotrione was recently registered for use in corn production and suppresses volunteer potatoes when applied either pre-emergence or post-emergence. Mesotrione has not been tested for volunteer potato control under reduced tillage systems in corn but preliminary research suggests mesotrione may adequately reduce new tuber production without subsequent cultivation.

Many benefits can be derived from reducing tillage in PNW irrigated cropping systems. Shifts in weed species should be expected whenever altering tillage or cropping practices. Dependence on effective herbicides and crop residues to suppress weeds is increased as tillage is reduced.

Many effective herbicides are available in corn, wheat, and potatoes to manage most weeds that are currently present in PNW crop rotations. Less herbicide options are available in crops such as carrots and onions making reduced tillage more challenging in those crops.

Integrating many weed control strategies such as, cover crop use, herbicide use, and cultural practices can help delay or prevent the selection of dominant weed species in any cropping system.

Plant Diseases and Insects

Reduced tillage and large amounts of residues create a new environment or habitat. Both insects and plant pathogen communities react and adapt to the new environment. In general, a reduced tillage environment favors soil-dwelling and litter-dwelling insects and soil-borne diseases over foliar-feeding insects and foliar diseases.

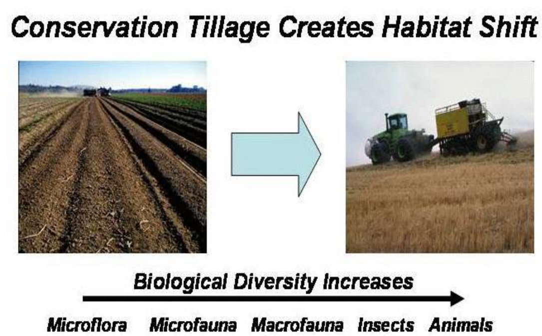


Figure 8. Shift in biological habitats.

Plant Pathogens

Abundant crop residues on the soil surface favor pathogens that over winter in infested crop residue. This infested residue can serve as an inoculum source and also maintains favorable moisture and temperature conditions in the top 6 inches of a soil where pathogens are most active.

Pathogens that have been shown to increase in crops currently grown under reduced tillage conditions include Fusarium head blight, tan spot, leaf blotch, Cephalosporium stripe, take-all and Rhizoctonia root rot in wheat, flax wilt, white mold on canola and legumes, and Ascochyta blight of chickpea.

Some pathogens are actually eliminated or cause less disease in reduced tillage. Prominent examples include foot rot and common root rot of wheat, and blackleg of canola. Some diseases, such as white mold on canola can be increased or decreased depending on the rotation.

For some diseases, such as, stem or leaf rusts, crop residues have little influence on infections because the source of these diseases are spores that are carried long distances in the wind. They originate from diseased plants and not from spores arising from the residue.

However, the intensity or severity of diseases caused by some foliar pathogens may increase with the presence of residues because it also serves as an inoculum source and because the stubble modifies the microclimate.

Generally, the amount of residue does not influence which disease is most common or the ratio of the pathogens that might be present. The amount of residue only contributes to the intensity of a disease potential.

Table 1. Influence of crop residues and reduced tillage on field and sweet corn diseases.

Disease	Pathogen lives in	Trend/w reduced till	Rotation interval
Seed rot	Res./soil	unknown	1-2 yr
Stalk rot	Res./soil	unknown	1-2 yr
Smuts	Soil/plant	NC	NA
HPV	Mite	NC	NA
MDV	Aphid	NC	NA

NC-No change, NA- Not applicable. From Oregon State Cooperative Extension.

Tables 1-3 provide a summary of corn, wheat, and pulse diseases that are influenced by reduced tillage.

Table 2. Influence of crop residue and reduced tillage on wheat diseases.

Disease	Pathogen lives in	Trend/w reduced till	Rotation interval
Root rot	Res./soil	Decrease	2-3 yr
Pythium	Res./soil	NC	3-4 yr
Ceph. stripe	Res./soil	Varies	2-3 yr
Take-all	Residue	Varies	1-2 yr
Leaf Spot	Residue	Increase	1-2 yr
Rusts	plants	NC	NA
Smut	Seed	NC	NA
Bunt	Soil/seed	NC	NA

NC-No change, NA- Not applicable. From Krupinsky, et al., 1997.

Table 3. Influence of crop residue and reduced tillage on pulses (peas, beans, lentils).

Disease	Pathogen lives in	Trend/w reduced till	Rotation interval
Ascochyta	Res./seed	Increase	2 yr
Sclerotinia	Soil	Decrease	3+ yr
Anthracnose	Res./seed	Increase	3-4 yr
Damping off	Res./soil	Increase	3+ yr
Botrytis rot	Res./seed	Increase	2-3 yr
Powdery mildew	Residue	NC	3-4 yr

NC-No change, NA- Not applicable. From Krupinsky, et al., 1997.

Seed-treatment fungicides are not effective against most soil-borne diseases with the exception of damping-off diseases that act directly on the seed or emerging seedling caused by *Pythium* or *Rhizoctonia*. Thus, management of these diseases relies heavily on good cultural management and host resistance.

Insects

Conservation tillage is an effective insect pest management tool if the insect pest habitat is less suitable for development under reduced tillage conditions. For example, various workers have shown that abundance of several insect pests, including Mexican bean beetle, banded cucumber beetle, and lesser corn-stalk borer, was lower in reduced tillage and no-till fields compared with conventional tillage systems.

Particularly, modified tillage systems with cover crops may be useful for potato production. An example of an insect pest managed by conservation tillage in potato fields is the Colorado potato beetle.

Studies conducted in tomato fields in Maryland and Virginia showed that Colorado potato beetles were more abundant in conventionally tilled than in no-till fields. Conventional fields supported higher numbers of overwintering adult beetles than no-tilled fields.

Apparently, non-host vegetation (such as rye and wheat) and crop residues in no-till fields impede the search for potato plants by emerging adult beetles, resulting in lower numbers of first generation adults and larvae. Also, lower soil surface temperatures found in reduced-tilled field limit beetle walking and flying activities in the spring.

Planting potatoes through a spring cover crop would have the benefit of reducing the population of beetles initially colonizing potato fields. A study conducted in Virginia indicated that the use of a rye cover crop, which is mowed in the spring, reduced early spring armyworm damage in corn; similar work may be adaptable to potatoes, particularly as rye and other small grain cover cropping is becoming a common practice with many potato growers.

Another important aspect of the use of reduced or no-tillage in many agricultural crops, including potatoes, is the enhancement and conservation of several beneficial arthropods, natural enemies of several insect pests. This is especially true when this conservation tillage is coupled with crop rotation.

Figure 9. Predatory stink bug feeding on Colorado potato beetle larva.

Results of several studies looking at these two tactics, used alone or combined, showed that these practices significantly increase populations of many beneficial arthropods, including spiders, predatory mites, lady beetles, ground beetles, rove beetles, tiger beetles, minute pirate bugs, plant bugs, assassin bugs, big-eyed bugs, damsel bugs, stink bugs, lacewings, hover flies, tachinid flies, and several parasitic wasps.

Many of these natural enemies are generalist predators and will feed on several potato pests including Colorado potato beetle, aphids, wireworms, and mites (Figure 9).

Studies have also shown that mulches can play several beneficial roles in potato integrated pest management programs. Mulches can reduce potato field colonization by the Colorado potato beetle and can also increase populations of several predators such as spiders and ground beetles.

Less tillage may also allow for greater weed presence during parts of the growing season. The presence of flowering weeds provides nectar and pollen for the non-predacious adult parasitic wasps and lacewings (Figure 10).

Figure 10. Lacewing larva feeding on an aphid.

Although the impact of these beneficials on potato pests is not well known, these organisms play a very important role in regulating potato pests, especially if more selective and soft insecticides are used.

One of the important potato pests that may be reduced by these beneficial arthropods is the green peach aphid, a major vector of potato viruses, including potato leaf-roll virus (PLRV) and potato virus Y (PVY). Adopting reduced tillage would help maximize the impact of these natural enemies on potato.

Initial concerns about insecticide distribution and efficacy in residue-covered fields have decreased. Pesticide labels now provide information about soil factors (texture, pH, organic matter content), climate, insect or disease development, and crop residue that may effect the efficacy of a given chemical. Chemical manufacturers put on their labels times of application and rates that compensate for complicating factors.

Integrated pest management programs can be used in any production system. Long-term control measures such as crop rotation, insect resistant seeds, planting dates that avoid peak periods of insect outbreaks, trap crops and cover crops are easily incorporated into a reduced tillage system.

Soil Organic Matter and Microbial Activity

Organic C, N, P and S concentrations and microbial biomass and activity are known to increase greatly in the surface layer of soils under reduced tillage than under conventional inversion tillage.

Tillage affects the amount of soil organic matter (SOM) buildup in two fundamental ways, (1) through the physical disturbance and mixing of soil and the exposure of soil aggregates to disruptive forces and (2) through controlling the incorporation and distribution of plant residues in the soil profile.

The degree of residue incorporation has a major effect on the rates of decomposition. In temperate climates, decomposition rates of residues are generally slower with residue left on the soil surface than when buried in soil. The combination of reduced litter decomposition rates and less soil disturbance usually results in greater amounts of SOM in reduced tillage vs conventionally tilled systems after a few years.

Differences in SOM between no-till and conventional till are most extreme near the soil surface, primarily due to differences in the distribution of residue inputs. The increase in SOM under no-till averages about 3000 lbs/acre after 5 years for soils managed without irrigation. The range of SOM increase is 5 to 20% dependent upon soil type and the amount of initial soil organic matter.

Irrigation will significantly increase decomposition rates of surface residues because of improved water and nitrogen availability through overhead applications as well as a greater more active biological community. However, few estimates of the build-up of SOM under irrigation are available.

Tillage determines the spatial distribution of habitats and substrates that regulate the dynamics of soil microbial populations and the biological processes they mediate.

Table 4 shows representative ratios of the major groups of soil microbial populations between no-till and conventional tillage systems. Microbial populations increase in the surface of no-till compared to conventionally tilled soils. At the depth populations of aerobic organisms (especially nitrifiers, NH_4, NO_3 oxidizers) with tillage are significantly higher than those with no-tillage; however, populations of anaerobes and denitrifiers were higher with no-tillage. This indicates that the biological environment of no-till is less oxidative than conventional tilled systems.

Under such conditions, SOM and total nitrogen would tend to increase. These results indicate that soils with residue left on the surface may need more N then those with residues incorporated.

Table 4. Ratio of microbial populations between no-till (NT) and conventional till(CT). A value of 1 indicates no difference between NT and CT, >1 higher populations in NT, <1 higher populations in CT.

	Ratio of microbial population (NT/CT) with depth		
Microbial Group	0-3 in	3-6 in.	0-6 in
Total Aerobes	1.35***	0.71***	1.03
Fungi	1.57***	0.76**	1.18
Actinomycetes	1.14***	0.98	1.08
Aerobic bacteria	1.41***	0.68***	1.03
NH_4 oxidizers	1.25*	0.55**	0.89
NO3 oxidizers	1.58*	0.75**	1.14
Anaerobes	1.57*	1.23	1.32*
Denitrifiers	7.31*	1.77	2.83

Significant at the * p=0.05, **p=0.01,***p=0.001.

Of the many biological processes influenced by conservation tillage, mineralization and immobilization of plant nutrients are most important. Mineralization is the process regulating the release of plant nutrients through microbial decomposition of crop residues or soil organic matter. Immobilization is the process where released nutrients are incorporated into the soil micro-flora during decomposition and are temporarily rendered unavailable to plants.

The processes of mineralization and immobilization occur in all natural and cultivated systems, and are fundamental to a healthy, active microbial population, important in disease suppression, the improvement of soil chemical and physical conditions, and sustaining long-term and efficient nutrient cycling.

Of particular importance in conservation tillage systems is the decreased decomposition of surface residues and increased immobilization of surface fertilizer N applications (broadcast or through irrigation). Where residues remain on the surface and crops are directly planted into residues of high C/N ratio, i.e. greater than 20:1, (wheat - <100-1, corn - 50:1 residues), the immobilization of soluble N will be greater in reduced-tilled than tilled surface soils.

The distribution of crop residues, soil organic matter and soil organisms with reduced tillage management slows the cycling of N compared with conventional tillage operations until a new equilibrium is reached (2-3 y). Surface soil levels of organic matter, microbial biomass, and potentially mineralizable N are all significantly higher with reduced-tilled as compared with inversion tillage systems. As a result of increased residue and organic matter levels and more optimal water status, greater microbial biomass in surface reduced tillage soils is associated with greater reserves of potentially mineralizable N.

The timing of release and subsequent incorporation of mineralizable N into the developing crop is important to its growth and resultant quality. Availability of N through a late season release can delay crop maturity and harvest. Continued development of fertilizer application timing and equipment such as banding, split applications, injection and variable rate irrigation delivery systems will greatly improve N-use efficiency under reduced tillage.

Summary

With experience, and the increasing availability of reduced tillage equipment for planting, growers should be able to reach yields at least as high as with conventional tillage practices.

Economics will dictate the adoption of many of these practices. To be economically viable over an existing system, conservation tillage should be assessed as either less expensive or more efficient or both.

A system is less expensive if it requires less fuel, labor, and equipment. A system is more efficient if it increases yield or quality. Labor and equipment expenses can be reduced by eliminating field operations, reducing the number of time-intensive operations, or by using larger equipment. A lower labor and equipment requirement is a major advantage of reduced and no tillage cropping systems because three and sometimes more operations can be eliminated. The labor and equipment savings are offset to some degree by higher expenses of herbicides. If yields are increased or if reduced tillage permits better utilization of farm resources, economic returns to the particular production systems are increased by using the reduced tillage system.

Conservation Tillage Information Sites:

http://pnwsteep.wsu.edu/tillagehandbook

http://www.wsu.edu/pmc_nrcs/technotes/plant_materials/tntpm27.htm#Reduced%20Tillage-

http://www.ctic.purdue.edu

http://www.ag.uiuc.edu/~notill/notill.html