KEYS TO SUCCESSFUL PRODUCTION OF TRANSPLANTED CROPS IN HIGH-RESIDUE, NO-TILL FARMING SYSTEMS

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INTRODUCTION

The Relationship Between Tillage and Soil Quality

Reducing or minimizing tillage (particularly inversion of the soil, using the moldboard plow, disk, etc.) increases soil organic matter content, which in turn increases soil quality (Ismail et al., 1994; Doran and Jones, 1996). From the perspective of both the farmer and the soil scientist, in-situ production and retaining high levels of crop residues (high-residue farming) on untilled soil (no-tillage) is the most cost- and time-efficient way of increasing soil organic matter (Crovetto, 1996). Indeed, high-residue/no-till (HR/NT) farming systems can play a major role in achieving a sustainable agriculture worldwide (Lal et al., 1990).

The Advantage of Using Transplants in HR/NT Systems

High-residue covers can interfere with seed germination and seedling growth, lowering the chance of achieving adequate plant survival and stand with direct-seeded crops. Conversely, proper establishment of large, vigorous transplants minimizes crop interference and dramatically increases the chance of plant survival in high-residue covers. In addition, using transplants favors rapid canopy closure and weed suppression, reducing the need for chemical weed control (Morse, 1995).

No-till Equipment: A Limiting Factor

For many decades, home gardeners and small-scale farmers have applied organic mulches to conserve their soil and water resources, improve weed and pest control, and increase yield and quality of vegetable crops (Dutton, 1957). No-tillage systems (using *in-situ* mulches) have all the advantages of using applied mulch, without disturbing the soil and requiring the time-consuming and often uneconomical practice of purchasing, hauling and applying straw and organic waste materials.

If organic mulches are such a valuable resource, why are HR/NT systems not widely practiced in the United States and other areas of the world? Until recently, a major problem slowing adoption of no-till systems has been lack of available equipment. However, during the past five years, equipment and associated technology have been developed and are commercially available for small-scale farm production of transplanted crops in HR/NT systems (Morse et al., 1993). This paper will attempt to briefly outline and summarize key components of HR/NT systems that have been tested and used successfully by farmers in many areas of the United States in the 1990s.

NO-TILL TRANSPLANTED CROPS IN THE 1990S–KEYS TO SUCCESS

High, profitable yields are achievable using HR/NT production systems. Growers should use a year-round systems approach in HR/NT farming. Success depends on 1) selecting the most sustainable or appropriate crops, cultivars, soils and micro climatic conditions and 2) identifying and applying yield-enhancing practices inherent or specific for HR/NT systems. This paper will focus on the latter: yield-enhancing practices specific for HR/NT systems. In the sections that follow, four production strategies (objectives) are briefly presented, emphasizing proper use of available equipment and associated technology. These four objectives are explained more extensively in Morse et al., 1998.

Objective I: Produce a dense, uniformly distributed cover crop prior to transplanting

Sparse, unevenly distributed surface coverage is a major cause of poor results in NT transplanted crops. In contrast, establishing a dense, uniformly distributed cover crop prior to transplanting provides the greatest chance for success. Benefits from heavy, evenly distributed residues include weed suppression, reducing or even eliminating the need for preemergent herbicides; greater conservation of both soil and water; and greater trafficability resulting in improved flexibility in timing field operations.

With NT production systems, investing in cover crop residues prior to transplanting is like establishing a savings account: you receive the input (deposit) back plus interest later. Every effort and expense to establish a relatively weed-free, dense cover crop will be rewarded later in the form of improved crop yields and quality. Recommended cultural practices include selecting the most adaptive and compatible cover crops, obtaining a uniform dense stand by drilling high seed rates at close between-row spacing and providing adequate growth inputs (water, lime and fertilizer) and growing time to maximize cover crop biomass.

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Objective II: Kill cover crops prior to transplanting, leaving a heavy, uniformly distributed mulch cover over the soil surface

Weeds reduce crop yields predominantly by interspecific (weed-crop) competition for water, nutrients and light. To minimize interspecific competition, the cover crop must be killed and subsequently managed in such a manner that the *in situ* mulch effectively covers and shades the soil surface but does not excessively shade or compete with transplanted crops for light, nutrients and water. Either chemical and/or mechanical methods can be used to kill and generate a dense mulch (Dabney et al., 1991; Morse, 1995).

Chemical methods. Contact herbicides such as glyphosate (Roundup) and paraquat (Gramoxone Extra) are needed to desiccate perennial and immature annual weed and cover crop species. Desiccation should be done two to five weeks prior to transplanting to ensure complete vegetative kill. Glyphosate should be applied at least four weeks prior to transplanting to avoid any potential stunting of the transplanted crops from root-to-root transfer of active glyphosate exuded from roots of the treated cover crop to the roots of the transplanted crops. Often two or more sprays are required to completely desiccate all vegetation.

Mechanical methods. Many species of mature annual grass and legume cover crops can be effectively killed using mechanical methods (Morse, 1995). To be successful, however, mechanical treatments must occur after the annual species have developed beyond their vegetative stage and ideally after flowering. When attempting to kill mixtures of annual species (both cover crops and/or weeds) mechanically, all species should be mature and incapable of regrowth following mechanical treatments. Mechanically killing cover crops has two distinct advantages over using contact herbicides: 1) because herbicides are not used, negative environmental impacts are reduced; and 2) cover crops can be killed just before planting, which maximizes the growth potential and maturation of the residues. Since a relatively high percentage of transplanted crops are irrigated, potential soil moisture depletion problems from drought prior to planting are negated.

Flail mowing and rolling have been used effectively to kill black oat (*Avena strigosa* Schreb.), cereal rye (*Secale cereale* L.), wheat (*Triticum aestivum* L.), foxtail millet *(Setaria italica* L.), buckwheat (*Fagopyrum saggitatum* Grlib.), crimson clover (*Trifolium incarnatum* L.) and soybean (*Glycine max* L.). Flail mowing effectively kills most mature annual cover crops and distributes a uniform layer of organic mulch over the soil surface. Rotary mowers are not recommended because they tend to windrow the chopped residues. Flail mowers contain many small double-edged knives affixed to a parallel rotor that uniformly distribute the finely cut residues over the soil surface.

Rolling can effectively kill many cereal grain crops and some legumes. Cover crop kill is often less complete when rolled than when mowed. However, the NT transplanters function better, and after transplanting cover crop persistence and weed suppression are better in rolled than in mowed plots.

When rolled effectively, dense stands of mature annual cover crops are laid prostrate uniformly over the ground and remain lodged. Complete kill takes from a few days to several weeks, and in some cases partial greening may remain throughout the growing season of the transplanted crop. With most crops, however, any interspecific competition between the transplanted crop and the living cover is not a serious yield-limiting factor and is more than compensated by the many growth-promoting benefits of rolled, heavy crop residue mulch. Planting the transplanted crops in multiple rows often helps considerably to minimize greening of the rolled cover crops and thus reduces interspecific competition effects.

Many types of equipment have been used to roll mature annual cover crops, including:

1. *Disengaged flail mower.* When disengaged and pulled over the ground, the roller gauge wheel of the flail mower can effectively flatten mature crop residues.
2. *Grain drills*. Modified grain drills equipped with coulters and cast-iron press wheels spaced 5 in. apart have been effectively used to roll some cover crops.
3. *Turf or construction rollers.* Commercially available water-filled rollers used for compacting and rolling turf and roadways could be used to roll crop residues.
4. *Roller-crimper drum.* Water-filled drum rollers modified with horizontal welded blunt steel blades or metal strips have been used in Brazil and other locations to roll-crimp cover crops, thus facilitating killing yet leaving plant stems intact.
5. *Undercutter-roller.* A modified blade plow (V-plow sweep) has been used as an undercutter, designed to sever the cover crop roots, followed by a rolling harrow which rolls the residues flat over the ground. This undercutter-roller functions well on raised beds under dry, non-rocky conditions.
6. *Rolling stalk chopper*. When properly adjusted or modified, stalk choppers can effectively roll and evenly distribute high-residue cover crops.

Rolling appears to have considerable merit for mechanically killing cover crops. Ongoing crop residue management research and field testing in several states (Virginia, North Carolina, Pennsylvania, Alabama, Maryland and California) should help clarify the relative advantages and specific uses of different rolling methods for mechanically killing cover crops in HR/NT vegetable production systems.

Chemical/mechanical methods. In some situations where contact herbicides are required to achieve an adequate kill, mowing or rolling may be used to minimize shading of the transplanted crop. For example, contact herbicides combined with or without pre-emergent herbicides can be used to desiccate tall-standing, dense residues, followed by mowing or rolling prior to transplanting or mowing (with mower blades held above the established transplants) after transplanting. With sparse, low-growing cover crops, mechanical methods would not be needed.

The Subsurface Tiller-Transplanter (SST-T - Objective III) functions best in upright standing (intact) residues, regardless of the height of the cover crops. In contrast, in some situations the SST-T functions poorly in lodged desiccated residues or coarsely chopped, unevenly distributed residues such as derived from rotary mowers.

Recently, several cover crops have been effectively killed by rolling first followed by applying paraquat. This method looks very promising since rolling can optimally orient and distribute flattened residues, which facilitates transplanting effectiveness with the SST-T.

Objective III: Establish transplants into cover crops with minimum disturbance of surface residues and surface soil

Lack of reliable NT transplanters and inconsistent stand establishment have been major factors limiting the adoption of NT systems for transplanted crops. Generally, low yields occur when no-tillage is practiced in poorly drained, compacted soils. In NT systems, when a device (chisel plow, coulter, rototiller, undercutter, etc.) is used to loosen or fracture a strip of in-row soil prior to transplanting, both stand establishment and subsequent plant growth are improved, approaching or even surpassing that achieved in tilled soils. With the recent development of the Subsurface Tiller-Transplanter (SST-T), no-tillage with in-row soil loosening and transplanting are combined in one pass across the field. The SST-T is a “hybrid,” combining subsurface soil loosening to alleviate soil compaction and effective setting transplants–in one operation with minimum disturbance of surface residues or surface soil.

The SST-T has an upright, high-clearance design with a double-disk shoe similar to that of earlier custom-made models used in the 1970s. However, in addition, the SST-T has a unique subsurface tiller (SST) aligned in front of the double-disk shoe of the transplanter. The conceptual design and functioning of the SST-T is uniquely different from that of earlier and present-day NT transplanters. With some NT models, the cultivator-type shoe performs both the tilling and the planting functions. Under compacted, rocky conditions, the rigid-mounted shoe is easily bent or broken, which seriously reduces its usefulness for NT systems. In contrast, the spring-loaded soil-loosening component of the SST has heavy-duty construction and subsurface tills a narrow strip of soil ahead of the double disk shoe of the transplanter. The double-disk shoe moves through the residues and tilled strip with relatively little resistance and with minimal surface soil and surface residue disturbance. The SST-T is an efficient (less equipment breakdown) and effective (less transplant resetting needed) NT transplanter that, when used in heavy residues, maximizes soil and water conservation and early field reentry permitting planting, spraying and harvesting operations to be done within a few hours following irrigation or rainfall.

The single coulter and/or double-disk shoe of other NT models often do not loosen enough in-row soil for optimum root-soil contact, resulting in reduced plant survival and slow early growth of the improperly set transplants. Fluted or ripple coulters can loosen more in-row soil than the smooth coulters; however, they do not cut the residues as effectively as the smooth coulter and may cause hair pinning (pressing of the residues into the soil without cutting).

The SST-T is also equipped for precision placement of 1) liquid starter fertilizer-pesticide solutions around the root system of the transplant, 2) liquid or granular fertilizers underneath the transplant and 3) granular fertilizers surface applied in bands on both or either side of the transplant row. A combination of these treatments is expected to eventually give the most efficient use of soil amendments. Also, a drip layer attachment became available in 1997. This attachment places drip tubing at varying depths below the crop residues and in close proximity of the crop row.

Objective IV: Practice year-round weed control

The old adage “an ounce of prevention is worth a pound of cure” is particularly valid in HR/NT farming. Weed control can be achieved two ways--directly using both chemical and mechanical means and indirectly by using cultural practices that promote rapid plant growth and canopy closure. Preemergence and post-emergence herbicides can be applied and, in conjunction with physical and allelopathic effects associated with high-residue covers, often provide adequate weed control. However, the best direct method is to lower weed and seed populations prior to transplanting (i.e., apply aggressive weed-control measures prior to and/or during production of the cover crop).

Of critical importance, NT fields should not have a serious perennial weed problem such as nutsedge, quackgrass, Johnsongrass or morning glory. Weedy fields should be cleaned up prior to seeding the cover crop; and/

or, if necessary, herbicides should be used in conjunction with production of the cover to minimize weed population prior to transplanting. Appropriate use and timing of pretransplant herbicides to achieve a "stale seedbed" (reduced weed seed population) and a dense weed-free cover crop are generally an inexpensive, more environmentally friendly use of herbicides than if applied later in conjunction with production of the transplanted crop.

The term "stale seedbed" (more appropriately stale transplant bed) refers to techniques allowing weed seeds in the soil surface to germinate and be killed without redisturbing the soil other than the seeding operation. Fallowing the NT field prior to seeding the cover crop and eradicating emerged weeds, either by mowing or with herbicides, followed by NT drilling cover crops is an excellent way of obtaining both a stale seedbed and a weed-free cover crop prior to transplanting.

Using cultural practices that promote rapid plant growth and canopy closure will result in improved weed suppression and higher crop yields. Recommended cultural practices include 1) using large, vigorous transplants; 2) arrangement of plants in multiple rows; and 3) precision placement and timing of fertilizer and water.

FUTURE NEEDS–2000 AND BEYOND

Strengthen competitive position of small farms in American agriculture

A recent report from the USDA National Commission on Small Farms emphasized adoption of sustainable agriculture as a profitable, ecological and socially sound strategy for small farms (USDA, 1998). Availability of affordable and effective small-scale, no-till equipment is essential to expedite adoption of no-tillage, especially HR/NT farming systems. Farmers and researchers must continue to refine and develop no-till equipment for mechanically killing high-residue cover crops, plant establishment (both direct seeding and transplanting) and harvesting.

Develop HR/NT systems for organic farmers

Historically organic farmers have avoided NR/NT systems because mechanical weed control is generally complicated by surface residues. Paradoxically, primary tillage and weed implements used by organic farmers incorporate surface residue, excessively aerate the soil and reduce soil organic matter content and soil quality. Research is urgently needed to evaluate utilization of legume-grass mixtures and injectable (liquid, granular, pelleted, etc.) organic fertilizers in HR/NT systems for production of organic vegetables.

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