Project report submitted to the Organic Farming Research Foundation:

Project Title:

Using High-residue Cover Crop Mulch for Weed Management In Organic No-till Potato Production Systems

FINAL PROJECT REPORT

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Summary

Weed management is considered the most challenging production problem facing organic farmers. Without effective herbicides, organic growers normally rely on hand weeding and multiple cultivations, which can be expensive, time consuming and degrade soil quality. Applying thick layers of organic mulch can control weeds; however, this practice is normally cost-prohibitive. Although equally challenging, organic no-tillage (NT) systems offer cost-effective improvements in both weed management and soil quality. This paper highlights recent research (2002-2004) funded by the Organic Farming Research Foundation on organic NT potatoes (*Solanum tuberosum* L.) and includes relevant data from past NT potato studies (1995-2001).

Based on these data (1995-2004), high-residue raised-bed NT systems are a viable option for producing organic potatoes, particularly in warm long-season climates. Success is most likely achieved in climates and situations where high-residue mulch favorably impacts the growing environment of the potato crop—e.g. suppression of weeds and pests (e.g. Colorado potato beetle), moderation of soil temperature, increased plant-available water and nutrients, and improved soil quality. Recommended best-management practices arising from these studies include (1) erecting and nutrient loading (soil building) raised beds before seeding cover crops; (2) drilling high-residue grass-legume mixtures on raised beds--e.g. rye/hairy vetch and barley/hairy vetch; (3) achieving high soil tilth in in-row areas (grow zones) by using potato planters equipped with a wide-wing subsoil shank; and (4) post-plant killing cover crops (2-3 wk after planting potato seed pieces). Suggestions are also given for using strip-till methods in field and climatic situations not suitable for high-residue NT systems.

Introduction

Weed management without herbicides—the organic farmer's greatest nightmare. Organic growers have expressed interest in using high-residue (3 or more tons/acre) cover crops as an *in-situ* no-tillage (NT) mulch instead of incorporating them as green manure (Morse, 2000). In the traditional organic system, cover crop residues are incorporated, leaving the soil surface uncovered and prone to soil erosion and proliferation of weeds. Under this traditional system, weed control has become the greatest production problem facing organic growers, as documented by National Organic Surveys of certified organic growers (Walz, 1999 and 2004).

In lieu of modern herbicides, organic growers utilize mechanical cultivation as a major component of their integrated weed management strategies (Regnier and Janke, 1990; Infante and Morse, 1996). While cultivation can effectively control weeds, it may lead to soil erosion and decline in soil organic matter, especially in sloping fields. Organic mulches suppress weeds and build organic matter; however, growing, harvesting and spreading mulch are both costly and labor intensive. Legume and brassica green manure provide nitrogen, but weeds flourish after residues are incorporated (Al-Khatib, 1994; Morse, 2001).

Organic no-till—a challenging, but rewarding production system. Weed management with reduced or no cultivation is appealing to many organic producers, who want to conserve soil, improve soil quality and prevent nutrient runoff (Regnier and Janke, 1990; Wicks et al., 1994; Gallandt et al., 2000). Soil organic matter and soil quality increase more rapidly when high-residue cover crops are retained intact as surface mulch than when incorporated as green manure (Schomberg et al., 1994).

A second area of concern among organic growers is crop vigor, which can be limited by soil moisture and nutrient availability (Phatak et al., 2002; Walz, 1999 and 2004). Often nutrient demand by cash crops is poorly synchronized with nutrient release, resulting in low plant vigor and increased disease and insect problems (Deldon, 2001). Nutrient imbalances tend to be a common problem during transition from conventional to organic systems (Haraldson etal., 2000; Berry et al., 2002). Frequent cultivation can accelerate soil moisture losses during dry spells, and promote surface crusting that hinders penetration of rain water. Organic mulches conserve soil moisture, and can also improve crop nutrient availability (Tindall et al., 1990; Morse, 1993; Schonbeck and Evanylo, 1998; Mundy et al., 1999).

Insect pests and crop diseases are also constraints of major concern to organic producers (Walz, 1999 and 2004). Biological management of pathogens and harmful insects for many crops can be achieved by adopting high-residue NT systems, especially long-term continuous use (Phatak, 1998; Phatak et al., 2002). Successful biological pest management, however, depend on proper selection and management of diverse cover crop and vegetable crop rotations (Phatak, 1998; Grooms, 2002).

This paper summarizes current research (2002-2004) on organic NT potatoes, data from previous NT potato research (1995-2001), and related grower and investigator experience on no-till and strip-till systems for growing potatoes (Hoyt and Monks, 1996; Carrera et al., 2005).

Objectives

The overall goals of this project are to (1) optimize potato yield without using chemical herbicides or fertilizers, and (2) disseminate the knowledge and results generated from this study to farmers and agricultural professionals throughout the United States. The specific objectives of this study are to (1) evaluate high-residue, raised-bed NT systems on weed suppression and tuber yield, (2) assess the potential of different cover crop species and mulch levels to suppress weed growth, and (3) disseminate the results using field days, final report, and grower meetings and publication of an extension leaflet, entitled “No-till Organic Production of Potato—With Emphasis on Weed Management.”

Materials and Methods

A 3-year research project (2002-2004) was conducted at the Kentland Agriculture Research Farm (KARF), located near Blacksburg, VA. Field soil at KARF was a Hayter loam (fine-loamy, mixed mesic Ultic Hapludalf), with pH 6.5, medium potassium and high phosphorus. A different field was used each year and none of the field plots had been planted with potato or other Solanaceous crops for three or more years.

Site preparation. The experimental design each year was a randomized complete block, with three replications. Each complete block (24 ft wide x 220 ft long) included four randomized tillage/cover crop treatments (see Table 3). Each treatment plot (24 ft x 55 ft) consisted of four raised beds (6 ft wide center-to-center, 8 inches high, 4 ft wide on bed tops, and 55 ft long). Dates of main cultural operations are summarized in Table 1. In late September of the preceding year of each experiment, designated fields were disked twice and beds were erected with a

custom-made bed maker. In 2004, aged chicken manure at 3 tons/acre was applied before disking. In NT plots, cover crops were seeded (Table 2) with a 6-ft wide NT Tye drill, adjusted to fit the contour of the bed. Rows were 7 inches apart and uniform high-density stands were achieved for all cover crops each year (Fig. 1U & 1L). Conventional-till (CT) plots were left unseeded, resulting in an uneven cover of winter weeds. No fertilizer or irrigation water were applied after seeding.
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Potato planting. Immediately before planting potato seed pieces, biomass samples were taken of each cover crop, dried for several days at 70 C in a forced-air oven, and weighed to determine biomass yield. Before planting, CT plots were rototilled to a depth of 5-6 inches, and NT plots were left untouched. Certified seed potatoes were cut into seed pieces (averaging 1.5 oz). Seed pieces were placed in a wire bucket, submerged for 5 minutes in a 50:1 water dilution of OxiDate[1], air-dried, and cured for 7-10 days before being planted. Potato seed pieces were planted on all beds in twin rows (24 inches apart, 9 inches in-row, and 5-6 inches deep) with a 2-row Subsurface Tiller-Transplanter (SST-T) (Morse et al., 1993). In one pass across the field, the SST-T sliced the living cover crops in NT plots and tilled soil in CT plots, loosened two in-row grow-zone areas (6-8 inches wide and 8 inches deep), incorporated pelleted Harmony Organic 5-5-3 fertilizer (in lb/acre, 40N-17P-25K), set treated potato seed pieces 5-6 inches deep in the grow zones, and laid drip tubing (2 inches deep in-row) (Fig. 2U & 2L).

Table 1. Dates of cultural practices used, 2002-2004.

Cultural practice[z]	**2002**	**2003**	**2004**
Seed cover crops	Oct. 4	Oct. 3	Oct. 3
Determine cover crop biomass	May 3	April 24	May 5
Plant potato seed pieces	May 13	April 24	May 6
Flail mow cover crops	May 24	May 15	May 27
Apply nitrogen sidedressing	June 20	May 22	------
Apply nitrogen in drip tubing	-----	June 24	June 15
Determine weed biomass	July 7	June 13	July 1
Flail mow potato vines	July 26	-----	-----
Harvest potato tubers	Aug. 2	Aug. 25	Sept. 1

[z]Cover crops were seeded in the year previous to that designated in the table.

[1] OMRI-approved as of Sept. 2005.

Killing cover crops. Just before potato sprouts emerged through the soil surface (2-3 wk after planting), all vegetation (cover crops and weeds) not killed by the planting operation was flail mowed at ground level with a Alamo-Mott flail mower, leaving a thick dead mulch over the entire 6-ft bed (Fig. 3U). The quantity of mulch in the in-row areas (potato grow zones) was normally less than in the adjacent areas, permitting potato sprout emergence without serious physical impedance.

Cultural practices. Plants were sidedressed by hand with 32 lb N/acre (2002) and 52 lb N/acre (2003) from an equal mixture of feather meal, soybean meal, blood meal and sodium nitrate.[2] Plants were fertigated through drip tubing with 4 lb N/acre from a 3:1 mixture of sodium nitrate and Neptune's Harvest liquid fish emulsion. Supplementary water was applied through drip tubing as needed and escape weeds were rogued (pulled or topped) throughout the growing season. Plots were not hilled, cultivated or sprayed with pesticides (organic or chemical).

Table 2. Potato cultivars, cover crops and rainfall. Kentland Agriculture Research Farm, 2002-2004.

Factor	**2002**	**2003**	**2004**
Potato cultivar[z]	Red skin creamer	Kennebec	Elba
Cover crops (seeding rates, lb/acre)[y]	Rye (110, AW&BT)	Rye (110, AW&BT)	Rye (110, AW); oats/rye/hairy vetch (30/35/40, BT)
	Rye/hairy vetch (65/40, AW&BT)	Rye/hairy vetch (65/40, AW&BT)	Rye (110, AW); barley/hairy vetch (65/40, BT)
	Rye/crimson clover (65/25, AW&BT)		Rye (110 AW); oats/hairy vetch/ Austrian winter pea (30/25/35, BT)
Rainfall (inch/month):			
May	3.3	5.5	4.6
June	3.5	8.3	6.0
July	5.1	7.1	3.0
August	1.0	4.6	2.8
TOTAL	**12.9**	**25.5**	**16.4**

[z]Potato cultivars: In 2002, a non-commercial numbered creamer cultivar (B1145-2) was used from the breeding program of Dr. Kathleen Haynes (ARS/USDA, Beltsville, MD).

[y]Cover crops: Rye (*Secale cereale* L.), hairy vetch (*Vicea villosa* Roth), crimson clover (*Trifolium incarnatum* L.), Austrian winterpea (*Pisum sativum* L. subsp. sativum var. arvense [L.] Poir.), barley (*Hordeum vulgare* L.), oats *(Avena sativa* L.). Seeding cover crops—location on bed: AW = interbed or alleyway areas (24 inches); BT = bed top areas (48 inches wide).

[2] Under the national organic standards, sodium nitrate is prohibited unless use is restricted to 20% or less of a crop's total nitrogen requirement.

Data collection and analysis. Weed biomass samples were collected in each plot, dried, and weighed to assess treatment effects on weed suppression. Thirty-foot sections of each plot were harvested with a two-row potato harvester. Tubers were washed and separated into size grades according to USDA standards (Anonymous, 1991). The Statistical Analysis System (SAS) was used to perform all statistical analysis procedures. Fisher's *LSD* test was used for mean separation.

Results and Discussion

Raised beds. To achieve high tuber yields in organic NT systems, beds must have good drainage, be of adequate tilth to provide sufficient soil aeration and structure for tuber set and enlargement, and be adequately covered with mulch (*in-situ* or applied) to provide weed suppression. In a 4-year study, potato yields were 24% higher on NT raised beds than on NT unbedded (flat) soil (Morse, 1997; Morse, 1998). Raised beds are highly beneficial, except for unirrigated well-drained soils in dry climates. Beds can enhance soil drainage and tilth and minimize the danger of excessive soil moisture (waterlogging) (Tindall, 1991; Morse, 1997). Preformed (constructed before drilling cover crops) raised beds provide organic growers the opportunity to improve soil drainage, soil fertility and water storage (>rooting depth).

Table 3. Effects of tillage/cover treatments on biomass of cover crops and weeds and marketable potato tuber yield, 2002-2004.

	Biomass (lb dry wt/acre)		Marketable tuber yield[z]	
Tillage/cover crop	**Cover Crops**	**Weeds**	**Cwt/acre**	**Rel. yield (%)**
2002				
Conventional-till (CT)	-----	81	124ab	100
No-till (NT)--rye	6,050	57	116b	94
NT--rye/hairy vetch	5,630	158	138a	113
NT—rye/crimson clover	6,240	205	111b	90
Significance	-----	-----	*	-----
2003				
Conventional-till (CT)	-----	903	146	100
NT—rye	6,880	1,420	121	83
NT—rye/hairy vetch	6,550	1,060	141	97
Significance	-----	-----	*NS*	-----
2004				
Conventional-till (CT)	-----	960	167b	100
NT—oats/rye/hairy vetch	6,550	71	208a	125
NT—barley/hairy vetch	8,580	107	216a	129
NT—oats/hairy vetch/Aust. pea	4,410	178	192ab	115
Significance	-----	-----	*	-----

[z]Relative yield, compared to the control, CT plots (100); cwt = hundred weight (100 lb).
NS, *Nonsignificant and significant at P = 0.05. Mean separation by Fisher's *LSD* test.

Erecting wide raised beds is the first step in developing permanent controlled-traffic production systems (Magdoff and van Es, 2000; Morse and Creamer, 2005). Broadcasting, subsoiling and deep incorporating needed soil amendments such as lime, gypsum, compost and aged manure before erecting wide beds can enhance the odds of achieving success with organic NT systems (Morse and Creamer, 2005).

Tuber yield. Yield of marketable creamer (2002) and table-stock (2003-2004) potatoes was equal or higher in NT rye/hairy vetch and NT barley/hairy vetch plots than in NT rye or CT plots (Table 3). In 2002, similar yield responses in NT rye and NT rye/crimson clover plots probably occurred because the proportion of crimson clover was very low (<5%) in the rye/crimson clover plots. Final potato germination was high every year, averaging 89%. Although first-emerged plants were mainly in CT plots (at 3 wk after planting, WAP), final counts at 5 WAP were not affected by treatment (data not shown).

In 2004, organic tuber yields in NT plots were similar to the state average for non-organic commercially grown CT potatoes (Anonymous, 2004). Potato yields in 2003 were approximately 35% lower than in 2004 (Table 3). Near record rainfall occurred in 2003 (Table 2), accompanied by abnormal cloudy weather, compared to more normal conditions in 2004. These weather differences probably contributed heavily to yield differences between years. The soil was unusually compacted in 2003, possibly caused by pounding heavy rainfall and reduced microbial activity arising from excessive soil moisture throughout much of the growing season.

Since hilling is not used in raised-bed systems, achieving proper soil tilth and aeration in the potato grow zones is a major determinant for success in organic NT systems (Morse, 1997; Mundy et al., 1999). To ensure proper tilth and aeration in grow zones at planting, the SST-T was equipped with an aggressive 6-inch wide winged subsoil shank that loosened in-row bed areas (grow zones) (Fig. 1L). In 2003, however, the SST-T was equipped with a less aggressive soil loosening system, which possibly contributed to the compacted beds and reduced marketable tuber yields.

Weed suppression. Overall, weed growth in this 3-year study was held below yield-limiting levels without applying herbicides, indicating that the cover crop production and management system employed in these experiments can be used to produce organic potatoes. Cover crop biomass was thick and evenly distributed over the entire bed surface in all NT plots in these experiments (Table 3; Fig. 3L, 4U and 4L). Generally, mature high C:N cereal grain residues persist longer and suppress weeds better than low C:N legumes (Morse, 1999). Although the proportion of cereal grains (rye and barley) was considerably higher in 2002 and 2003 than 2004 (data not shown), weed suppression did not correlate strongly with cover crop types (Table 3). Weed biomass, however, was correlated with seasonal rainfall (Tables 2 and 3). Highest weed biomass levels occurred in 2003, which had near record seasonal rainfall. Much of the weed biomass in NT plots in 2003 was cover crop regrowth. Enhanced weed growth in wet years is a predictable response, especially in organic systems, where herbicides are prohibited (Barber and Bhowmik, 2001). Infante and Morse (1996) showed that weed biomass levels exceeding 1,000 lb/acre at canopy closure were needed to reduce broccoli yield. Weed biomass was at or above this critical level in 2003 and the CT plots in 2004 and possibly explains the reduced potato yields associated with these plots.

When attempting to adopt NT systems, a major challenge is to accurately predict the weed suppression potential of any given situation. Six criteria for assessing the probability of achieving weed suppression in organic NT systems are presented in Table 4 (Morse and Creamer, 2005). Weed suppression is likely when most or all the six factors are in the medium to high probability categories (Table 4). Using the six factors listed in Table 4 as a guide helps explain why weed suppression was high in these experiments. Mulch quantity and quality were in the medium-high categories. Delayed killing cover crops until near potato sprout emergence and planting high-density twin rows favored rapid canopy closure (4-5 wk from emergence). All applied organic fertilizer and irrigation water were precision placed in the potato grow zones, favoring growth of potatoes over weed growth.

In 2002, subplots were sprayed with recommended herbicides (S-metolachlor and linuron) to assess effectiveness of the high-residue mulches to suppress weed growth. Both weed biomass and potato tuber yield were unaffected by herbicide applications, indicating that the high-residue mulch system used held weeds below yield-limiting levels (data not shown).

Insect management. High-residue cereal grain straw mulch is known to greatly reduce potato yield losses caused by Colorado potato beetle (CPB) (Wyman et al., 1994). Although CPBs were present at KARF all three years in non-organic vegetable and potato fields, incidence of CPB in organic plots was very low (data not shown). Low incidence of CPBs in these studies is attributed to persistent high-residue mulch in the NT plots and associated farmscape plantings (Wyman et al., 1994).

Table 4. Criteria for assessing probability of weed suppression in organic no-till systems (Morse and Creamer, 2005).

Site factor	**Probability of achieving weed suppression**		
(criterion)[z]	**Low**	**Moderate**	**High**
Mulch quantity[y]—dry wt (ton/acre)	<2	2-4	>4
—soil coverage (%)	<75	75-95	>95
—depth (inch)	<2	2-4	>4
Mulch quality—C/N ratio	<15	15-25	>25
Perennial weeds (% of total weeds)	>20	2-20	<2
MWFP (canopy closure, wk)	>6	4-6	<4
Monthly in-season rainfall (inch)	>4	2-4	<2
Fertigation method	overhead	furrow	drip

[z]C/N ratio = carbon to nitrogen ratio (wt to wt basis); MWFP = minimum weed-free period, defined as the length of time a crop must remain free of weeds after planting in order to prevent yield loss—normally, the MWFP coincides with the time of canopy closure; fertigation = when water and soluble organic fertilizer are applied in the irrigation system.

[y]John Teasdale, personal communication.

Recommendations

This research has assessed the capacity of high-residue NT systems to suppress weeds and achieve profitable marketable yield of organic potatoes. Success with organic NT potato systems is most likely to occur in fields where high-residue surface mulch favorably impacts the growing environment of the potato crop—e.g. suppresses weeds and pests, enhances availability of water and nutrients, moderates soil temperature, and improves soil quality. Based on these research data, related experiments and grower experiences, several recommendations are presented.

Grow potatoes on raised beds. Erecting preformed raised beds in late summer before drilling cover crops can be of critical importance, especially in fine-textured soils and cooler short-season climates. Erecting and maintaining wide beds (5-7 ft center-to-center, 3-5 ft on bed tops, and 7-9 inches high) and using high-density plantings (2-3 rows per bed) constitute a permanent controlled-traffic system that can achieve rapid canopy closure and improve weed suppression on bed tops (Magdoff and van Es, 2000).

Judicious use of crop rotations on permanent wide raised beds can enhance both short- and long-term soil tilth and plant-available nutrients and water, especially if organic-approved soil amendments (compost, manure, lime, gypsum) are thoroughly mixed deep in the soil profile during bed establishment. After harvesting, the location and integrity of beds can be maintained by using zone tillage implements (rototillers, spading machines, powered harrows) and ridging (bed-making) equipment to rebuild the beds and incorporate crop and weed refuse and applied soil amendments. Bed rebuilding and drilling cover crops immediately after harvest can prevent or minimize weed seed production, soil erosion and leaching of nutrients, and enhance long-term weed suppression and soil quality (Morse and Creamer, 2005).

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Produce *in-situ* high-residue cover crops. High-residue mulch—either produced *in*-situ and/or applied—can increase potato tuber yields, especially in warm climates and under moisture-deficit conditions (Midmore, 1991). Weeds can be held below yield-limiting levels in organic NT systems, provided that requisite (1) production and management of high-residue cover crops and (2) stand establishment and vigorous crop growth are achieved. Diverse crop rotations involving different cover crops and cash crops are highly recommended for all productions systems—chemical-based, organic, and integrated.

Use of high-residue cover crop mulch is considered essential for weed suppression in organic NT systems, particularly for inter-bed areas (alleyways). Uniform high-density cover crop stands are achieved more readily by seeding with precision drills than broadcasting and mechanical seed incorporation. Properly adjusted precision drills are particularly effective for achieving uniform dense stands on raised beds (Fig. 1U). Generally, grass cover crops or grass-legume mixtures suppress weeds better and persist as dead mulch longer after being killed than legume monocultures.

Strip intercropping high-residue weed-suppressing cover crops such as cereal rye in alleyways and growth-promoting cover crops on bed tops offer great potential for future research (Chen et al., 2004; Morse and Schonbeck, unpublished data, 2004; Tanaka et al., 2005). Examples of growth-promoting cover crops are (1) legume monocultures or legume-grass mixtures (e.g. rye/hairy vetch or barley/hairy vetch) for enhancing plant-available nitrogen, and (2) tropical winter-killed species (e.g. sunn hemp and/or sorghum sudangrass), brassica monocultures (e.g.

oilseed radish), or brassica-legume mixtures (e.g. oilseed radish and crimson clover) for improved nitrogen fertility, pest suppression, and vertical zone building.

Manage cover crops to maximize weed suppression. To be an effective weed management tool, cover crops must (1) produce high biomass levels (3 or more tons/acre) (2) be easily killed by mechanical methods, (3) suppress weed-seed germination and/or weed growth for a sufficient duration to minimize weed-crop competition, and (4) not interfere directly with crop growth—i.e. must not be allelopathic to crop growth. Many factors interact to determine the capacity of cover crops to suppress weeds below crop yield-limiting levels (Table 4).

For potatoes, proper coordination (timing) of crop establishment (planting date) and killing date of cover crops can play a major role in achieving weed management and tuber yield. High-residue living cover crops suppress weeds better than dead mulch; thus, delayed killing cover crops until just before potato sprout emergence (2-3 wk after planting) will improve weed suppression on bed tops, especially in twin-row high-density potato plantings. To effectively suppress weeds, dead cover crop mulch must be spread uniformly over the soil surface. Thus, use roller-crimpers or flail mowers (Fig. 3U) to kill mature cover crops and avoid using implements such as rotary mowers that windrow residues (Creamer and Dabney, 2002). In times of excessive early-season rainfall, remedial weed management measures (hand weeding, cultivation, acetic acid sprays) may be required to minimize weed-crop competition and crop yield losses (Al-Khatib, 1994; Barber and Bhowmik, 2001; Morse and Creamer, 2005). In all cases, roguing to prevent production of weed seeds is an important cultural practice for organic growers, and is considered essential for organic farmers who are exploring NT systems for production of potatoes or any other crop. Roguing out escape weeds by hand or using high-residue cultivators can prevent weed seed production.

Use properly equipped planters to establish potato seed pieces in untilled mulched beds. For best results, NT planters should be equipped to slice surface residues, till in-row strips (grow zones), precision place potato seed pieces 5-6 inches deep in the grow zones, and precision place organic fertilizer and drip tubing, if needed. Planting must be accomplished with minimum disturbance of surface residues and surface soil. To improve weed management, plant twin rows (18-24 inches apart and 9-12 inches in-row), mix fertilizer in the grow zones, delay killing cover crops until just before sprouts emerge, irrigate as needed, and apply extra mulch 1-2 wk after sprout emergence, if needed.

In situations not amenable to high-residue NT systems, strip-till bed tops and use conventional potato planters. Situations in which growers may appropriately choose alternative conventional systems include (1) in cold short-season climates; (2) when cover crop failures occur, leaving sparse uneven stands and proliferation of winter weeds; (3) when winter-killed cover crops such as spring oats and purple vetch are grown, leaving inadequate residues and winter weeds; and (4) when properly equipped NT planters are not available. Tilling only bed tops or the in-row areas (grow zones) of bed tops and leaving the alleyways untilled and covered with sod or cover crops is an alternative "hybrid' system that can be used in the above situations. Growers can use shallow surface equipment on bed tops (rototillers, spading machines, powered harrows) that will incorporate winter weeds and cover crop residues, maintaining the basic integrity of beds and enabling planting and cultivation of bed tops using conventional equipment (Jackson et al., 2003).

In normal strip-till systems with deep incorporation and single rows, weed-crop competition and subsequent reduced crop yields will probably occur, unless weed growth is curtailed by applying organic mulch or cultivation (Al-Khatib, 1994; Hoyt and Monks, 1996; Mundy et al., 1999). However, improved weed suppression can occur when organic residues (weeds and cover crops) are flail mowed and shallow incorporated in the surface soil (0-2 inches). Integration of twin rows on wide raised beds and shallow incorporation of winter weeds and cover crop residues 2 wk after planting potato seed pieces gave good weed suppression through canopy closure (Barber and Bhowmik, 2001; Morse, unpublished data, 2003).

Figure 1. Upper (U)—Drilling rye on 6-ft wide raised bed; down pressure was adjusted separately on each row to achieve uniform seed depth across the bed. Lower (L)—Uniform high-density rye-legume cover crop in early April, suppressing winter weeds and resulting in uniform high-residue mulch in May.

Figure 2. Upper (U)—SST-T planting potato seed pieces in living rye cover crop. Lower (L)—Underside view of SST, showing twin-row configuration (left to right), 20-inch straight counters to slice rye, wide-wing subsoil shanks to till (loosen) soil in potato grow zones and attached tubes to surface band organic fertilizer in grow zones, and 18-inch wavy coulters to incorporate the fertilizer in the grow zones. Two NT planters (not shown) were mounted directly behind the wavy coulters to set potato seed pieces 5-6 inches deep in the grow zones.

Figure 3. Upper (U)—Flail mowing remainder of living rye in NT plot, just before potato sprouts emerge through soil surface. Lower (L)—Twin-row arrangement on NT rye raised-bed system (4-5 wk after planting); note uniform dense mulch still remaining over the entire bed.

Figure 4. Upper (U)—Complete canopy closure in NT rye raised-bed (8-9 wk after planting. Lower (L)—Side view of NT raised bed (7-8 wk after planting).

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