No-Till Production of Irish Potato on Raised Beds

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INTRODUCTION

In an extensive review of organic mulches applied on conventionally tilled (plow-disk) fields, Dutton (1957) concluded: 1) that organic mulches such ashay and straw often increased both yield and quality of Irish potato *(Solanum tuberosum* L.) and 2) that improved soil physical properties under the mulch, particularly lower soil temperatures and conservation of soil moisture, were responsible for the yield and quality enhancement. In these mulching studies, highest yield increases generally occurred in hot climates where temperatures were above optimum during tuber development and where soil moisture deficits are prevalent. Thus, applying organic mulches in hot, dry climates normally results in increased potato yield (Dutton, 1957).

Although mulching generally retards growth and reduces tuber yield in cool, wet climates, yield of potato often increases in hot, humid regions, if provisions are made to assure adequate soil drainage. Under conditions of adequate soil moisture in hot climates, reduced soil temperatures under organic mulches can increase tuber yield and quality. However, many potato mulch experiments (Dutton, 1957) have clearly shown that, when heavy (thick) mulches are prematurely applied (at or soon after planting), slow emergence, poor stands, and stunted early growth often result.

Because applying thick layers of organic mulches is economically prohbitive on large-scale commercial farms, researchers have assessed the potential of reduced tillage systems for production of Irish potato (Midmore, 1991; Lanfranconi et al., 1993; Hoyt and Monks, 1996). Although the results of reduced tillage systems have been encouraging, in most cases potato planted in flat, untilled, or strip-tilled soils have required conventional hilling practices to achieve yields equal to that of conventional tillage systems (Lanfranconi et al., 1993; Hoyt and Monks, 1996). In such cases, organic residues were either incorporated or buried, leaving bare soil which minimizes or even negates potential soil-cooling and moisture-conserving effects during tuber bulking.

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In Mame, potato seed pieces were planted on 6 June 1990 on bare tilled soil (conventional tillage, CT), flat untilled soil (NT), and fall preformed, ridged soil (RT). A sparse cover of barley *(Hordeum vulgare* L.) was grown on NT and RT plots. All plots were hilled on 30 July 1990. Marketable yields were 98, 117, and 56 cwt/a for CT, RT, and NT respectively (Tindall, 1991).

After reviewing the available data on organic mulching of conventionally planted potato fields (applied organic mulches) and reduced tillage potato systems *(in situ* mulches), the following conclusions can be drawn:

1. Applying thick layers of organic mulches after crop emergence will often increase tuber yield in hot climates where summer temperatures are above the optimum for tuber development and particularly where summer droughts are common.

2. Except in areas where spring planting temperatures are unusually high, thick mulches applied at or near planting may slow germination, reduce stands and retard early plant growth. Premature application of thick mulches is particularly harmful in humid climates.

3. Applying thick mulches in cool, wet soils is likely to retard growth and reduce yield.

4. To achieve high yields with no-till mulch systems the untilled soil must have good drainage, be of adequate tilth to provide sufficient aeration and structure for tuber growth and enlargement, and be adequately covered with an *in situ* mulch to improve soil physical properties during tuber bulking, yet not be excessively covered at planting that might delay plant emergence, reduce plant stands and retard early growth.

5. Applying mulches or using no-till mulch systems in hot, dry climates should improve soil physical properties and increase tuber yield. In hot, arid regions, growing potato on preformed beds is not recommended, particularly where imgation is not practiced.

6. In hot humid areas where no-tilled mulching might improve soil properties and increase tuber yield and quality, using preformed beds should minimize the danger of excessive moisture (waterloggmg).

A strong movement in the 1990s toward a more sustainable agriculture has stimulated the development of the Subsurface Tiller Transplanter (SST-T), which was released in late May 1992 (Morse et al., 1993). The transplanter component of SST-T has an upright, highclearance design with a double-disc shoe. In addition, the SST-T has a unique subsurface tiller (SST) aligned in front of the double-disc shoe of the transplanter. The conceptual design and functioning of the SST-T is uniquely different from that of the earlier NT transplanters. With the NT models of the 1980s (NT80s), the cultivator-type shoe performs both the tilling and the planting functions. Under compacted, rocky conditions, the rigid-mounted shoe of the NT80s was easily bent or broken, which seriously reduced its usefulness for conservation tillage system. In contrast, the Spring-loaded in-row soil looseness device (Morse et al., 1993) of the SST has heavy-duty construction and subsurface tills a narrow strip of soil ahead of the double disc shoe of the transplanter. The double-disc 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 resetting needed) transplanting system 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 hr following irrigation or rainfall. In 1995, the SST-T was modified to plant potato seed pieces in flat or bedded NT fields.

In 1994/1995 and 1995/1996, experiments were conducted at Vigmia Polytechnic Institute and State University to assess the potential of using *in situ* cover crop mulches in no-tillage production systems to modify soil properties for production of Irish potato. The objectives were to assess the potential of 1) using preformed raised beds to assure adequate drainage, 2) using the SST-T and grain rye *(Secale cereale* L.) no-till systems to provide *in situ* mulch and adequate soil tilth for tuber development, and 3) applying additional rye straw *after* plant emergence to maintain surface coverage during tuber bulking on yield of marketable Irish potato.

MATERIALS AND **METHODS**

Field experiments were conducted in 1994/1995 and 1995/1996 at the Virginia Polytechnic Institute and State University, Kentland Agriculture Research Farm, Blacksburg. The soil was a Hayter loam (fine-loamy, mixed, mesic, Ultic Hapludalf), with a pH of 6.4. The experimental design was a randomized complete block with a split-split plot arrangement of treatments and three replications. Main plots (12 x *50* ft) were bed elevation: flat and raised (6 in. high). Subplots (6 x 50 ft) were tillage: conventional tillage (CT) and no-tillage (NT). Sub-subplots (6 x25 ft) were applied mulch: control (no mulch applied) and mulched (0.1 1b rye straw/ft^2 of bed surface, applied 2 wk after emergence of first potato plants).

In early fall of 1994 (27 Sept.) and 1995 (28 Sept.), cereal rye was drilled in all plots in rows 7 in. apart at 140 lb/a on 6-ft. wide beds made 2 d prior to seeding with a KMC bedmaker (Kelley Manufacturing Company, Tifton, Ga). Beds were flat on top (42 in. wide). In mid-March of both 1994 and 1995, granular fertilizer was surface broadcast by hand with 50 lb N/a as NH_4NO_3 on all NT plots to maximize growth of cereal rye, and 1.1 -dimethyl-4-4 -bipyridiniumum ion (paraquat) was used at 0.5 a.i./a to desiccate rye and weeds on all CT plots.

One wk prior to planting, the rye and weeds of all plots were desiccated with paraquat at 0.5 a.i./a and CT plots were tilled twice with a 42-in.-wide, Ferguson Tilrovator (Ferguson Manufacturing Company, Suffolk, Va). On 28 April 1995 and 25 April 1996, a 2-row SST-T was used to establish and precision place fertilizer in all plots. In a one-pass operation across the field, the SST-T cleared a 10-in.-wide in-row area of rye residues; loosened an in-row soil area (8 in. wide x 8 in. deep); precision banded granular fertilizer (in lb/a, 90N-39P-82K) 6 in. below the soil surface (2 in. below the seed); and planted and covered seed pieces (2 oz/seed piece) in twin rows, 28 in. apart, 8 in. in-row, and 4 in. deep Martin row cleaners (Martin & Company, Elkton, KY), mounted in front of the SST, were used to clear in-row rye residues. One wk after planting, all plots were sprayed with a herbicide tank mixture of 2-chloro-N-(2-ethyl-6-methylphenyl)-N-(2-methoxy-l-methylethyl) acetamide (metolachlor) at 2.5 lb a.i./a and N'-(3,4-dichloropheny1)-N-methoxy-N-methylure(linuron) at 0.8 lb ai./a. Overhead sprinkler irrigations were used as needed ($\leq$ 1 in./wk) to supplement rainfall in all plots throughout the growing season to minimize moisture stress. Pesticides were applied at planting and at regular intervals thereafter, according to the Virginia Commercial Vegetable Production Recommendations (Baldwin et al., 1995).

During the first wk of September, a 20-ft. section of each sub-subplot was hand harvested, separated into size grade categories according to United States Department of Agriculture standards (Anonymous, 1991), counted, and weighed. Yield data were analyzed across years by analysis of variance (Gomez and Gomez, 1984). The Statistical Analysis System (SAS) was used to perform all statistical analysis procedures (Schlotzhauer and Littel, 1987).

RESULTS AND DISCUSSION

Although first-emerged plants (at 3 wk after planting, WAP) were mainly in CT plots, final emergence at 5 WAP was high (90% average) for all treatments. There were no significant differences among treatments in percentage emerged or plant height at 5 WAP (data not shown). Rye residues were cleared at planting in a 10-in.-wide, in-row area in the NT beds, which probably resulted in a more uniform seedling emergence among treatments.

There were no significant ($P \leq 0.05$) yield interactions among treatments or between years and treatments. Although differences were nonsignificant, yield response to tillage appeared to differ with bed elevation--NT yields increased (4%) on raised beds but decreased (7%) on flat land, compared to CT yields. Research is needed to delineate any possible interactions. In hot, humid climates where irrigation is uncommon, yield response would be expected to vary considerably among treatments with differences in frequency and distribution of rainfall.

Bed Elevation

Growing potato plants on raised beds increased tuber yield by 24%, compared to plants grown on flat soil (Table 1). Increased tuber yields on raised beds occurred in both NT (> 30%) and CT (> 18%) plots. Since rainfall was above average both yr, apparently improved soil drainage increased tuber yields in raised CT and NT beds. Soil tilth appeared to be better in NT beds than flat beds and could explain the additional yield enhancement (30% for NT vs. 18% for CT).

In areas where irrigation is unavailable, the advantages of fall bedding would probably be less in dry years or in arid regions. Possibly, unbedded fields would even outyield bedded fields in dry years without irrigation.

Tillage

Similar yields occurred in NT and CT plots (Table 1). Rye biomass was similar in raised and flat NT plots (averaging 1,800 lb dry matter/a). Based on the yield data of these experiments, the growing environment created by the rye NT cover crop and the in-row soil loosening of the SST-T planting system alleviated any potential yield-lowering compaction and aeration problems that can occur in NT plots (Tindall, 1991). Soil moisture deficits probably did not differ significantly between CT and NT plots because there was ample rainfall and irrigation water was applied as needed.

Marketable tuber yields were high in all plots, more than doubling the average commercial yield in Virginia (Anonymous, 1996). There were no quality differences (size, shape, visual deficits, incidence of pest damage) in tubers from CT and NT plots. All visual observations from planting to harvest indicated that the soil tilth in the NT plots was as good and probably better than that in the CT. In these experiments, cultural practices were followed that maximized soil tilth in the root and tuber growing area without disturbing the entire bed. With exception of in-row soil loosening at planting, the integrity of the rye covered NT bed was undisturbed, maintaining the soil quality advantages of an overwintering rye sod. The rye cover crop was thick and relatively uniform over the entire bed. After plant emergence, hilling was done only on the CT, flat plots.

A custom made twin-wing shank was mounted on the SST that effectively loosened the in-row soil ahead of the modified planter. The potato seed pieces were placed in the center of this loosened area and subsequent root and tuber growth occurred predominantly in this loosened zone.

Applied Straw Mulch

Application of straw mulch 2 wk after crop emergence resulted in increased yields in both CT and NT and bedded and flat plots (Table 1). Possibly the rye residues (both *in situ* and applied) increased tuber yield by cooling the soil and creating more d o r m soil moisture levels (even in irrigated fields) during tuber set and tuber bulking. In dry yr, these favorable yield-enhancing effects from applied mulch would probably be greater than obtained in 1995 and 1996 (both wet years), especially in unirrigated fields.

CONCLUSIONS

Based on 2-yr data the no-till (NT) system used in these studies is a viable option for improving soil physical properties and sustaining tuber yields. Preformed raised beds and post-emergence applied straw mulch significantly increased tuber yield. However, applying thick organic mulches at or shortly after planting potato seed pieces is known to delay crop emergence, reduce stand, and reduce tuber yield. Future research is needed to determine if the presence of thick cover crops *(in situ* mulch) retained over the entire bed surface after planting would be deleterious to tuber yield in NT systems.

On-going and future experiments will determine the advantages and disadvantages of the NT raised bed systems for Irish potato. Detailed soil quality measurements will be taken. Also, cover crop species, residue management techniques, and relay intercropping will be studied to determine best management practices to minimize deleterious early season mulchmg effects and favorably alter mid-late season soil properties of no-till raised beds to improve tuber set and tuber bulking in hot climates.

LITERATURE CITED

Anonymous. 1991. United States standards for grades of potatoes. USDA Agr. Marketing Serv., Washington DC.

Anonymous. 1996. Virginia Agricultureal Statistics. Bulletin No. 68, Virginia Agnc. Statistics *Serv.*, Richmond, VA.

Baldwin, R E., J. F. Derr, H. E. Holt, C. R. O'Dell, S. B. Sterrett, H L. Warren, and H. P. Wilson. 1995. Commercial vegetable production recommendations. Virginia Cooperative Extension ***Service,*** Publication No. 456-420, Virginia Polytechnic Institute and State University, Blacksburg, VA.

Dutton, P. R. 1957. The mulching of vegetables--potatoes. p. 67-96. ***In*** Technical Communication No. 24, CAB, London.

Gomez, K. A,, and A. A. *Gomez.* 1984. Statistical procedures for agricultural research. 2nd ed. Wiley, New York.

Hoyt, G. D., and D. W. Monks. 1996. Weed management in strip-tilled Irish potato and sweetpotato systems. HortTechnology 6(3):238-240.

Lanfranconi, L.E ., R. R. Bellinder, and R. W. Wallace. 1993. Grain rye residues and weed strategies in reduced tillage potatoes. Weed Technology 7:23-28.

Midmore, D. J. 1991. Potato production in the tropics. pp. 728-793. ***In*** P. H. Harris (ed.). The Potato Crop, 2nd edition Chapman and Hall, London.

Schlotzhauer, S. D. and R. C. Littell. 1987. SAS system for elementary statistical analysis. SAS Inst., Cary, NC.

Tindall, T. T. 1991. Potato available nitrogen from barley legume underseedings and reduced tillage/ridge tillage potatoes. M. S. Thesis. University of Maine, Orono, ME.

Table 1. Effects of bed elevation, tillge, and applied mulch on yield of Irish potato ('Yukon Gold'), 1995 and 1996.

Treatment	Marketable tuber	yield (U. S. No. 1)[1]
	(cwt/a)[2]	(%)[3]
Bed elevation		
Flat	294	100
Raised	365*	124
Tillage		
Conventional (bare soil)	334	100
No-tillage (in *situ* mulch)	325[NS]	97
Applied mulch (rye straw)		
Control (no straw)	319	100
Straw mulch	340*	107

[1]US no. 1, all marketable tubers equal or greater than 1 7/8 in. diameter and free of exterior blemishes.
[2]Cwt/a, hundred weight (100-lb units) per a.
[3]Relative yield, compared to the standard or control treatment (100).
[NS, *]For *each* treatment category, F-test nonsignificant or significant at $P \leq 0.05$, respectively. Yield values are means of two years (1995 and 1996). There were no interactions among treatments or between years and treatments.