A Conservation-Tillage, Cover-Cropping Strategy and Economic Analysis for Creamer Potato Production

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ABSTRACT

A two-year experiment was conducted at the Beltsville Agricultural Research Center (BARC), MD, and Virginia Polytechnic Institute and State University Kentland Agricultural Research Farm (KARF), VA, to evaluate potato (*Solanum tuberosum* L.) production of 32- to 57-mm-size-range tubers (referred to hereafter as creamers) in a conservation-tillage, cover-cropping strategy. The experiments used a split-plot design in which the main-plots were cover crop treatments and the sub-plots were different potato selections. Main plot treatments included rye (*Secale cereale* L.), crimson clover (*Trifolium incarnatum* L.), Austrian winter pea (*Pisum sativum* L.), rape (*Brassica napus* L.), oat (*Avena sativa* L.), rye/crimson clover mixture, rape/crimson clover mixture, bare soil/raised beds, and bare soil/flat beds (control). Potato selections tested were B1145-2, B1491-5, and B1492-12 in 2000 and B1145-2, B1102-3, and B0811-4 in 2001. Yields in the conservation-tillage treatments were equal to or better than those in the bare soil/flat bed control with few exceptions. Large-sized tubers (<57 mm) in almost all cases remained below 6% of total marketable yield even when the tubers were harvested late. Delayed harvest did not reduce creamer-sized yields nor did it increase yield of large-sized tubers. Economic analysis shows that net returns from some conservation-tillage treatments are equal to or higher than the conventional-tillage strategy and confirms the viability of the conservation-tillage, cover-cropping strategy. Furthermore, the conservation-tillage strategy in many cases allows timely planting using machinery in the wet soils of Maryland and Virginia during the narrow window of spring potato planting time, whereas the conventional tillage strategy does not offer this advantage.

RESUMEN

Un experimento de dos años de duración fue realizado por el Centro de Investigación Agrícola de Beltsville (BARC), MD y el Instituto Politécnico de Virginia en la Granja de Investigación Agrícola Kentland de la Universidad del Estado (KARF), VA, para evaluar la producción de tubérculos de papa (*Solanum tuberosum* L.) de 32 a 57mm de tamaño (referidos en lo sucesivo como "creamers") con estrategia de labranza de conservación, cultivo de cobertura. Los experimentos se hicieron empleando el diseño experimental de parcelas divididas, en el cual las parcelas principales fueron con tratamiento de cultivos de cobertura y las subparcelas fueron diferentes selecciones de papa. Los tratamientos

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de las parcelas principales incluyeron centeno (*Secale cereale* L.), trébol rojo (*Trifolium incarnatum* L.), guisante austriaco de invierno (*Pisum sativum* L.), colza (*Brassica napus* L.), avena (*Avena sativa* L.), mezclas de centeno/trébol rojo, colza/trébol rojo, suelo sin labranza/camas altas y suelo sin labranza/camas a nivel (testigo). Las subparcelas incluyeron las selecciones de papa B1145-2, B1491-5 y B1492-12 en el 2000 y B1145-2, B1102-3 y B0811-4 en el 2001. Los rendimientos de los tratamientos de labranza de conservación fueron iguales o mejores, con pocas excepciones, que los de los controles sin labranza / camas a nivel. Los tubérculos de tamaño grande (<57mm) en casi todos los casos estuvieron por debajo del 6% de rendimiento total comerciable aun cuando se cosecharon un tiempo después. La cosecha diferida no redujo los rendimientos de los tubérculos del tamaño "creamer" ni tampoco se incrementó el rendimiento de tubérculos de mayor tamaño. El análisis económico muestra que las ganancias netas de algunos de los tratamientos con labranza de conservación, son iguales o mayores que los de la estrategia de labranza convencional y confirman la viabilidad de la estrategia de labranza convencional, cultivos de cobertura. Más aun, la estrategia de labranza de conservación permite, en muchos casos, la siembra a tiempo, utilizando maquinaria en suelos húmedos de MD y VA, durante la corta temporada de siembra de papa de primavera, mientras que la estrategia de labranza convencional no ofrece esta ventaja.

INTRODUCTION

Use of minimum tillage in grain production has become an established practice and has demonstrated beneficial effects on soil conservation, water infiltration, and weed suppression (Williams 1966; Williams and Doneen 1960). Potatoes traditionally required tillage for hilling, weed control, and harvesting, and are therefore less suitable to reduced tillage practices than other crops. However, several studies have explored the potential for reduced tillage potato production (Bennett et al. 1975; Grant and Epstein 1973; Russell and Bellinder 1989; Schuler 1979).

Grant and Epstein (1973) conducted studies at Presque Isle, ME, to evaluate the effects of minimum tillage on tuber yield and quality in commercial potato production. They compared six tillage treatments: chisel-plant, direct-plant, plow-plant, chisel-plant with large hill, control (standard production practice), and control with large-hill/no cultivation. The six treatments did not appreciably affect yields, but did induce differences in tuber firmness and water content, temperature of the soil, and emergence of the potato plants. Bennett et al. (1975) combined the use of cover crops and conservation tillage in commercial potato production. They compared yields in conventional and conservation tillage in which ryegrass (*Lolium multiflorum* x *L. perenne* L.) had been planted into raised beds and reported increased yields under conservation tillage. Dubetz and Bole (1975) and O'Sullivan (1978) reduced N input by using cover crops in potato production. Griffin and Hesterman (1991) evaluated alfalfa (*Medicago sativa* L.), hairy vetch (*Vicia villosa* Roth.), red clover, and sweet clover (*Melilotus* spp.) as green manures in potato production with and without supplemental N. They reported a positive vegetative response by potatoes to green manures, without an increase in tuber yield. However, supplementing the green manures with commercial fertilizer improved yields. They attributed the failure of cover crops alone to enhance yield to the lack of synchronization of legume N mineralization and N demand by the potato crop. Mundy et al. (1999) compared potato production in two locations under three tillage systems: no tillage, conservation tillage, and subsurface tillage. 'Atlantic' potatoes were planted in plots containing residues of sorghum/sudan (*Sorghum bicolor* L./*Sorghum sudanense* (Piper) Staph). In fine sandy soil with high organic matter, yields of U.S. No. 1 potatoes did not differ significantly between the three systems, whereas in sandy soil with low organic matter, conventional tillage outyielded the other two systems. Differences in organic matter content and fineness of soil texture between the two locations may have mediated changes in soil bulk density and soil tilth that affected yields. Stivers-Young and Tucker (1999) evaluated oat (*Avena sativa* L.), rye (*Secale cereale* L.), clover (*Trifolium pratence* L.), and wheat (*Triticum aestivum* L.) following early-harvested vegetables including potatoes and found that cover crops retained N early in the fall, thus reducing N losses through leaching and runoff. Honeycutt (1998) reported that an alfalfa-potato rotation without supplemental N increased yield by 50 kg ha^{-1} over a potato-potato or an oat-potato rotation. Despite inconclusive yield enhancement by cover crops in early studies (Griffin and Hesterman 1991), incorporation of cover crops into potato production rotations has increased and was practiced on 36%

of western New York potato acreage in 1997 (Stivers-Young and Tucker 1999).

Liebman et al. (1996) conducted studies aimed at reducing the use of pesticides in controlling weeds in potato production by using two cover crops, oat and berseem clover (*Trifolium alexandrinum* L.), in combination with moldboard and chisel plowing. Biomass of the dominant weed species (*Chenopodium album* L., *Brassica* spp., and *Raphanus* spp.) was lower when plots were moldboard plowed than when chisel plowed. Weed competition reduced yields of U.S. No. 1 potatoes by 12% with moldboard plowing, compared to 43% with chisel plowing. Russell and Bellinder (1989) evaluated the effect of reduced tillage with a rye cover crop on weed populations and potato yields as compared to conventional tillage. Common lambsquarter (*Chenopodium album* L.) populations were similar in both tillage systems, but redroot pigweed (*Amaranthus retroflexus* L.) populations were significantly greater in reduced tillage plots. Reduced tillage decreased yields by 22% compared to conventional tillage, which they attributed to delayed emergence. Their results disagreed with earlier findings (Bennett et al. 1975; Grant and Epstein 1973; Schuler 1979), which concluded that reduced tillage did not decrease yield. All of the earlier studies dealt with conventional production of potatoes.

The objectives of this study were (i) to determine the feasibility of using cover crops and conservation-tillage practices in the production of 32- to 57-mm-size-range potato tubers (referred to hereafter as creamers); (ii) to evaluate the yield potential of creamer potato clones under field conditions; and (iii) to compare net returns of creamer potato production under conventional and conservation-tillage cropping strategies. We recognize that the term "creamer" has not officially been introduced into potato science. Therefore, we only chose to use it for convenience to denote tuber size 32 to 57 mm.

MATERIALS AND METHODS

Field experiments were conducted in 2000 and 2001 at the USDA Beltsville Agricultural Research Center (BARC), MD, and at the Virginia Polytechnic Institute and State University Kentland Agricultural Research Farm (KARF), Blacksburg, VA. The soil at BARC was a Codorus silt loam in 2000 and a Metapeake silt loam in 2001, with 0% slope, whereas the soil at KARF was a Hayter loam. Neither site had been planted with potatoes or any solanaceous crop for several years. Plots for the cover crop treatments were seeded in the fall of the prior year. Dates of major operations in both sites appear in Table 1.

Experimental Design

In 2000, the experimental design at both sites was a split-plot design with four replications at BARC and three at KARF. Each plot consisted of two raised beds except for the bare soil/flat control. The main plots at BARC consisted of seven cover crops and two bare soil treatments. The cover crop treatments included rye (*Secale cereale* L.), crimson clover (*Trifolium incarnatum* L.), Austrian winter pea (*Pisum sativum* L.), rape (*Brassica napus* L.), and oat (*Avena sativa* L.) as monocultures, and rye/crimson clover, and rape/crimson clover as mixtures. The conventional bare soil/flat beds served as a control. Bare soil/raised beds was included to compare with the bare soil/flat beds. These same treatments were applied at KARF except that the oats treatment and crimson clover were omitted. In 2000, the sub-plots at both sites consisted of three creamer potato selections (clones): B1145-2, B1491-5, and B1492-12.

In 2001, the experimental design at both sites was similar to that of 2000 with four modifications: (1) the number of cover crops was reduced to four instead of seven at BARC, and two instead of six at KARF, (2) B1491-5 and B1492-12 were dropped due to a seed shortage and were replaced by two additional selections, B1102-3 and B0811-4; (3) there were four replications at both BARC and KARF; and (4) an additional harvest 3 wk later was taken at BARC to determine if delayed harvest would increase yield of larger-sized potatoes at the expense of creamer-sized tuber yield.

TABLE 1—*Dates of cultural practices applied at BARC and KARF.*

	BARC		KARF	
Operation	2000	2001	2000	2001
Seed cover crop*	3 Sept	18 Sept	15 Oct	2 Oct
Cover crop biomass	6 Apr	5 Apr	4 May	2 May
Kill cover crop	7 Apr	13 Apr	4 May	7 May
Plant potatoes	10 Apr	6 Apr	5 May	3 May
N side dressing	15 May	23 May	2 June	1 June
Herbicide application	20 June	6 June	15 May	11 May
Desiccate crop	23 June	2 July	2 July	28 June
Harvest potatoes	6 July	21 June 21 July	14 July	12 July

*Cover crops were planted in the year previous to that designated in the table.

Seeding and Managing the Cover Crops

The cover crop treatments (main plots) were randomly assigned in the field and seeded into the raised beds in the fall of the previous year (Table 1). Each sub-plot consisted of two raised beds except for the two bare soil/flat beds (control). Each of the two beds that constituted the sub-plot was 26 m long and 1.5 m wide (center to center). The double bed provided the space for three creamer clones plus additional separation zones between them. Seeding rates (kg ha^{-1}) in both years and sites were similar and consisted of the following: crimson clover (22), Austrian winter pea (90), rape (11), oat (45), rye (45), rape/crimson clover mixture (11/22), and rye/crimson clover mixture (45/22). They were seeded using a Brillion seeder (Brillion Iron Works, Brillion, WI, USA) and received no supplemental irrigation water or fertilizer during the growing period. The cover crops were terminated by applying the contact herbicide paraquat (1, 1'-dimethyl-4, 4'-bipyridinium ion) (Syngenta, Greensboro, NC, USA) at a rate of 0.53 kg a.i. ha^{-1} plus 0.25% nonionic surfactant prior to planting the potatoes in 2000, and prior to potato emergence in 2001. Just before potato planting, a random area 1 m^2 was selected in the middle of the bed and the aboveground foliage of each cover crop was cut, dried for 2 wk at 65 C, and weighed for biomass determination.

Preparing and Planting the Tubers

Tubers were cut into pieces approximately 60 g each, 3 wk before planting. After the cut surfaces healed, seedpieces were treated with Maneb 75DF (Manganese ethylenebisdithiocarbamate) (Cerexagi, Inc., King of Prussia, PA, USA) at a concentration of 100 g a.i. L^{-1} of water, and stored at 15 to 21 C. Each sub-plot contained two potato rows in each of the two beds. Fifteen pieces (10 in 2001) per clone were planted in each of the four rows, thus using 4.6 m linear length of the double bed (3.0 m in 2001). Seedpieces were spaced 23 cm within the row. Hence each replication per treatment per clone was randomly assigned to the sub-plot and consisted of 60 seedpieces (40 in 2001). Since all clones had red skin, tubers of a white-skinned cultivar were planted at both ends of the double beds and between clones to separate the clones of each replication for accurate determination of yields. A single-row, no-till planter (Subsurface Tiller-Transplanter, B&B No-Till, Laurel Fork, VA, USA) was used to plant into all plots with raised beds in both years. However, at BARC, soil in the bare soil/flat control was tilled and planted by hand in both years because it was too wet to allow mechanical planting as a result of frequent rain events that kept the soil wet at planting time. Planting dates appear in Table 1.

Cultural Practices

All treatments received 1,120 kg ha^{-1} of 5-10-10 fertilizer applied to the furrow at planting. In addition, all treatments were side-dressed between rows at a rate of 39 kg ha^{-1} of supplemental N using ammonium nitrate thus resulting in a total NPK of 95, 112, and 112 kg ha^{-1}, respectively.

Weeds in the bare soil/flat bed control treatment at BARC and KARF were controlled by mechanical cultivation. In addition, all treatments received one application of the selective pre-emergence herbicide Dual-Magnum (*S*-Metolachlor), (chloro-*N*-(2-ethyl-6-methylphenyl)-*N*-(2-methoxy-1-methylphenyl) acetamide) (Syngenta, NC, USA) at a rate of 1.89 kg a.i. ha^{-1}, and Lorox DF(Linuron, 3-(3,4-dichlorophenyl)-1-methoxy-1-methylurea) (Griffin L.L.C., Valdosta, GA, USA) at a rate of 1.12 kg a.i. ha^{-1} (Table 1). Potato stand determinations were made 25 and 30 days after planting using all the creamer plants in the two inner rows of the double-bed sub-plot.

Harvesting and Grading

Harvest dates at BARC and KARF appear in Table 1. Yield was measured on tubers harvested from both beds of the sub-plot. The tubers were washed and sized into three categories before weighing: creamers (3.2 to 5.7 cm diameter); large (>5.7 cm diameter); and small (<3.2 cm diameter). Both large and creamer-sized tubers were used for determining total yield. However, since the focus of this research was on creamer-sized production, only creamers were used in determining the marketable yield and in economic analysis. Specific gravity was determined by the weight method (Murphy and Goven 1959). In addition, tuber grading was carried out at BARC, including evaluation of skin color, texture, shape, eye depth, skin set (feathering), greening, secondary growth, *Rhizoctonia*, hollow heart, common scab, and soft rot.

Statistical Analyses

Data were analyzed using a mixed model analysis of variance using Proc Mixed of SAS (SAS Institute 1999), with cover crops and potato clones treated as fixed effects, and replicates and error terms as random effects. Heterogeneity of variance was modeled by grouping treatments with similar variability. Mean comparisons were generated using the Bonferroni t-test with an adjusted P value.

Economic Analysis

Net returns were calculated for creamer-sized tubers of each harvest for the clones grown under each treatment at BARC. In this analysis, net returns are defined as the difference between gross returns and variable cost, and are calculated using the following formula:

$$NR = PY - \sum W_i X_i,$$

where NR is net return in \$ ha^{-1}, P is the price of potatoes in \$ kg^{-1}, Y is the yield of potatoes in kg ha^{-1} (so that PY is gross returns), W is the price of input i in dollars per quantity, and X is the quantity of input i per ha (so that $\sum W_i X_i$ is total variable cost). Since the primary purpose of this economic analysis was to compare returns between different treatments, fixed costs (cost of machinery, land, insurance, etc.) were assumed to be the same for all treatments and therefore not included in the calculations. The price of creamers was derived from the average price of a 50-lb box of creamers at the Baltimore wholesale market, for the months of June, July, and August of 2000 and 2001, obtained from the archives of the USDA's Agricultural Marketing Service (http://www.ams.usda.gov/fv/mncs/index.htm). Input usage and yields were extrapolated to a per ha basis using the input usage and yield rates documented on the experimental plots. Inputs used in these calculations included only those relevant to variable costs, including field operations (plowing, disking, planting, cultivating, harvesting, etc.), materials (seed, herbicide, fungicide, fertilizer, etc.), and operating loan cost. Prices for field operations were based on Maryland Custom Rates (Johnson, 2002). Actual equipment use time and cost of materials used in field operations were stipulated in the budget. All prices are in real terms, with base year 2000.

RESULTS

Rainfall

During the 30-day period before planting the potato tubers, the field plots at BARC received 12 rain events with a total of 121 mm of rainfall in 2000 and 10 rain events with a total of 81 mm of rainfall in 2001. During the same period at KARF, the field plots received 14 rain events with a total of 86 mm of rainfall in 2000 and seven rain events with a total rainfall of 10 mm of rainfall. In both years, the amount of rainfall at BARC was higher than that at KARF, especially in 2001. Cover crops in both sites developed without the need for supplemental irrigation. However, the frequency and amount of rainfall resulted in wet soils that made mechanical planting of potatoes in flat, tilled soils impossible in both years at BARC. As a result, these treatments had to be planted by hand. Thus, one of the advantages of using cover crops or raised beds and conservation tillage for this region is to permit mechanical planting in wet soils early in the spring. The delayed planting of almost one month at KARF allowed planting all treatments mechanically (Table 1).

Cover Crop Biomass

All cover crops used in these experiments were winter annuals. They typically are planted in late summer and make most of their growth the following spring (mid-March to mid-May). Since potato-planting time in MD falls in early April, these cover crops did not produce maximum biomass. Yet biomass yields of rape, rye, rye/crimson clover and rape/crimson clover mixtures at BARC were high and ranged from approximately 4000 to 5000 kg ha^{-1} (Table 2). Since planting potatoes occurred in early May at KARF, rye and rye/crimson clover mixture cover crops grew an extra month, achieving exceptionally high biomass yields compared to those at BARC. All cover crops were killed by herbicide treatment except for rape at BARC. Rape plants recovered from herbicide treatment and resumed growth to become a weed competing with potato plants.

TABLE 2—*Cover crop dry biomass (t ha^{-1}) in creamer potato plots at BARC and KARF for 2000 and 2001.*

	BARC		KARF	
Cover Crop[y]	2000	2001	2000	2001
R + Cc	4,860 a[z]	5,100 a	10,200 a	12,870 a
R	3,500 bc	4,390 a	10,070 a	12,300 a
Cc	3,420 bc	—	4,360 b	—
O	3,450 bc	420 b	—	—
Ra	5,040 a	—	3,800 b	—
Ra + Cc	4,280 ab	4,050 a	4,600 b	—
Awp	2,690 c	—	5,400 b	—

[y]R = rye; Cc = crimson clover; O = oats; Ra = rape; Awp = Austrian winter pea
[z]Numbers with the same letter within the same year and location are not significantly different ($P = 0.05$).

Potato Plant Growth and Yield

Target potato populations were successfully attained in each of the cover crop treatments with no significant population differences between cover crops treatments (data not shown). Total yield consisted of creamer yield, which is the focus of this investigation, plus large-sized tuber yield. The latter was measured to determine the efficiency of the clones in regard to yielding creamer-sized potatoes and to determine if a delay in harvest alters the ratio of creamers to large-sized tubers in the total yield. Creamer yield analysis at BARC showed significant differences between cover crops (Table 3) and clones (Table 4) during both years. However, there was no significant interaction between cover crop and clone. Creamer yields at BARC in 2000 were significantly lower following cover crops of rape and rape/crimson clover mixture than those following rye, crimson clover, oat and rye/crimson clover mixture (Table 3).

TABLE 3—*Yields of conservation-tillage creamers and large-sized potato tubers grown at BARC in the summers of 2000 and 2001.*

Year	Cover crop	Creamers	Large tubers	% Large tubers in total yield
		——Yield (kg ha^{-1})——		
2000	R + Cc	9,260 a[x]	597	6.1
	R	8,330 ab	579	6.5
	Cc	8,570 ab	427	4.7
	O	8,420 b	532	5.9
	Ra	5,310 d	127	2.3
	Ra + Cc	5,650 cd	120	2.1
	Awp	6,690 bcd	300	4.3
	B/RB	7,160 bc	348	4.4
	Control	7,200 abcd	0	0
2001 Early[y]				
	R + Cc	5,820 b	27	0.5
	R	6,920 ab	185	2.6
	O	8,630 a	171	1.9
	Ra + Cc	5,910 b	185	3.0
	B/RB	8,100 a	164	2.0
	Control	6,060 b	0	0
2001 Late[z]				
	R + Cc	7,410 bc	131	1.7
	R	6,920 c	75	1.0
	O	9,710 a	233	2.3
	Ra + Cc	5,000 d	82	1.6
	B/RB	9,420 ab	69	0.7
	Control	4.540 d	0	0

[v]R = rye; Cc = crimson clover; O = oats; Ra = rape; Awp = Austrian winter pea; B/RB = bare soil/raised bed; Control = bare soil/flat bed.
[w]Yields are averages of three clones.
[x]Numbers with the same letter within the year, harvest date, and column are not significantly different (P = 0.05).
[y]June harvest.
[z]July harvest.

The low creamer yield of rape and rape/crimson clover mixture can be attributed to the competition from rape plants that were not killed by the herbicide. Also at BARC in 2000, significantly more creamers were produced on the rye/crimson clover mixture residues than on the two bare soil treatments, whereas creamer potato yields on all other cover crop residues were not significantly different from these bare soil treatments. In 2001, creamer yields in oat residues and in bare soil/raised beds were significantly higher than the bare soil/flat control in both June and July harvests, whereas creamer yields in rye and rape/crimson clover residues were not significantly different from the control in both harvest times.

There was no significant difference in creamer yields between June harvest and July harvest at BARC in 2001 (data not shown). Creamers following oats and rye, as well as in bare soil/raised beds, yielded higher (though not statistically) than the control, whereas those following rape/crimson clover and rye/crimson clover yielded lower than the control (Table 3). In contrast, creamer yields in all treatments at the later harvest were higher than the control. These results are based on one year, and should be interpreted cautiously. However, they may indicate that, with the clones used in these experiments, tuber size did not increase once the tubers reached mature size (Table 3). This suggests that under the experimental conditions described here, a delay of 3 wk past the typical June harvest time may not reduce creamer yields, while giving growers additional time to harvest. This is especially helpful in bad weather. However, additional research is needed to confirm this observation.

Yield of large-sized tubers, though not the focus of this research, was determined to establish the efficiency of the clones regarding creamer-sized tuber production in different cover crop residues and climatic conditions (Tables 3 and 4). Except for the control treatment at KARF in 2001 where large-sized tubers reached 9.8% of total marketable yield, creamer-sized tubers in all treatments, locations, and years ranged from zero to 6.5%. Delaying harvest did not increase the percentage of large-sized tubers.

Yield analysis at KARF showed significant differences between cover crops both years (Table 4).

TABLE 4—*Yields of conservation-tillage creamer and large-sized potato tubers grown at KARF in the summers of 2000 and 2001.*

Year	Cover crop[x]	Creamers	Large tubers	% Large tubers in total yield
		Yield (kg ha^{-1})[y]		
2000	R + Cc	14,900 a[z]	362	2.4
	R	10,430 d	416	3.8
	Cc	10,245 cd	524	4.9
	Ra	10,335 cd	425	4.0
	Ra + Cc	13,550 ab	525	3.7
	Awp	12,941 ab	507	3.8
	B/RB	12,887 abc	516	3.9
	Control	12,930 ab	642	4.7
2001	R + Cc	9,380 ab	270	2.8
	R	8,830 b	245	2.7
	Control	11,290 a	1,223	9.8

[x]R = rye; Cc = crimson clover; O = oats; Ra = rape; Awp = Austrian winter pea; B/RB = bare soil/raised bed.
[y]Yields are averages of three clones.
[z]Numbers with the same letter within the year and column are not significantly different (P = 0.05).

TABLE 5—*Yields of conservation-tillage creamer potatoes by clone at BARC and KARF for 2000 and 2001.*

	Yield (kg ha^{-1})[v]				
	BARC			KARF	
Cover Crop[y]	2000[w]	2001[w]	2001[x]	2000[w]	2001[w]
B1145-2[y]	8,810 a[z]	10,430 a	9,770 a	12,470 NS	13,470 a
B1491-5	9,120 a	—	—	11,580 NS	—
B1492-12	4,560 b	—	—	11,070 NS	—
B1102-3	—	6,440 b	7,940 b	—	9,170 b
B0811-4	—	3,850 c	3,790 c	—	6,080 c

[v]Yields are averaged over cover crops.
[w]June harvest.
[x]July harvest.
[y]Clone numbers as assigned by the breeder.
[z]Numbers with the same letter within the year are not significantly different (P = 0.05).
NS = No significant differences.

There were no significant differences between clones in 2000, but there were highly significant differences in 2001. Interactions between cover crop and clones were not significant in either year. In 2000, creamer yields in residues of rye/crimson clover, rape/crimson clover, Austrian winter peas and bare soil/raised beds did not differ significantly from the control (Table 4). Creamer yields in residues of rye, crimson clover, and rape, however, were significantly lower than the control. In 2001, creamer yields in residues of rye/crimson clover mixture did not differ significantly from the control, whereas creamer yields on residues of rye alone were significantly lower.

Although five clones were tested during these experiments, only clone B1145-2 was tested at BARC and KARF in both years (Table 5). The remaining four clones were evaluated for only one year at both sites. Therefore, no recommendation can be made as to the suitability of any of these clones for commercial production. The purpose of this study was to determine if the production of creamer-sized potatoes in a conservation-tillage, cover-cropping strategy would be feasible in the MD and VA areas, and not to recommend a particular clone for production. However, significant clone effects were found within years; clone B1145-2 yielded as well as or better than the other clones in the study and warrants further evaluation.

The additional evaluations carried out at BARC on physiological tuber characteristics (skin color, texture, shape, eye depth, skin set, greening, secondary growth, and specific gravity), and disease presence (*Rhizoctonia*, hollow heart, common scab, and soft rot) showed no significant differences between clones produced in the various cover crop residues (data not shown).

Economic Results

Net returns for each treatment at BARC are found in Table 6, and for KARF in Table 7. In both years and at both locations, all creamer yields from potatoes grown on cover crop residues as well as the bare soil treatments resulted in favorable net returns, primarily due to the high market price for creamer potatoes. Average price per kg of creamers in the Baltimore wholesale market in 2000 was $0.90 and $0.87 in 2001. At BARC, variable costs were higher for all treatments in 2000 than in 2001, due largely to higher spraying costs. In 2000, net returns ranged between $2550 ha^{-1} for creamers grown following a rape/crimson clover cover crop, and $5810 ha^{-1} for those grown following a rye/crimson clover cover crop. Returns for potatoes following a rape-based cover crop were lowest among treatments in 2000. This can be attributed to lower potato yields by the rape-based treatments as compared to the other treatments, due to high competition by the rape plants. Net returns at BARC in 2001 ranged

TABLE 6—*Variable cost and net returns for creamer-sized potato production at BARC in 2000 and 2001, in \$ ha*$^{-1}$.

	Variable Cost			Net Returns		
Treatment[v]	2000	2001[w]	2001[x]	2000	2001[w]	2001[x]
R + Cc	1265	908	908	5810 a[z]	3220 b	5510 b
R	1195	840	840	5110 ab	4310 ab	5260 b
Cc	1249	N/A	N/A	5220 ab	N/A	N/A
O	1201	846	846	4480 ab	5780 a	7560 a
Ra	1199	N/A	N/A	2680 c	N/A	N/A
Ra + Cc	1268	911	911	2550 c	3290 b	3530 c
Awp	1285	N/A	N/A	3460 bc	N/A	N/A
B/RB	1119	778	778	4210 b	5460 a	7380 a
Control	1285	903	903	3920 abc	1630 c	2120 d

[w]June harvest.
[x]July harvest.
[y]R = rye; Cc = crimson clover; O = oats; Ra = rape; Awp = Austrian winter pea; B/RB = bare soil/raised bed; Control = bare soil/flat bed.
[z]Numbers with the same letter within the year are not significantly different (P = 0.05). Figures are rounded to the nearest \$10.

TABLE 7—*Variable cost and net returns for creamer potato production at KARF in 2000 and 2001, in \$ ha*$^{-1}$.

	Variable Cost		Net Returns[z]	
Treatment[y]	2000	2001	2000	2001
R + Cc	595	875	12,820 a	7,250 ab
R	525	808	8,860 c	6,840 b
Cc	579	N/A	8,640 bc	N/A
Ra	529	N/A	8,780 c	N/A
Ra + Cc	599	N/A	11,600 a	N/A
Awp	615	N/A	11,040 a	N/A
B/RB	449	N/A	11,150 ab	N/A
Control	590	847	11,050 a	8,930 a

[y]R = rye; Cc = crimson clover; Ra = rape; Awp = Austrian winter pea; B/RB = bare soil/raised bed; Control = bare soil/flat bed.
[z]Numbers with the same letter within the year are not significantly different (P = 0.05). Figures are rounded to the nearest \$10.

between \$1630 ha^{-1} for the control treatment (bare soil, no beds) and \$5780 ha^{-1} for creamers grown following oats.

It should be noted that Fisher's LSD procedure for means separation is based on both the mean estimates and standard errors. Heterogeneity of error variances makes it possible to have a mean estimate of lower magnitude that cannot be distinguished statistically from a higher mean estimate if the standard error of one of these estimates is sufficiently large. Thus, in net returns from 2000 at BARC (Table 6), for example, the lower mean estimate of the control can overlap the range of a higher estimate such as B/RB. Other such examples occur in the results.

The increase in yield of the delayed harvest in all treatments in 2001, though statistically insignificant, generated higher net returns at no additional cost to the grower. It should be noted that with regard to fresh market sales, net returns can be affected not only by yield, but also by prevailing market prices, which may fluctuate during the harvest period. The average market price used here did not address this issue. At KARF, net returns for treatments in both years were higher than for their BARC counterparts, due to higher yields and lower variable costs due to the use of less-expensive fungicide. KARF net returns in 2001, for all tested treatments, were substantially lower than in 2000 because of reduced yields and higher spraying costs.

DISCUSSION

A conservation-tillage, cover-cropping system for creamer potato production is viable in Virginia and Maryland, as evidenced by the high yields and positive net economic return. No single cover crop was consistently superior across all years and sites suggesting that more research is needed to identify optimum cover crops and management. It is important to point out that development of creamer potato cultivars has not been a priority of the major potato-breeding programs in the USA because of limited consumer demand. However, the economic analysis contained herein suggests that breeders should consider evaluating available germplasm to make use of the market that exists. The conservation-tillage, cover-cropping strategy offers two advantages over conventional tillage: (1) the ability to enter the field with machinery shortly after rain for timely planting; and (2) improving the soil by adding organic matter and reducing erosion. Both advantages are important for Maryland and Virginia due to an often continuously wet season at potato planting time as well as frequently observed high soil erosion in vegetable production fields. Net returns from the economic analysis suggest that the conservation-tillage, cover cropping strategy appears to be a viable system for creamer potato production at present market prices. However, the size of the market niche and how quickly it could be saturated were not examined in this paper.

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