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Delayed Tillage and Cover Crop Effects in Potato Systems

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Abstract Delayed tillage and the inclusion of cover crops can substantially reduce erosion in intensively tilled potato systems. Both of these practices can potentially impact potato (*Solanum tuberosum* L.) yield and quality via changes in soil temperature and soil water status, and suppression or enhancement of soil-borne diseases. Research was conducted over six rotation cycles at two Maine locations to evaluate the effects of timing of primary tillage (fall vs. spring) and cover crop [none, red clover (*Trifolium pratense* L.), ryegrass (*Lolium perenne* L.), or winter rapeseed (*Brassica napus* L.)] on grain yield, ground cover, and tuber yield and quality within the context of 2-year barley (*Hordeum vulgare* L.)]–potato rotations. Delaying primary tillage until spring, immediately before planting potato, resulted in higher soil water content early in the growing season (before or immediately after planting) in some rotation cycles, and also provided nearly complete ground cover during potentially erosive periods in fall and early spring. The inclusion of clover or ryegrass cover crops had small, positive effects on the proportion of the soil surface covered by crop residue (determined by the line intercept method) in both tillage systems. A significant tillage effect on total tuber yield was seen in only one rotation cycle, when delaying tillage until spring reduced yield by about 12%. Cover crop treatments had no effect on total tuber yield, and neither tillage or cover crop affected the proportion of marketable tubers. Tillage did not affect black scurf (*Rhizoctonia solani* Kühn) and common scab [*Streptomyces scabiei* (Thaxter) Lambert & Loria], which were significantly reduced by red clover in some rotation cycles. This research shows that conservation practices can be implemented, including delaying primary tillage until spring and including underseeded cover crops during the grain phase of the rotation, while maintaining potato yield.

Resumen La labranza tardía y la inclusión de cultivos de cobertura pueden reducir sustancialmente la erosión en sistemas de labranza intensiva. Ambas prácticas pueden potencialmente afectar el rendimiento y calidad de la papa (*Solanum tuberosum* L.) por medio de cambios en la temperatura y estado hídrico del suelo, y supresión o intensificación de enfermedades trasmitidas por el suelo. Se realizó la investigación en dos localidades de Maine durante seis ciclos de rotación para evaluar el momento (otoño vs. primavera) de la labranza principal y cultivos de cobertura [(ninguno, trébol rojo (*Trifolium pratense* L.), ballico (*Lolium perenne* L.) o colza de invierno (*Brassica napus* L.)] sobre el rendimiento de granos, cobertura, y rendimiento de tubérculos y calidad en el contexto de dos años de rotación de cebada (*Hordeum vulgare* L.)–papa. El retrasar la labranza principal hasta la primavera, inmediatamente antes de sembrar papa, dio como resultado un contenido más alto de agua al inicio de la temporada de cultivo (antes o inmediatamente después de la siembra) en ciertos ciclos de rotación, y también proporcionó una cobertura casi completa durante los periodos potencialmente erosivos en el otoño e inicios de primavera. La inclusión de cultivos de trébol y ballico tuvo pequeños efectos positivos en la proporción de suelo cubierto por residuos del cultivo (determinado por el método de línea intercepto) en ambos sistemas de labranza. Se observó un efecto significativo de la labranza sobre el rendimiento total de tubérculos en un ciclo de rotación solamente, cuando el retraso de la labranza hasta la primavera redujo el rendimiento en casi 12%. Los tratamientos con cultivos de

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cobertura no tuvieron efecto sobre el rendimiento total de tubérculos, tampoco la labranza o cultivos de cobertura afectaron la proporción de tubérculos comerciables. La labranza no afectó la costra negra (*Rhizoctonia solani* Kühn) ni a la sarna común [*Streptomyces scabies* (Thaxter) Lambert & Loria], los cuales fueron reducidos significativamente por el trébol rojo en algunos ciclos de rotación. Esta investigación muestra que se pueden implementar las prácticas de conservación, incluyendo el retraso de la labranza principal hasta la primavera, siembra de cultivos de cobertura intercalados durante la fase de formación de grano del cultivo, mientras se mantiene el rendimiento de papa.

Introduction

Potato (*Solanum tuberosum* L.) production in the Northeast U.S. and Atlantic Canada is characterized by short (2- or 3-year) rotations, extensive tillage, and minimal crop residue return, especially during the potato phase of the rotation. Two-year rotations in Maine utilize oat (*Avena sativa* L.) or barley (*Hordeum vulgare* L.) as the rotation crop, often underseeded with red clover (*Trifolium pratense* L.) or ryegrass (*Lolium perenne* L.). Within the 2-year rotation cycle, there are several periods where the potential for runoff and erosion is particularly high. Prominent among these is the period after potato harvest, due to both the lack of crop residue and the compaction from harvest traffic. In comparison, the period after grain harvest is characterized by nearly complete soil coverage from straw. However, fall primary tillage (moldboard or chisel plowing) is still common in this production system. This practice leaves the soil surface exposed to rainfall from early fall (September) until the soil freezes, and again from snow melt until the subsequent potato crop has achieved sufficient canopy growth in the following cropping season (usually June). This problem is made more severe by the prevalence of sloping fields, ranging from nearly level (0–2% slopes) to slopes in excess of 10%.

There are several options to reduce the potential for erosion in potato systems. Longer rotations, especially those that include perennial sod crops, both stabilize soil and add soil organic matter (Gyssels et al. 2007). In cool, humid climates, this is most often a 3-year rotation of barley (underseeded with red clover or timothy [*Phleum pratense* L.]), followed by a full year of sod, and then a potato crop. The effects of longer rotations on productivity and soil properties have been evaluated by Carter and Sanderson (2001), Carter et al. (2007), and Peters et al. (2004). Because potato production is typically not in proximity with animal production, the sod crop may be treated as a green manure, *i.e.* remaining un-harvested during the second year of the rotation. A second option is to reduce the frequency and intensity of tillage within the rotation, which could be accomplished even within the context of 2-year rotations. The production practices associated with the potato crop (planting, cultivation, hilling, and especially harvest) are significant soil disturbance events, and potential reductions in tillage during the potato phase have been evaluated in a number of situations (Carrera et al. 2005; Ekeburg and Riley 1996; Grant and Epstein 1973; Lanfranconi et al. 1993; Wallace and Bellinder 1989). Tillage could also be reduced or eliminated during the remainder of the rotation, which would yield conservation benefits by extending the duration of vegetative ground cover, and economic benefits by reducing the number of passes across the field (Carrera et al. 2005; Holmstrom et al. 1999; Sijtsma et al. 1998). And third, the use of either underseeded or no-till cover crops could be expanded to both provide longer duration of living ground cover and to increase the amount of plant residue protecting the soil.

Producer adoption of any of these practices would also depend on yield and quality impacts on the subsequent potato crop. Field experiments were conducted at two locations in Maine to assess the interactive effects of tillage timing (fall versus spring before potato) and cover crop options on grain yield, soil coverage, potato yield, and the incidence of soil-borne tuber diseases.

Materials and Methods

Site Description

Field experiments were established at USDA-ARS research sites at Newport (44° 52′ N, 69° 17′W) and Presque Isle (46° 39′N, 68° 00′W), Maine, USA, in 2002. Soil types were Nokomis sandy loam and Caribou gravelly loam at Newport and Presque Isle, respectively. Both of these soil types are classified as fine-loamy, mixed, frigid Typic Haplorthods. Soil properties and soil test results at the initiation of the experiments, using the Modified Morgan extraction (McIntosh 1969), are shown in Table 1. Although long-term mean air temperature at the two sites are similar (Table 2), air temperatures during the growing season when this research was conducted were typically 2–3°C cooler in Presque Isle, with similar precipitation at both sites (Table 2).

Treatment Description

Treatments were a factorial combination of *tillage* and *cover crop*. The conventional tillage system, referred to here as Fall Tillage, includes chisel plowing of grain

Table 1 Initial characteristics of soils from Newport and Presque Isle, Maine

	Location	
	Newport, ME	Presque Isle, ME
Sand (%)	42	51
Silt (%)	52	41
Clay (%)	6	8
pH	5.7	6.1
Organic matter (%)	3.8	2.3
CEC (me 100 g^{-1})	3.9	5.5
P (kg ha^{-1})	14.8	30.8
K (kg ha^{-1})	200	244
Mg (kg ha^{-1})	101	497
Ca (kg ha^{-1})	787	1,560

residue approximately 30 d after grain harvest, disking (2×) prior to potato planting, and disking (1×) after potato harvest, in addition to field operations necessary for the potato crop (planting, cultivation, hilling, and harvest). The reduced tillage system (Spring Tillage) includes as its only tillage those operations that were needed for production of potato, i.e. the barley rotation crop was established without tillage, chisel plowing was conducted in the spring immediately before potato planting, and soil was not disturbed after potato harvest.

There were four cover crop treatments: a control (no cover crop); red clover and ryegrass, each underseeded at the time of barley planting; and winter rapeseed (*Brassica napus* L.) no-till seeded into barley stubble immediately after grain harvest.

Crop Management

There were three 2-year rotation cycles at each location: 2002–2003, 2003–2004, and 2004–2005. The first and last cycle at each location took place on the same plots, and the 2003–2004 cycle was adjacent in the same field.

The date of all field operations in all rotation cycles is shown in Table 3. In both tillage systems, barley (cv. Robust) was planted using a 1.8 m wide grain drill at a rate of 125 kg seed ha^{-1}. In the Fall Tillage system, barley was planted using a conventional grain drill after disking, while in the Spring Tillage system, barley was planted with using a no-till drill. For both tillage systems, red clover (cv. Mammoth) and ryegrass (cv. Lemtal) were planted at the same time as the barley, at rates of 17 and 28 kg ha^{-1} for clover and ryegrass, respectively. Nitrogen fertilizer (urea; 84 kg N ha^{-1}) was topdressed at the tillering stage, usually 21–28 d after planting. Weeds were controlled with a single application of MCPA (2-methyl-4-chlorophenoxyacetic acid; 0.5 kg a.i. ha^{-1}). Grain yield was estimated by harvesting a 1.5 m by 12.2 m area in the center of each plot with a small plot combine. Rapeseed (9 kg ha^{-1}) was planted after barley harvest, using a no-till drill. Barley planted in 2002 and in 2003 followed a potato crop.

Both Fall Tillage and Spring Tillage of barley residue used a chisel plow (2 m wide; five curved shanks spaced approximately 0.3 m apart, with rolling disk cutters in front of shanks) equipped with a rigid, straight-toothed harrow, to

Table 2 Growing season air temperature and precipitation for Newport and Presque Isle, Maine, for the period 2002 to 2005

	Newport, ME					Presque Isle, ME				
	2002	2003	2004	2005	30 year mean	2002	2003	2004	2005	30 year mean
Precipitation (mm $month^{-1}$)										
May	77	88	112	137	95	101	81	65	65	87
June	82	77	46	81	97	81	103	99	155	87
July	67	40	65	112	87	149	155	109	106	94
August	22	54	166	107	92	14	89	83	119	100
September	110	162	55	85	97	106	50	62	103	87
October	75	219	26	307	97	70	167	52	187	73
November	102	88	99	208	96	87	97	73	140	70
Total	534	729	569	1037	661	609	743	544	875	608
Mean air temperature (°C)										
May	11.3	11.4	12.3	9.8	11.9	9.3	9.8	10.3	9.0	11.4
June	16.3	17.7	15.9	18.9	16.9	14.1	16.6	13.5	17.3	16.4
July	20.2	20.3	19.5	20.7	19.8	17.8	18.4	18.4	19.1	19.0
August	21.0	20.3	19.6	20.3	18.6	18.3	18.0	17.6	18.3	18.0
September	16.6	16.1	15.4	16.6	13.7	14.4	14.7	12.6	13.5	12.9
October	6.8	8.3	9.1	9.8	7.2	4.6	6.2	7.2	8.1	6.6
November	0.8	3.1	2.4	3.2	1.3	−2.0	0.4	−1.2	1.1	−0.3

Table 3 Chronology of field operations for all rotation cycles in Newport (NP) and Presque Isle (PI), Maine

Location	Newport, ME			Presque Isle, ME		
	2002–2003	2003–2004	2004–2005	2002–2003	2003–2004	2004–2005
Field operation	Date					
Barley planting	21 May 2002	6 May 2003	8 May 2004	29 May 2002	28 May 2003	17 May 2004
Barley harvest	22 Aug 2002	15 Aug 2003	24 Aug 2004	19 Sept 2002	9 Sept 2003	16 Sept 2004
No-till rapeseed	5 Sept 2002	19 Aug 2003	1 Sept 2004	19 Sept 2002	9 Sept 2003	23 Sept 2004
Fall chisel plow	22 Oct 2002	20 Oct 2003	27 Sept 2004	15 Oct 2002	4 Nov 2003	23 Sept 2004
Spring ground cover	19 May 2003	9 May 2004	3 Jun 2005	28 May 2003	18 May 2004	25 May 2005
Spring chisel plow	21 May 2003	10 May 2004	3 Jun 2005	28 May 2003	18 May 2004	25 May 2005
Potato planting	22 May 2003	13 May 2004	9 Jun 2005	30 May 2003	20 May 2004	2 Jun 2005
Potato harvest	20 Oct 2003	15 Sept 2004	29 Sept 2005	31 Oct 2003	21 Sept 2004	20 Sept 2005

level the soil surface and distribute residue. Both tillage systems were disked twice with a 2.5 m wide offset disk immediately before potato planting.

Prior to implementing the Spring Tillage treatment, ground cover was estimated using the line intercept method (Morrison et al. 1995), for all plots that were planted to grain the previous year. A linear transect (15.2 m long) with 50 equally spaced points was placed across the soil and residue; the number of points directly over bare soil was noted (remaining points were over either living or dead plant material). Four transects were used per plot, for a total of 200 points.

Potato (cv. Russet Burbank in 2003; cv. Russet Norkotah in 2004 and 2005) was planted using a four-row (0.95 m row spacing) commercial potato planter. Cut seed pieces ranged in size from 50 to 75 g, with an average size of 61 g. In-row spacing was 35 cm in 2003, and 30 cm in 2004 and 2005. Seed pieces were placed at a depth of 7.5 cm. Fertilizer (224 kg ha^{-1} of N, P_2O_5, and K_2O) was applied through the planter, placed in two bands approximately 5 cm distant and 5 cm below the seed piece. Weed management included a pre-emergent application of metribuzin [0.5 kg a.i. ha^{-1}; 4-amino-6-(1,1-dimethylethyl)-3-(methylthio)-1,2,4-triazin-5 (4H)]. In-season cultivation included one or two shallow passes with cultivator, and one pass with a hiller. Yield estimates came from the harvest of either one or two center rows by 12.2 m of each plot. A 20 kg subsample was separated into non-marketable (less than 114 g) and marketable size classes. Marketable tuber yield was calculated as yield of tubers greater than 114 g, which did not have external defects. Thirty tubers of marketable size were evaluated for severity (percent of tuber surface covered) of black scurf (*Rhizoctonia solani* Kü) and common scab [*Streptomyces scabiei* (Thaxter) Lambert & Loria].

In 2004 and 2005, temporal changes in soil water status were measured for the first 30–40 days of the growing season. Ten soil cores (2.5 cm diameter by 20 cm deep) were collected for each tillage system, taken from plots that did not have a cover crop (*i.e.* the control plots). These samples were mixed, sieved (2 mm) and weighed. They were then dried (105°C, 24 h) and weighed again, to determine gravimetric soil water content.

Experimental Design and Analysis

The experimental design was a randomized complete block, with four replications. Treatments were in a split plot arrangement, with Tillage as the main plot (15 m wide by 12.2 m long) and cover crop as the subplot (3.7 m wide by 12.2 m long). There was a 6 m buffer between replicates. Treatment differences due to Tillage, Cover Crop, and Tillage×Cover Crop interaction were identified using Analysis of Variance. The Cover Crop and interaction effects were tested using the residual mean square error (MSE) of the model, while the Tillage effect used Replicate×Tillage as the error term.

Results and Discussion

Grain Yield

Grain yield was affected by treatment in three of six rotation cycles (Table 4). In two of the rotation cycles at Newport (Newport 2002 and 2004 barley crops), interseeded ryegrass reduced barley yield averaged across tillage systems by 10 to 20%, compared to both the control and red clover underseeding. In the first rotation cycle at Presque Isle (2002), grain yield was lower for no-till (Spring Tillage) compared with conventional-planted barley. The opposite effect was observed in Newport in 2004, when conventional-planted barley yield was lower than no-till. Our results demonstrating that the impact of underseeded legume cover crops on small grain yields is generally small is supported by previous reports by Stute and Posner (1995) and Hesterman et al. (1992). The growth of the underseeded legume is suppressed by shading from the grain. The underseeded ryegrass is sup-

Table 4 Effect of tillage system and cover crop on barley grain yield in three rotation cycles at Newport and Presque Isle, Maine

		Newport, ME			Presque Isle, ME		
		2002	2003	2004	2002	2003	2004
Grain yield (kg ha^{-1})							
Tillage	Cover						
Fall	None	2,477	2,113	1,924	3,717	3,019	3,930
	Clover	2,584	1,836	1,945	3,750	2,630	4,121
	Ryegrass	2,426	1,977	1,612	3,467	2,662	3,691
Spring	None	2,624	2,580	2,042	3,343	3,022	4,134
	Clover	2,775	2,363	2,778	3,284	2,954	3,696
	Ryegrass	2,247	2,662	1,962	2,909	2,758	3,306
Significance							
Effect	Tillage	NS	NS	*	**	NS	NS
	Cover	***	NS	*	NS	NS	NS
	Tillage×cover	NS	NS	NS	NS	NS	NS

In the Fall Tillage system, barley was planted using a conventional grain drill after disking, while in the Spring Tillage system, barley was planted with using a no-till drill

*, **, *** denotes statistical significance at 0.05, 0.01, and 0.001 levels of probability, respectively. *NS*, not significant at P=0.05

pressed to a lesser extent and, perhaps more importantly, competes with the small grain for soil N, other nutrients, water, and light.

Ground Cover

As expected, the timing of primary tillage had a large impact on ground cover measured in the spring (Figs. 1 and 2). Fall tillage resulted in ground cover of less than 25% in the first two rotation cycles at both locations, and ground cover of 30–50% in the last rotation cycle. In contrast, delaying primary tillage until just prior to potato planting consistently resulted in ground cover in excess of 90%. As shown by Grande et al. (2005), there is a curvilinear relationship between residue cover and sediment load under erosive conditions; when there is little ground cover (20% or less), small increases result in a disproportionate reduction in sediment loss. Once ground cover of more than 50% is achieved, sediment losses may be reduced by 90% or more, compared to bare soil or minimally covered soil.

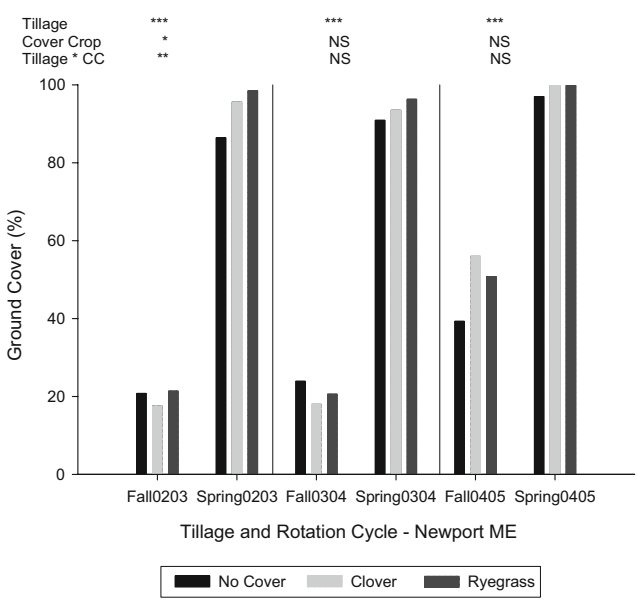

Fig. 1 Effect of tillage system and cover crop on ground cover, over three rotation cycles in Newport, ME. (*, **, *** denotes statistical significance at 0.05, 0.01, and 0.001 levels of probability, respectively. *NS*, not significant at P=0.05)

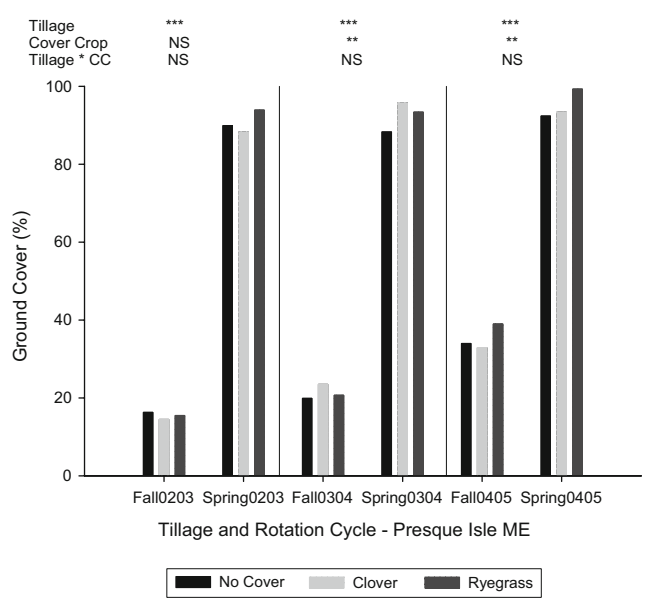

Fig. 2 Effect of tillage system and cover crop on ground cover, over three rotation cycles in Presque Isle, ME. (*, **, *** denotes statistical significance at 0.05, 0.01, and 0.001 levels of probability, respectively. *NS*, not significant at P=0.05)

Table 5 Effect of tillage system and cover crop on total tuber yield of subsequent potato crop in three rotation cycles at Newport and Presque Isle, Maine

		Newport, ME			Presque Isle, ME		
		2003	2004	2005	2003	2004	2005
Total tuber yield (Mg ha^{-1})							
Tillage	Cover						
Fall	None	30.2	27.1	35.8	36.0	32.5	25.9
	Clover	33.9	25.2	35.0	34.6	29.3	23.7
	Ryegrass	33.3	24.5	35.4	35.6	29.6	23.4
Spring	None	30.5	26.9	31.8	33.9	26.9	24.0
	Clover	31.3	26.0	30.9	27.1	27.8	19.2
	Ryegrass	33.0	26.1	34.2	32.6	25.8	22.2
Significance							
Effect	Tillage	NS	NS	NS	NS	*	NS
	Cover	NS	NS	NS	NS	NS	NS
	Tillage×cover	NS	NS	NS	NS	NS	NS

*, **, *** denotes statistical significance at 0.05, 0.01, and 0.001 levels of probability, respectively. *NS*, not significant at P=0.05

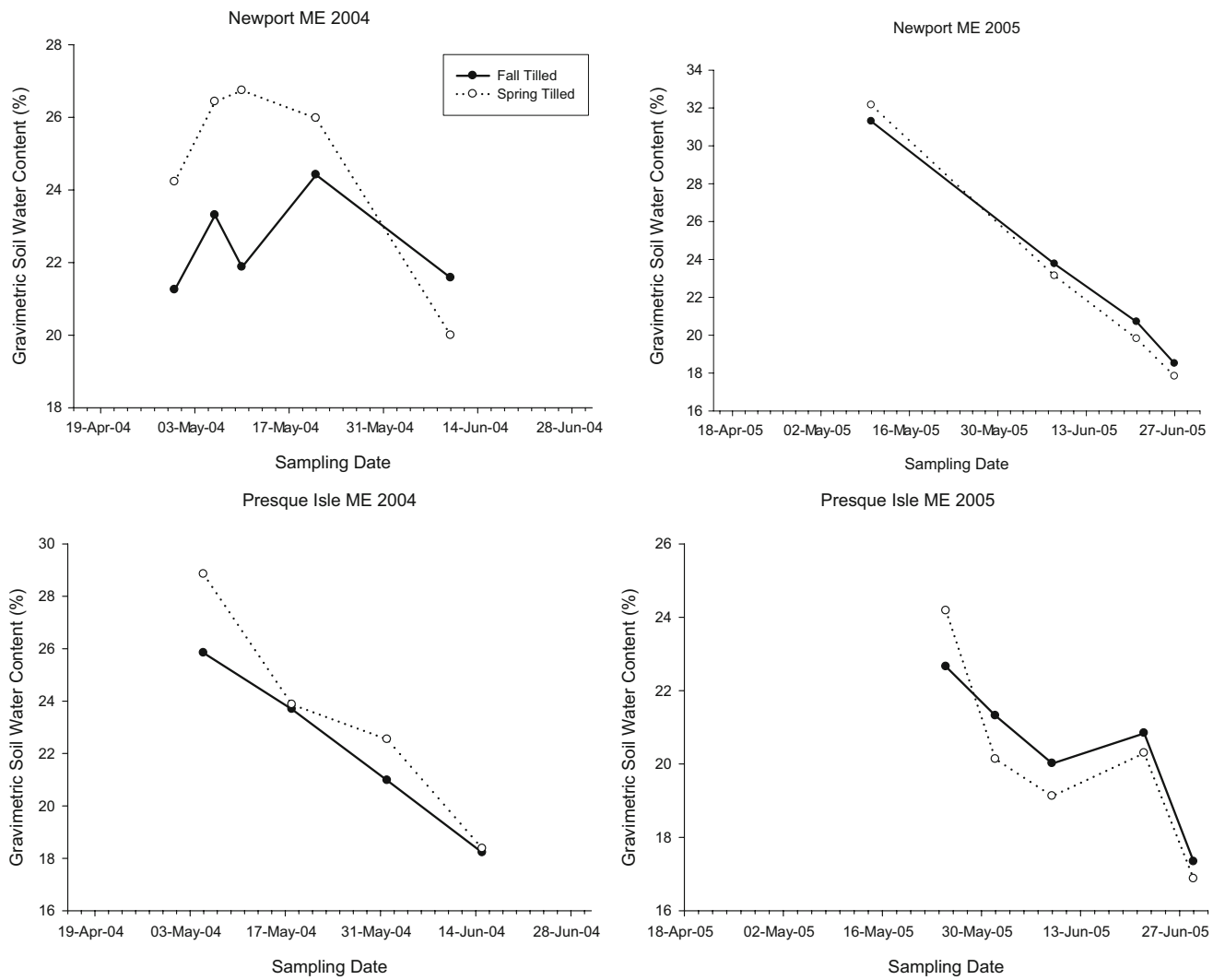

Fig. 3 Temporal changes in gravimetric soil water content in control (no cover crop) treatments, as affected by Fall and Spring primary tillage

Table 6 Effect of tillage system and cover crop on the severity of common scab on the subsequent potato crop in three rotation cycles at Newport and Presque Isle, Maine

		Newport, ME			Presque Isle, ME		
		2003	2004	2005	2003	2004	2005
Percent of tuber surface with common scab							
Tillage	Cover						
Fall	None	0.03	3.33	1.82	0	2.93	1.24
	Clover	0.03	3.12	1.55	0	2.55	1.50
	Ryegrass	0	3.08	1.77	0	2.60	1.57
Spring	None	0.03	2.38	1.72	0	3.08	1.50
	Clover	0	2.57	1.65	0.10	2.64	1.52
	Ryegrass	0	2.86	1.77	0.08	3.22	1.48
Significance							
Effect	Tillage	NS	NS	NS	NS	NS	NS
	Cover	NS	NS	**	NS	*	NS
	Tillage×cover	NS	NS	NS	NS	*	NS

*, **, *** denotes statistical significance at 0.05, 0.01, and 0.001 levels of probability, respectively. *NS*, not significant at P=0.05

The winter rapeseed did not successfully overwinter in any rotation cycle; thus it is not included in the analysis and discussion presented here. In half of the rotation cycles (Newport 2002–2003, Presque Isle 2003–2004 and 2004–2005), the cover crop treatments affected ground cover, although to a much lesser extent than did the tillage treatments. In Newport (2002–2003), ground cover was increased (compared to no cover crop) in the Spring Tillage treatment only. In Presque Isle, cover crop inclusion resulted in higher ground cover, compared to no cover crop. The differences were only around 5%, which would be more critical in the low cover situations associated with Fall Tillage treatment.

Tuber Yield

Total tuber yield ranged from 19.2 to 36.0 mg ha^{-1}, and was strongly affected by year (Table 5) as a result of differences in precipitation. The lower yield at Newport in 2004 was affected by dry conditions during June; precipitation was less then 50% of the 30-year mean (Table 2). Conversely, the lower yield in Presque Isle in 2005 may have resulted from wetter than normal conditions (*i.e.* more than 20% greater than the 30-year mean) in June and August of that year.

There was only one instance where treatment significantly affected total yield: Fall Tillage resulted in higher total yield

Table 7 Effect of tillage system and cover crop on the severity of *Rhizoctonia* or black scurf on the subsequent potato crop in three rotation cycles at Newport and Presque Isle, Maine

Site×cycle		Newport, ME			Presque Isle, ME		
		2003	2004	2005	2003	2004	2005
Percent of tuber surface with *Rhizoctonia*							
Tillage	Cover						
Fall	None	2.76	1.26	3.49	2.54	1.38	2.01
	Clover	2.91	1.09	2.00	2.78	1.17	1.91
	Ryegrass	2.79	1.35	3.13	2.33	1.10	2.27
Spring	None	2.86	1.39	3.78	2.82	1.41	1.28
	Clover	2.60	1.26	1.68	2.90	1.27	1.27
	Ryegrass	2.62	1.18	3.26	2.72	1.34	1.95
Significance							
Effect	Tillage	NS	NS	NS	NS	NS	NS
	Cover	NS	NS	*	NS	NS	NS
	Tillage×cover	NS	NS	NS	NS	NS	NS

*, **, *** denotes statistical significance at 0.05, 0.01, and 0.001 levels of probability, respectively. *NS*, not significant at P=0.05.

(30.3 mg ha^{-1}) than Spring Tillage (26.8 mg ha^{-1}) in Presque Isle in 2004. These are the mean yields for each tillage system, averaged across the cover crop treatments. Although the Spring Tillage treatment had a greater soil water content in early May, 2004 (Fig. 3), soil water content on the day of tillage (18 May 2004) was identical in the two tillage systems, and remained similar until sampling ended 15 June, 2004. Figure 3 shows that soil moisture is not consistently impacted by delayed tillage; this is the other primary complaint about delayed tillage. Across the four rotation cycles where soil water was monitored, the tillage treatments differed substantially only at Newport in Spring, 2004, where soil was wetter in the Spring Tillage treatment for almost the entire month of May. The proportion of total yield in the marketable size classes was also not affected by either tillage or cover crop treatments (data not shown).

These results are consistent with previous experiments that have shown that potato is relatively insensitive to differences in the timing of tillage operations prior to planting (Carter and Sanderson 2001; Carter et al. 2005; Liebman et al. 1996). Although forage legumes and perennial grasses are often used in rotation with potato, most previous comparisons utilize these as rotation crops, *i.e.* they were grown for the entire growing season preceding potato. The results from these experiments are mixed. For example, Porter and Sisson (1991) evaluated fertilizer N response of potato following either oat or red clover, finding that the primary response was an increase in tuber yield at low N application rates, while Griffin and Hesterman (1991) found significant vegetative response to legume N, but no tuber yield responses. There are few previous studies that have evaluated different cover crops for potato. The research reported here is a barley–potato rotation, with the differences in the underseeded crop. Given the short duration of cover crop growth, especially in the Fall Tillage treatments, it is not particularly surprising that yield responses are lacking, especially since the potato crop received the same amount of N in all tillage and cover crop combinations.

Common Scab and Rhizoctonia

The timing of tillage had little impact on the severity of common scab, which was quite low in all rotation cycles (Table 6), similar to the findings of Carter et al. (2003) and Peters et al. (2004). In two potato crops (Newport 2005, and Presque Isle 2004), scab severity was lower following red clover than following ryegrass or the control. The red clover cover crop also reduced the severity of black scurf in the Newport in 2005 (Table 7). Carter et al. (2003) found that over an 8-year period, the use of red clover as a green manure rotation crop also reduced the severity of common scab, compared to ryegrass managed in the same way, and also reduced the severity of black scurf. There is also evidence that when red clover is grown for longer periods (*i.e.* the second year of a 3-year rotation), increases in the incidence and severity of black scurf may occur (Larkin and Honeycutt 2006), although this is in contrast to the results of Peters et al. (2004).

Conclusions

The short rotations, intensive tillage, and low crop residue return of potato systems put conservation practices at a premium. A standard potato rotation, which included fall tillage after grain harvest along with other tillage in preparation for planting, was compared to a 2-year rotation which limited tillage to only those operations associated with the potato crop. In the latter, the primary tillage operation was delayed until spring, immediately before potato planting. This delay in tillage resulted in nearly 100% soil coverage for both late fall and spring, when soils are likely to be saturated and are prone to runoff and erosion. The inclusion of underseeded red clover or perennial ryegrass with the barley crop increased ground cover slightly in some rotation cycles. Total tuber yield was not affected by cover crop, and was reduced by delaying tillage in only one out of six rotation cycles. These treatments had small effects on soil-borne diseases, with red clover suppressing both Rhizoctonia and common scab significantly in some rotation cycles. This research demonstrates that alterations in tillage system, which have a large conservation benefit, can be implemented without reducing tuber yield and quality.

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