

PREVENTING EROSION OF MUCK SOILS BY REDUCING TILLAGE IN ONION PRODUCTION

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Summary:

The problem with using conventional tillage practices for onion production on muck soils is that it results in the subsidence of muck via wind and water erosion and oxidation of organic matter at a rate of one foot every 10 years, which is not sustainable for preserving these non-renewable natural resources for long-term productivity. Onions are one of the most valuable vegetable crops produced in New York State with the majority of the 13 000 acres being grown on muck soil. Producing onions using conventional tillage practices results in degradation of soil health and increased subsidence. This leads to increased fertilizer and crop protection chemical input to maintain productivity, resulting only in increased subsidence and declining productivity at ever increasing costs. It is a scientifically proven fact that wind and water erosion, and subsidence decreases as ground cover increases and cultivation decreases. In this project, we developed and evaluated growing onions from direct seed in reduced tillage production systems using oat and wheat cover crops on muck soil on a commercial scale. This was the first attempt of its kind, and a success with the minimum tillage systems producing comparable yields to the conventional system, having reduced onion thrips, bacterial rots and Botrytis leaf blight, and significant reductions in soil compaction and reduced wind erosion compared to the conventional system.

Introduction:

The problem with using conventional tillage practices for onion production on muck soils is that it results in the subsidence of muck via wind and water erosion and oxidation of organic matter at a rate that is not sustainable for preserving these non-renewable natural resources for long-term productivity.

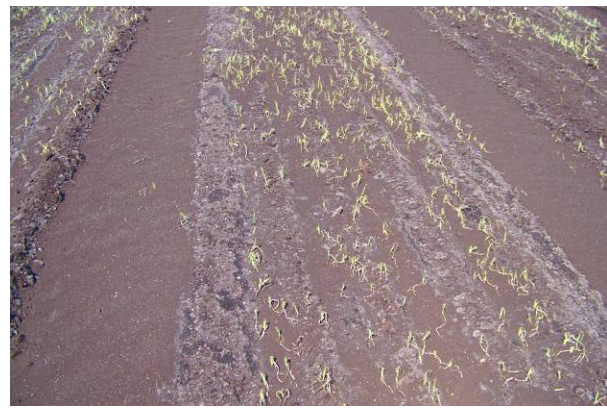
Onions are one of the most valuable vegetable crops produced in New York State and rank sixth in the nation with a five year average value of \$45.7 million. The majority of the 13 000 acres of onions are direct seeded yellow onions grown on muck soil in five regions across the state. Muck or organic soils contain at least 20% and up to 80+ % organic matter. They are rich in nutrients, have excellent water-holding capacity and are used extensively for vegetable production, especially onions. Onions produced on muck soil are of superior quality compared to onions grown on mineral soil, because the high sulfur content of muck soils improves onion flavor, cooking quality and storability. Muck soil is a non-renewable resource that was

developed underwater by several generations of plants that were preserved under anaerobic conditions. It takes nature about 500 years to accumulate one foot of muck soil.

Unfortunately, muck soils are prone to subsidence, which is the permanent lowering of the surface elevation, a phenomenon resulting from the oxidation of soil organic matter by aerobic microorganisms, and by wind and water erosion. An estimated rate of soil subsidence on intensively cropped muck soil is one foot every 10 years. As much as one inch of muck can be eroded during a severe wind storm when dry muck soil is exposed to the elements. Also, drainage ditches can be filled in and onion seedlings can be decapitated, severely damaged, uprooted or buried during high winds (Figure 1). The use of windbreaks (i.e. willow hedgerows), inter-planting small grains and maintenance of a moist soil surface via sub or overhead irrigation are common techniques used to reduce wind erosion. Winter cover crops are used on a portion of the acreage, particularly where onions are harvested early. Although these strategies help to reduce erosion, the use of conventional tillage including plowing, disking and harrowing allow subsidence to continue at an unsustainable pace.



a) drainage ditch.



b) direct seeded onions



c) transplanted onions



d) direct seeded onions.

Figure 1. Effects of wind-eroded muck, Elba muck land, 2009. a) Drainage ditch filled in with wind-eroded muck. b) Severe wind erosion of muck resulting in death of direct seeded onion seedlings and deposition of muck between the seed beds. c) Transplanted onions severely beaten by wind-blown muck. d) Direct seeded onions severely beaten by wind-eroded muck.

Conventional tillage results in the degradation of soil health. During tillage, large soil aggregates, which in muck soil are essentially large clumps of partially decayed plant parts, are broken up into very fine particles. These fine particles do not stick together, because there is nothing to provide a mechanism for binding them together into larger and more stable aggregates. Fine particles of muck are like dust and are easily eroded by wind and water. When it rains, the particles on the surface soak up water quickly, but water cannot infiltrate into the lower soil profile because of the lack of soil structure in the plow layer. Excess water runs off into surface ditches or collects in depressions in the field (i.e. “wet spots”). Onions growing in wet spots yield less, and can have higher incidence of bacterial diseases. Erosion of muck can result in the loading of watersheds with pesticides and fertilizers, especially phosphorous.



Figure 2. Stunted onions in a wet spot of a poorly drained field, Elba muck land, 2009.

More aggressive tillage methods temporarily alleviate the effects of degraded soil health by “fluffing up” the soil at planting time, but the main result is further degradation of soil health and increased subsidence. This leads to increased fertilizer and pesticide inputs to maintain productivity, resulting only in increased subsidence and declining productivity at ever increasing costs. The minimum use of tillage practices is essential for the long-term productivity of muck soils for onion production in New York.

In this study, we developed a reduced tillage production system for onion production on muck soils and evaluated the effects of using reduced tillage and cover crops on erosion. It is a scientifically proven fact that wind and water erosion, and subsidence decreases as ground cover increases and cultivation decreases. On a commercial scale, the grower cooperator direct seeded onions using a modified onion seeder, into cover crops planted in the fall in rows, including spring oats and winter wheat. This project was the first endeavor of its kind.

Objectives/Performance targets:

To develop, demonstrate and evaluate the production of growing direct seeded onions in a minimum tillage system in muck soil on a commercial scale.

Materials and Methods:

Minimum Tillage Systems Established (Table 1):

Growing direct seeded onions using a conventional system was compared to using minimum tillage systems with spring oats and winter wheat cover crops in side by side comparisons in the same field with each system being 10 acres. On September 18, 2007, in the minimum tillage plots, 470 lbs of 12-19-21 NPK fertilizer was broadcast and incorporated. On September 19, 2007, 50 lbs each of spring oats and winter wheat were seeded in rows spaced 10.5 inches. The following spring, Roundup was applied to wheat at 1.5 pts per acre on April 1, 2008.

At the conventional site, in the fall, 60 lbs per acre of spring oats were broadcast and lightly disked in. In the spring, the area was moldboard plowed and 600 lbs of 16-17-25 NPK was broadcast and incorporated on April 15, 2008, just before the trial was seeded on April 19. Barley windbreaks were drilled at 65 lbs per acre between the onion rows at the time of planting. These nutrient applications were based on soil tests not conducted by Cornell.

In the minimum tillage sites, onions were seeded between the cover crop rows using a regular onion seeder with coulters mounted on it and auto-steering and global positioning system (GPS) technologies on the tractor. Each bed consisted of 5 rows of yellow onions (cv. Milestone) spaced 10.5 inches apart and seeded at a rate of 7 seeds per foot. Three and 5 gal per acre of 6-24-6 NPK was applied in-furrow at planting in the conventional and minimum tillage sites, respectively.

On May 14, when the onions were at the first true leaf stage, 50 and 100 lbs of urea was broadcast and rained in at the conventional and minimum tillage sites, respectively. On June 13, when the onions were at 3 to 5 leaf stage, 100 lb of sulfur coated urea was applied to the minimum tillage systems, based on the results of a soil test conducted by Hoepting. The 10 acre area for each tillage system was divided into 4 replications across the length of the field.

Cover Crop Residue:

On April 17, prior to planting, the amount of ground cover was visually estimated. On April 14, May 14 and June 19, dry weight of cover crop residue, including barley windbreaks in conventional system was obtained. In each replicate, two 1 square meter areas were randomly selected from which all of the above-ground cover crop residue was collected and oven dried.

Stand Establishment:

Two sub-samples of 1 square meter were randomly selected for each replicate. The number of emerged plants per 1 m of row in each of 5 rows per sub-sample were counted on May 14, June 19 and July 31.

Table 1. Establishment of conventional and minimum tillage systems: planting and nutrient inputs.

Date (crop stage):	Conventional Tillage	Minimum Tillage Oats	Minimum Tillage Wheat
9-18-07		<i>Nutrient input:</i> 470 lbs 12-19-21 PPI ¹ = 56 lbs N, 89 lbs P, 98 lbs K	<i>Nutrient input:</i> 470 lbs 12-19-21 PPI ¹ = 56 lbs N, 89 lbs P & 98 lbs K
9-19-07		<i>Planted Cover Crops:</i> Spring oats @ <50 lbs in 10.5" rows using AutoSteer	<i>Planted Cover Crops:</i> Winter wheat @ > 50 lbs in 10.5" rows using AutoSteer
4-1-08			<i>Cover Crop Management:</i> Winter wheat: applied Roundup @ 1.5 pts
4-15-08	<i>Nutrient input:</i> 600 lbs 16-17-25 PPI ¹ = 96 lbs N, 102 lbs P, 150 K		
4-19-08	<i>Planted Onions:</i> coulters on seeder 10.5" rows <i>Planted nurse crop:</i> Barley @ 65 lbs between onion rows <i>Nutrient input:</i> 3 gal 6-24-6 in-furrow = 2 lbs N, 8 lbs P, 2 lbs K	<i>Planted Onions:</i> coulters on seeder 10.5" rows, between cover crop rows Using AutoSteer <i>Nutrient input:</i> 5 gal 6-24-6 in-furrow = 3 lbs N, 13 lbs P, 3 lbs K	<i>Planted Onions:</i> coulters on seeder 10.5" rows, between cover crop rows Using AutoSteer <i>Nutrient input:</i> 5 gal 6-24-6 in-furrow = 3 lbs N, 13 lbs P, 3 lbs K
5-14-08 1st leaf	<i>Nutrient input:</i> 50 lbs urea (46-0-0) broadcast = 23 lbs N	<i>Nutrient input:</i> 100 lbs urea (46-0-0) broadcast = 46 lbs N	<i>Nutrient input:</i> 100 lbs urea (46-0-0) broadcast = 46 lbs N
6-13-08 4 leaf		<i>Nutrient input:</i> 100 lbs sulfur coated urea (46-0-0) broadcast = 46 lbs N	<i>Nutrient input:</i> 100 lbs sulfur coated urea (46-0-0) broadcast = 46 lbs N
<i>TOTAL Nutrients Applied:</i>			
Nitrogen			
Total:	121 lbs	151 lbs	151 lbs
Spring:	121 lbs	95 lbs	95 lbs
Phosphorus	110 lbs	102 lbs	102 lbs
Potassium	152 lbs	101 lbs	101 lbs

¹PPI = pre-plant incorporated

Fertility:

Soil samples were collected before planting on April 17 by taking 2 composite sub-samples from 12 inches deep in each tillage system. Samples were sent to the Cornell Nutrient Analysis

Laboratory for analysis of phosphorous, potassium, pH and organic matter. Available nitrogen was quantified 5 days after planting on April 24, immediately before urea was side-dressed when the onions were at the first true leaf stage on May 14, 1 and 2 weeks after the urea was applied on May 21 and June 4, respectively, and again 1 week after the second application of urea on June 19. For the April 24, May 21 and June 4 samplings, 2 composite samples were collected from 12 inches deep per tillage system; on May 14, a single composite sample was collected per tillage system from the third replicate; on June 19, a single composite sample was collected from each replicate per tillage system. At all assessment dates except June 19, soil was collected separately from the plant rows and from between the plant rows. On June 19, soil was sampled randomly throughout the field. Available nitrate nitrogen was measured using a hand-held Cardy® meter (Spectrum Technologies Inc.). On July 22, samples were collected and sent to the Cornell Nutrient Analysis Laboratory for leaf tissue analysis of plant nutrients. Two sub-samples of 10 randomly selected plants were collected per replicate, from which the 4 middle-aged leaves per plant were submitted for leaf tissue analysis.

Plant Size:

To quantify plant size, the number of leaves per plant were counted, and the tallest leaf per plant was measured in 2 sub-samples of 10 plants in a row per replicate on June 19 and July 31.

Pest Pressure:

Total number of onion thrips (OT) and purple blotch (PB) lesions per plant were counted on 4 sub-samples of 6 plants per replicate on July 31 and August 19. Number of Botrytis leaf blight (BLB) lesions on the outer three leaves per plant were counted on 4 sub-samples of 6 plants per replicate on August 19. Incidence of bacterial rot was determined on August 19 by randomly selecting 4 sub-samples of 10 plants in a row per replicate and counting the number of plants that had canker or bulb rot.

Soil health and wind erosion:

Soil compaction was measured using a Penetrometer. A site was randomly selected for each replicate and soil compaction was measured at depths 0 to 6 inches and 7 to 12 inches in each of 5 rows and between each row across the bed. As the season progressed, ground cover appeared to hold the muck soil from being eroded by the wind. At the end of the season, ground cover and height of soil held underneath the remaining cover crop residues was estimated and used to estimate the amount of soil that was saved from being eroded by the wind.

Soil Temperature and Moisture:

Soil temperature and moisture at a depth of 2 inches were measured hourly using Spectrum Technologies Inc. WatchDogs®, which were set up on May 15 and taken down on August 25.

Yield:

On August 25 onions were pulled from 2 sub-samples of 5 x 5 square feet (1 bed wide = 5 rows of onions x 5 feet long) per replicate and windrowed. On September 30, they were topped, weighed and graded. The grower cooperator also kept track of the total yield per 10 acre tillage system.

Results and Discussion/Milestones:

Minimum Tillage Systems Established (Table 2):

This was the first attempt anywhere at growing direct seeded onions in a minimum tillage system on muck soil on a commercial scale. Just prior to planting, ground cover was 0%, ~ 10% and ~ 60% in the conventional, minimum tillage oats and minimum tillage wheat systems, respectively (Figure 3). At this time, the minimum tillage system had an average of 3039 grams per square meter of dry cover crop residue, compared to in the minimum tillage oats, which had 37 grams per square meter of dry cover crop residue, while the conventional system had none. One month after planting on May 14, the minimum tillage wheat system still had significantly more dry cover residue (205 g/m²), than the minimum tillage oats (37 g/m²) and conventional system (27 g/m²), although it decreased 16-fold. Two months after planting on June 19, the minimum tillage wheat system continued to have significantly more dry cover (183.5 g/m²) than the minimum tillage oats system (12.7 g/m²) and conventional system (11.5 g/m²) (Figure 3). The residue in the conventional system was due to the barley wind breaks. By July 31, estimated ground cover was reduced by half to 30% in the minimum tillage wheat system, to 0.3% in the minimum tillage oats, and back to 0% in the conventional system. It was observed that the soil was raised by 0.3 to 1.0 inch where the wheat and the oat residue remained (Figure 4). Although the target rates of wheat and oat cover crops were 50 lbs per acre, in actuality, the rate of wheat was higher and the rate of oats much lower, because when they were drilled in the fall with the same unit, the larger oat seeds dropped slower while the smaller wheat seeds dropped faster. Evaluating these cover crops at the targeted 50 lb per acre is warranted.

Table 2. Comparison of onions grown in minimum tillage and conventional systems: Estimated ground cover and dry weight of cover crop residue.

Tillage System	Visual estimate of ground cover (%)	Dry weight of cover crop residue (g/m ²)			Visual estimate of ground cover (%)
	Apr 17	Apr 17	May 14	Jun 19	Jul 31
Conventional	0	0 b ²	27 b ¹	11.5 b ¹	0
Min. Tillage Oats	10	37 b	37 b	12.7 b	0.5
Min. Tillage Wheat	60	3039 a	205 a	183.5 a	30

¹in conventional system, barley windbreaks were planted between the onion rows on the same day that the onions were seeded. Barley windbreaks were killed when the onions were at the flag leaf to 1st true leaf stage. ²Numbers in a column followed by the same number are not significantly different, Fisher's Protected LSD test, p<0.05.

Ground cover at planting: April 19, 2008



Ground cover at mid-season: June 19, 2008



Figure 3. Ground cover at planting (top) and mid-season (bottom) for conventional (right), minimum tillage with oat cover crop (center) and minimum tillage with wheat cover crop (left).



Figure 4. Oat (left) and wheat (right) cover crop residues hold muck soil from being eroded by wind and water in onions grown in minimum tillage systems, July 31, 2008.

Stand Establishment (Table 3):

The minimum tillage with wheat site had significantly the lowest stand establishment in the trial on May 14 (5.9 seeds per foot), June 19 (3.3 seeds per foot) and July 31 (2.9 seeds per foot). No significant differences occurred in stand establishment between the conventional and the minimum tillage oat site (seeds per foot: May 14 conv.- 6.6, oats- 6.8; June 19: conv.- 5.8, oats- 5.9; July 31: conv.-5.6, oats- 6.1). The reason why the minimum tillage wheat site had a stand that was almost half of the seedling rate, and of the conventional and minimum tillage oat systems was because the wheat cover crop resulted in ~60% ground cover, which prevented the sun from heating up the muck and held in the moisture, which caused high losses to seedling damping off (Figure 5). In the future, seed treatments to control damping off will be used.

Table 3. Comparison of onions grown in minimum tillage and conventional systems: Stand establishment.

Tillage System	Stand (No. of plants per foot)		
	May 14 (1 st true leaf)	Jun 19 (3-5 leaf)	Jul 31 (8 leaf)
Conventional	6.6 a ¹	5.8 a	5.6 a
Min. Tillage Oats	6.8 a	5.9 a	6.1 a
Min. Tillage Wheat	5.9 b	3.3 b	2.9 b

¹Numbers in a column followed by the same number are not significantly different, Fisher's Protected LSD test, $p < 0.05$.



Figure 5. Poor stand establishment of onion seedlings in minimum tillage system with wheat cover crop, due to increased rate of damping off. Note, the green algae on the soil surface, an indication of cool moist soil conditions, known to be suitable for damping off.

Fertility (Table 4 & 5):

In the spring, the minimum tillage systems had low levels of P (conv. – 232 #/A; oats – 47 #/A; wheat – 58 #/A) according to Cornell nutrient analysis tests taken just prior to planting, indicating that a portion of the P added in the fall was lost over winter. A total of 95 lbs of nitrogen was applied to the minimum tillage systems including the furrow applications at planting and two broadcast applications at the 1st and 3rd leaf stages, compared to 121 lbs of total nitrogen applied to the conventional system including, one broadcast and incorporated application prior to planting, and one broadcast application at the 1st true leaf stage (Table 1).

Soil nitrate tests showed that available nitrate was very low to low (range: 8.5 to 20.5 ppm) on April 24, May 14, May 21 and June 4 in both the wheat and oat minimum tillage systems, which was 1.7 to 5.5 times less than the available nitrate in the conventional system (range: 34 to 72 ppm). After the second broadcast application of urea on Jun-19, available nitrate levels were finally acceptable in the minimum tillage systems (oats – 23.5 ppm; wheat – 36.5 ppm), but were still 2 to 3 times less than in the conventional system (74 ppm). With a couple of exceptions, the amount of available nitrogen in the conventional system was excessive; 35 ppm is considered acceptable. By mid-July, the onions in the minimum tillage oats system had observably lighter green foliage than the minimum tillage wheat and the conventional sites (Figure 6). It is suspected, that during July, there is a release of nutrients when the wheat residue breaks down that is taken up by the onions.

Leaf tissue analysis conducted on July 22, showed that the onions in the minimum tillage oat system had 110 lb/A of nitrate nitrogen, which was one half as much than the amount in the onions in the conventional system (218 lb/A) and minimum tillage wheat system (295 lb/A). The leaf tissue analysis also showed that in the minimum tillage systems, phosphorous was 33 to 50% less (oats – 62 lb/A; wheat – 71 lb/A) compared to the conventional (113 lb/A), and zinc was about 50% less (oats – 12 lb/A; wheat – 14 lb/A) compared to the conventional (22 lb/A).

Table 4. Comparison of onions grown in minimum tillage and conventional systems: Available P and K prior to planting, and available nitrate nitrogen throughout the spring.

Tillage System	Apr 17		Available Nitrate Nitrogen (NO ₃ -) in ppm ²								
	Pre-plant (#/A)		Apr 24		May 14		May 21		Jun 4		Jun 19
			5 DAP		Pre-Urea ⁵		1 wk post U		2 wk post U		
	P ³	K ⁴	In-row	Btwn row	In-row	Btwn row	In-row	Btwn row	In-row	Btwn row	1 wk post U
Conventional	232	1295	42.0	60.5	72.0	66.0	37.5	51.0	34.0	25.5	74.0
	VH ¹	VH	H	VH	VH	VH	G	H	G	C	VH
Min. Tillage	47	968	16.5	8.5	19.0	21.0	11.0	4.5	10.0	8.5	23.5
Oats	L	VH	L	VL	L	C	L	VL	L	L	C
Min. Tillage	58	938	24.5	19.0	13.0	31.0	13.5	18.5	11.5	20.5	36.5
Wheat	L	VH	C	L	L	G	L	L	L	L	G

¹soil test results: VH – very high; H – high; G – good; C – close; L – low; VL – very low. ²Available nitrogen nitrate (NO₃-): 30-35 ppm = sufficient N. ³P: 41 – 100 #/A is low. ⁴K: >670 #/A is very high. ⁵N applied as urea (46-0-0 NPK) broadcast and rained in on April 19 to all systems, May 14 (1st true leaf), and June 13 (4 leaf) to minimum tillage systems only.

Table 5. Comparison of onions grown in minimum tillage and conventional systems: Nutrient analysis of leaf tissue, July 22, 2008.

Tillage System	Leaf tissue analysis (lb/acre): July 22									
	P	K	Mg	Ca	Fe	Al	Mn	Zn	NO3	%N
Conventional	113	873	1858	31365	1	48	42	22	218	2.5
Min. Tillage Oats	62	803	1825	30985	0	41	34	12	110	2.8
Min. Tillage Wheat	71	963	1960	31135	0	42	39	14	295	2.9



Figure 6. Onions grown in minimum tillage systems where the onions had visually greener leaves and almost 3 times the nitrogen content where winter wheat was used compared to where spring oat cover crop was used.

Plant Size (Table 6):

On June 19, the conventional system had significantly more leaves per plant (4.8) and the tallest plants (42 cm), while the minimum tillage oats system had significantly the fewest leaves per plant (3.5) and the shortest plants (25 cm). This was likely a reflection of the more available nitrogen in the conventional system. By July 31, there were no significant differences in plant height, and the minimum tillage wheat had significantly more leaves per plant (10) than the conventional (8) and the minimum tillage oats (8). The extra vegetative growth of the onion plants in the minimum tillage wheat system was a result of the stand being about 50% thinner

than the other systems, due to early damping off. It is normal behavior for onions to produce larger plants and bulbs when stand is thinner.

Table 6. Comparison of onions grown in minimum tillage and conventional systems: plant size.

Tillage System	No. of leaves per plant		Height of tallest leaf (cm)	
	Jun 19	Jul 31	Jun 19	Jul 31
Conventional	4.8 a ¹	8 b	42 a	82
Min. Tillage Oats	3.5 c	8 b	25 c	82
Min. Tillage Wheat	4.0 b	10 a	33 b	83

¹Numbers in a column followed by the same number are not significantly different, Fisher's Protected LSD test, $p < 0.05$.

June 19, 2008



July 31, 2008



Figure 7. Comparison of onions grown in minimum tillage and conventional systems: difference in stand and plant size on June 19 (top row) and July 31 (bottom row). Left – conventional tillage; Center – minimum tillage oats, Right – minimum tillage – wheat.

Pest Pressure (Table 7):

On July 31, the onions grown in the minimum tillage oats system had significantly fewer onion thrips (OT) per plant (1.0) than the conventional (3.9) and minimum tillage wheat (8.2) systems. On August 19, onions grown in the minimum tillage oats system had the lowest number of OT per plant (7.2), which was not significantly different than the minimum tillage wheat (11.2). Both of the minimum tillage systems had significantly lower OT per plant than the conventional

system (25.2), which had 2.2 to 3.4 times more OT per plant than the minimum tillage systems. We suspect that there is a relationship between reduced nitrogen fertility, lighter green plant tissue and reduced OT pressure, an area which warrants further study.

On July 31, the conventional system had significantly more purple blotch (PB) lesions per plant (0.8) than the minimum tillage systems (oats – 0.3; wheat – 0.4). By August 19, there were no significant differences in PB among treatments. The minimum tillage wheat system had significantly fewer Botrytis leaf blight lesions per plant (26.4) than the other two systems (conv.- 44.3; oats- 45.5) on August 19. Also on August 19, the conventional system had significantly higher incidence of bacterial cankers (58%) than the minimum tillage wheat treatment (27.5%). The minimum tillage oats system (40.6%) was not significantly different than the other two systems. We suspect that the minimum tillage wheat system has improved aeration due to the reduced stand, which is less favorable for development of leaf disease.

In general, there is a trend towards reduced pest pressure with the lower fertility minimum tillage systems, compared to the conventional.

Table 7. Comparison of onions grown in minimum tillage and conventional systems: pest pressure.

Tillage System	No. Onion Thrips per plant		No. Purple Blotch lesions per plant		No. BLB ¹ lesions per plant Aug 19	% bacterial rot/canker Aug 19
	Jul 31	Aug 19	Jul 31	Aug 19		
Conventional	3.9 a ²	25.2 a	0.8 a	1.0	44.3 a	58.1 a
Min. Tillage Oats	1.0 b	7.2 b	0.3 b	0.9	45.5 a	40.6 ab
Min. Tillage Wheat	8.2 a	11.2 b	0.4 b	0.8	26.4 b	27.5 b

¹BLB: Botrytis leaf blight, No. lesions on outer 3 leaves per plant. ²Numbers in a column followed by the same number are not significantly different, Fisher's Protected LSD test, p<0.05.

Soil Health and Reduced Wind Erosion (Table 8):

Penetrometer readings were taken on July 31; both minimum tillage systems had significantly less compaction within the top 6 inches (oats- 89 psi; wheat- 69 psi) compared to the conventional (125 psi). No significant differences were detected at 6-12 inches deep. Reduced soil compaction allows plant roots to better penetrate the soil to mine nutrients and water, and it reduces water from ponding and becoming water-logged.

Table 8. Comparison of onions grown in minimum tillage and conventional systems: soil compaction, July 31, 2008.

Tillage System	Soil compaction (psi) – higher numbers indicate more compacted soil	
	Soil depth: 0-6 inches	Soil depth: 6-12 inches
Conventional	125 a ¹	158
Min. Tillage Oats	89 b	144
Min. Tillage Wheat	69 c	147

¹Numbers in a column followed by the same number are not significantly different, Fisher's Protected LSD test, p<0.05.

By August, we observed that in the minimum tillage wheat system, approximately 30% of the ground was covered with wheat residue (Table 2). The soil underneath the wheat residue was approximately 0.7 inches above the surrounding bare ground, because the wheat residue prevented the muck soil from eroding away by the wind. We estimate that the wheat cover resulted in 30.2 inch³ per ft² that was not eroded by the wind, representing a 25% reduction in the normal rate of muck subsidence (i.e. 1 foot every 10 years equal to 119.5 inch³ per ft²). If this minimum tillage practice were continued, the useful life of the muck could be extended by 25%.

Soil temperature and Moisture (Table 9):

Very little differences in maximum, minimum and average temperature at 2 inch soil depth occurred throughout the season among the different tillage systems. The minimum tillage wheat system consistently had the wettest soil throughout the season. The higher moisture content of the soil in the minimum tillage wheat system was a result of it having the highest ground cover throughout the season (30 to 60%), which prevented the soil from drying out. In this study, the increased soil moisture in the minimum tillage wheat system resulted in stand being reduced by 50%, because of damping off, which are soil pathogens that are favored by wet soil conditions. In general, moisture was adequate for onion production during the 2008 growing season, but it is likely that the ability of the cover residue in a minimum tillage system to retain soil moisture could be quite advantageous in a hot dry growing season; a concept that warrants further study.

Table 9. Comparison of onions grown in minimum tillage and conventional systems: soil temperature and moisture.

Week	Tillage System	Temperature at 2 inches (°F)			Soil Moisture at 2 inches (kPa) ¹		
		Max	Min	Avg	Max	Min	Avg
May 15-19	Conventional	na	na	na	na	na	na
	Min. Tillage Oats	58	53	56	64	36	52
	Min. Tillage Wheat	58	51	54	60	38	52
May 20-28	Conventional	63 ²	50	57	100	68	85
	Min. Tillage Oats	60 ²	50	55	70	52	61
	Min. Tillage Wheat	61	49	55	58	46	52
May 27- Jun 2	Conventional	69	55	62	109	69	85
	Min. Tillage Oats	65	58	61	71	54	62
	Min. Tillage Wheat	63	58	61	56	49	52
Jun 3-9	Conventional	79	67	73	69	56	62
	Min. Tillage Oats	75	67	70	60	50	55
	Min. Tillage Wheat	71	66	68	49	43	46
Jun 10-16	Conventional	81	65	72	66	34	46
	Min. Tillage Oats	76	67	71	42	23	33
	Min. Tillage Wheat	74	68	71	60	22	36
Jun 17-23	Conventional	74	60	67	40	27	34
	Min. Tillage Oats	70	62	66	25	18	20
	Min. Tillage Wheat	69	64	66	93	64	76

Table 9 continued. Comparison of onions grown in minimum tillage and conventional systems: soil temperature and moisture.

Week	Tillage System	Temperature at 2 inches (°F)			Soil Moisture at 2 inches (kPa) ¹		
		Max	Min	Avg	Max	Min	Avg
Jun 24-30	Conventional	78	66	72	88	56	66
	Min. Tillage Oats	75	67	71	37	26	29
	Min. Tillage Wheat	73	69	71	18	13	15
Jul 1-7	Conventional	76	63	69	97	62	76
	Min. Tillage Oats	75	65	70	40	25	31
	Min. Tillage Wheat	74	67	71	17	11	14
Jul 8-14	Conventional	76	67	71	196	156	180
	Min. Tillage Oats	79	65	71	80	68	73
	Min. Tillage Wheat	79	70	74	26	19	23
Jul 15-21	Conventional	77	67	72	179	119	146
	Min. Tillage Oats	82	64	73	117	88	101
	Min. Tillage Wheat	82	69	75	33	24	29
Jul 22-28	Conventional	72	65	69	57	40	48
	Min. Tillage Oats	78	62	69	27	18	22
	Min. Tillage Wheat	77	67	71	11	7	9
Jul 29-Aug 4	Conventional	73	66	69	104	90	95
	Min. Tillage Oats	79	62	69	42	35	38
	Min. Tillage Wheat	78	67	72	29	25	27
Aug 5-11	Conventional	70	64	67	75	34	58
	Min. Tillage Oats	76	60	67	39	19	30
	Min. Tillage Wheat	73	65	69	28	18	22
Aug 12-18	Conventional	69	44	64	43	34	40
	Min. Tillage Oats	79	57	66	26	19	23
	Min. Tillage Wheat	72	63	67	19	14	17
Aug 19-25	Conventional	65	na	na	36	31	34
	Min. Tillage Oats	76	56	66	25	22	23
	Min. Tillage Wheat	75	64	69	20	16	18

¹kPa: kilopascals; higher numbers indicate drier soil, lower numbers indicate wetter soil.

²yellow highlights indicate highest value of the three tillage systems per variable per week; similarly, green highlights indicate the lowest value.

Yield (Table 10):

According to the grower cooperator's records, the conventional system yielded 620 1-ton boxes of onions per 10 acre, which was closely followed by the minimum tillage oats system (617 1-ton boxes of onions per 10 acres). The minimum tillage wheat system yielded a respectable 587 1-ton boxes of onions per 10 acre, considering that stand was reduced by half.

According to our yield evaluations, neither of the minimum tillage systems yielded significantly different than the conventional (707 cwt/A), although the minimum tillage oats (763 cwt/A) yielded significantly higher than the minimum tillage wheat (671 cwt/A), despite having the

poorest growth and lowest available nitrogen during the growing season. Despite having the lowest total yield, the minimum tillage wheat had significantly 4.7 and 7.8 times more jumbo weight, 2 times more medium weight, and 3.4 and 3.8 times less small weight, than the conventional and minimum tillage oats, respectively. The minimum tillage oats system yielded almost twice as much jumbo weight as the conventional. The minimum tillage wheat system yielded the highest weight of culls (18 cwt/A compared to: oats – 6.8 cwt/A, conv. – 6.6 cwt/A), because of double centered bulbs that rotted, which is not uncommon when onions are grown with a thin stand.

Table 10. Comparison of onions grown in minimum tillage and conventional systems: yield and grade.

Tillage System	Grower yield (No. 1-ton boxes per 10 acre)	Total yield (cwt/A)	Bulb Size Distribution (cwt/A)			
			Small (1-2")	Med (2-3")	Jumbo (>3")	culls
Conventional	620	707 ab ¹	33 a	632 a	42 b	6.6
Min. Tillage Oats	617	763 a	30 a	664 a	70 b	6.8
Min. Tillage Wheat	587	671 b	8.7 b	331 b	329 a	18

¹Numbers in a column followed by the same number are not significantly different, Fisher's Protected LSD test, p<0.05.

Impact of Results/Outcomes:

Overall, our first attempt at growing direct seeded onions using a minimum tillage system in muck soil was a success with comparable yields to the conventional system, reduced onion thrips and bacterial rots, and significant reductions in soil compaction and reduced wind erosion.

As a result of the success of this project, the grower cooperator plans to continue to pursue growing direct seeded onions in a minimum tillage system in 2009-2010. He plans to modify the rates of the cover crops and fertility program, as well as use a seed treatment with efficacy against damping off. It is also likely that another grower in the Elba Muckland will trial growing transplanted onions in a minimum tillage system.

The results from this project which showed that the minimum tillage oat system that had the least amount of available nitrogen and lightest green leaf color also had significantly lower onion thrips and bacterial canker, lead to the successful pursuit of a Pest Management Education Program (PMEP) grant by Cornell University researchers and Hoepting, which plans to take a multidisciplinary approach to a thorough investigation of the interactions among fertility and pest management. If it is found that onions can be grown with lower nutrient requirements without compromising yield, but reducing pest pressure, there is tremendous potential for onion growers to save thousands of dollars in the input costs of fertilizer and pesticide sprays. A preliminary fertility by pest interaction study is underway in Elba in 2009.

In this study alone, by keeping a minimum of 30% ground cover in the 10 acre minimum tillage wheat cover crop system, a minimum of 13.16 million cubic inches of soil was kept on the ground and not eroded by the wind.

Economic Analysis (Table 11 & 12):

Table 11. Comparison of onions grown in minimum tillage and conventional systems: cost of establishing tillage systems.

Cost per acre	Conventional	Minimum Tillage Oats	Minimum Tillage Wheat
Pre-plant and starter fertilizer	\$221	\$114 ¹	\$114 ¹
Side-dressed nitrogen	\$16.50	\$33	\$33
Total cost of fertilizer:	\$237.50	\$147	\$147
Cover crops	Fall oats: \$12 Barley wind break: \$13 = \$26	\$10	\$10
No. of trips across the field @ \$12 per acre (fuel + labor)	Fall: fertilizer Incorporate Drill cover crop Spring: Plow Fertilizer Incorporate Plant barley Seed onions Urea = 9 trips: \$108	Fall: Fertilizer Incorporate Drill cover crop Spring: Seed onions Urea 1 Urea 2 = 6 trips: \$72	Fall: Fertilizer Incorporate Drill cover crop Spring: Round-Up ² Seed onions Urea 1 Urea 2 = 7 trips: \$84
TOTAL	\$370	\$276	\$288

¹Fertilizer purchased in fall of 2007 for fall application of minimum tillage systems, fertilizer for conventional system purchased in spring 2008, after price of fertilizer soared. ²Round-Up @ \$12 per acre.

Overall, the cost to establish the minimum tillage systems were \$94 and \$82 less per acre than it cost to establish the conventional system (\$370 per acre) for the oats and wheat minimum tillage systems, respectively. Savings were due to using less fertilizer, cover crops and making fewer passes across the field (Table 11). In another attempt at growing onions in a minimum tillage system, it is likely that there would be no differences in fertility expenses, because in this trial, P and N were found to be low, and should be increased.

Table 12. Comparison of onions grown in minimum tillage and conventional systems: net profit, not including pesticide and labor expenses.

Price per acre	Conventional	Minimum Tillage Oats	Minimum Tillage Wheat
<i>Small bulbs (1-2 inches):</i>			
Cwt per acre:	33 cwt	30 cwt	8.7 cwt
@ \$4 per cwt:	\$132	\$120	\$35
<i>Medium bulbs (2-3 inches):</i>			
Cwt per acre:	632 cwt	664 cwt	331 cwt
@ \$15 per cwt	\$9480	\$9960	\$4965
<i>Jumbo bulbs (> 3 inches):</i>			
Cwt per acre:	42 cwt	70 cwt	329 cwt
@ \$15 per cwt	\$630	\$1050	\$4935
TOTAL:	\$10,242	\$11,130	\$9,935
Cost of establishing tillage system:	\$370	\$276	\$288
NET RETURN¹:	\$9872	\$10,854	\$9,647

¹Net return to cover labor costs and operators management and investment with respect to minimum tillage, does NOT include cost of pesticide inputs.

The minimum tillage oats system had the highest net profit (\$10,854 per acre), which was \$982 and \$1207 more per acre than the conventional and minimum tillage wheat systems, respectively (Table 12). This was primarily a function of the minimum tillage oats system having the highest yield, which is impressive considering that the onions in this system were smaller in size and had less nitrogen for most of the growing season.

The results of our study show that there is great potential to grow onions in a minimum tillage system without adding any cost to production or losing any profit due to reduced yield.

Publications/Outreach:

Preliminary results were presented at the Annual Elba Muck Onion Twilight Meeting on August 5, 2008, where 40 onion growers, allied industry representatives and Cornell Cooperative Extension professionals were in attendance.

This research project was highlighted on the front page of the newspaper, the Batavia "Daily News" on August 19, 2008, along with the other 2008 Partnership project funded by NESARE that was conducted by Hoepting, "Maximizing onion yield and economic feasibility of growing onions from plug transplants".

Preliminary results of this project were presented by Hoepting to 12 Cornell research faculty and Extension Educators at the onion session of the Annual Agriculture In-Service training in Ithaca, NY, on November 12, 2008.

A summary of the results of this project and the great potential of growing onions in a minimum tillage system will be written up as a newsletter article for Extension newsletters, which should be distributed in the fall of 2009.

Farmer Adoption:

As a result of the success of this project, the grower cooperator plans to continue to pursue growing direct seeded onions in a minimum tillage system in 2009-2010. He plans to modify the rates of the cover crops and fertility program, as well as use a seed treatment with efficacy against damping off. It is also likely that another grower in the Elba Muckland will trial growing transplanted onions in a minimum tillage system.

Areas Needing Additional Study:

It certainly would be worthwhile to repeat this study again, specifically, with the rate of oat and wheat cover crops applied at exactly 50 lb per acre (in our study, due to drilling difficulties, the rate of oats was much less and the rate of wheat was more than 50 lb). It would also be good to fine-tune nutrient management in the minimum tillage systems, specifically: i) Fall applied P, as it appeared in this study that some may be lost over winter, perhaps, more should be applied in the fall. ii) Study the dynamics of nutrient availability when a cover crop is killed in the spring versus winter-killed. For example, it appeared that once the winter wheat was completely dead that there was a surge of nutrients available to the onion crop. iii) Determine the best method of applying nitrogen to minimum tillage systems, including urea, sulfur-coated urea, use of a zone-tillage cart in a separate pass, or using reduced rates.

The increased moisture holding capacity of muck in minimum tillage systems could present a benefit in a dry year, as water availability is a rate limiting factor in growing onions and achieving the more lucrative large bulb size; this should be further studied. Also, increased soil moisture can greatly increase incidence of seedling damping off and reduce stand; using a reduced rate of wheat cover, or killing it earlier in the spring may alleviate some of this problem, and should be further studied. In addition, different fungicide seed and furrow treatments should be evaluated for control of seedling damping off.

Our finding that onions grown with 25% less applied nitrogen, 1.7- to 5.5-fold less available nitrogen, and with observably lighter green foliage in the minimum tillage oat system had significantly 50% fewer Botrytis leaf blight lesions per plant, 3 to 4 times fewer onion thrips per plant, and no significant differences in yield than onions grown in the conventional system, warrants a multi-disciplinary approach to thoroughly investigate fertility and pest interactions, especially for onion thrips. If it is found that onions can be grown with lower nutrient requirements without compromising yield, but reducing pest pressure, there is tremendous potential for onion growers to save thousands of dollars in the input costs of fertilizer and pesticide sprays.