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Wisconsin Department of Agriculture, Trade & Consumer Protection
Agricultural Development and Diversification Program
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Progress Report
(Year 1 Final Report)

Date: 26 July 2001 WDATCP Contract No.: **15042**

Project Title: Evaluation of Dairy Manure Use in Potato Production Systems (Year 1)

Contractor Name: Keith Kelling

Project Leader: Keith Kelling, Professor, Soil Science, UW-Madison
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Progress Report For: 1 April 2001 to 30 July 2001

This report is submitted in fulfillment of Appendix A of the contract. The reports should summarize project activities and key results for the reporting period, and describe project activities and results expected during the next phase of the project. (Attach additional pages of information, in needed).

This project was established to evaluate the use of dairy manure as a nutrient source within potato production systems. Specifically the objectives of this study are to:

1. Determine the availability of manurial nutrients, especially N and P to potatoes;

2. Determine the influence of manure on incidence and severity of potato common scab;

3. Evaluate the effect of time after manure applications on common scab incidence and severity;

4. Determine the interaction of varietal susceptibility to the common scab pathogen and manure applications;

5. Evaluate the relative movement and accumulation of N and P from manure and fertilizer sources; and

6. Determine if potato production practices can be defined which allow for the integration of the potato and dairy industry.

In the spring of 2000, four distinct field plot experiments were established at the Antigo Airport Potato Research Facility (Experiments 1a, 1b, and 2) and at the Rhinelander Agricultural Research Station (Experiment 2). Specific details on the conduct of these experiments during the 2000 cropping season, the sampling protocols followed, the crop yield and quality, and the post-harvest soil test results have been reported previously. This report presents data heretofore not reported from these experiments for the 2000 growing season and describes the establishment of new plots at each of these locations for the 2001 season.

Recent Progress

The April to July period has been used to complete the various analyses on the plant tissue, soil and water samples that were collected during the 2000 growing season. Table 1 of the third-quarter reported showed those data not yet summarized. To some extent, this continues to be a work in progress. All analyses are now complete, with the exception of the soluble-P analyses of the water samples for Experiment 1b. These analyses will be completed in early August.

Table 1 shows the petiole NO_3-N levels as affected by fertilizer N rate, manure rate, and date of sampling. These data clearly show the trends for increasing petiole NO_3-N levels with increasing amounts of N applied and decreasing petiole NO_3-N levels with increasing crop maturity. A comparison of the amounts of N in the petioles for the manure treatments with the amounts present from the various fertilizer rates suggests that 327 lb/acre of total manure N was supplying available N similar to between 60 and 120 lb/acre of fertilizer N. The high rate of manure resulted in petiole NO_3-N levels corresponding to 240 or more pounds of fertilizer N per acre. These data generally support the yield results where the low manure rate was about equivalent to 60 lb N/acre and the high manure rate resulted in yields exceeding any achieved with fertilizer.

Comparison of the petiole NO_3-N with the sufficiency levels established for the variety Snowden at the various days after emergence generally showed sufficiency at 120 to 180 or more lb N/acre. This matches the yield responses very well where top yields with fertilizer were achieved with 180 lb N/acre.

Table 2 presents the concentration of soil NO_3-N found in 1-foot increments prior to fertilizer applications, at harvest and in the top 1 foot twice during the growing season. It is very clear that the amounts of NO_3-N reflected the quantity of N applied from both sources and that by the end of the season, some movement of N had occurred to at least the 2- to 3-foot depth where the high manure or fertilizer rate was applied. In general, the later part of the growing season was quite dry so little leaching would have been expected. These data also tend to show soil NO_3-N levels for the low and high manure rates that are similar to those found in the 60 to 120 lb and 180 to 240 lb/acre fertilizer N treatments, respectively.

Suction-cup lysimeters were installed in selected treatments at a depth of 3 feet to sample the soil solution at about 2-week intervals throughout the growing season. Results of these samplings are shown in Table 3. In some cases, especially later in the growing season, samples were not collected from all replications due to lysimeter plugging or inadequate suction at this depth. Although significant variation existed, these data do tend to show that by mid-August the manure treatments resulted in more NO_3-N in the soil water. These data also show that even where the crop was quite nitrogen deficient (zero fertilizer N applied, except for 10 lb N/acre in the starter), the potatoes were apparently unable to extract all of the N from the soil solution below about 10 ppm.

Table 4 presents the results of the petiole analyses for total P from the phosphorus component of Experiment 1 at Antigo. For the first and last samplings, it is obvious that the rate of application was reflected in the petiole total P levels, and that petiole P levels generally decreased as the season progressed. I have no explanation as to why we were unable to distinguish treatment differences especially for the 8 August sampling. In general, all of these levels would be considered sufficient for optimum yield, and this corroborates our general lack of tuber yield and quality responses to P additions in this season. Based on these data, we would also suggest that the low manure rate was equivalent to about 60 to 120 lb of fertilizer phosphate, while the high manure rate resulted in those similar to or greater than those observed in the 240 lb P_2O_5/acre rate.

Soil samples to a depth of 2 feet were also taken prior to planting from Experiment 2 at Antigo and Rhinelander and tested for NO_3-N (Table 5). These samples were taken prior to the application of any commercial fertilizer so the effect of manure rate is obvious. On the sandier soil at Rhinelander, it is also obvious that some of the manurial N had moved into the second layer; however, variation between samples prevented this from being statistically significant. Results of the 1-foot sampling done at mid-season (Table 6) showed no differences in soil NO_3-N values between varieties at either location, but since nitrogen uptake was generally similar through this part of the season, none would be expected. More NO_3-N in the top 1 foot where manure was applied at Antigo is likely a result of the slower release nature of the N in the manure and perhaps the greater amount of total N applied. The overall higher amount of NO_3-N present at Rhinelander is likely due to the extra 75 lb N/acre inadvertently applied across all plots by the Agricultural Research Station crew.

Summary of 2000 Experimental Results

Results of our first year clearly showed that manure can be an important source of nutrients to potatoes. Although the apparent N fertilizer replacement value of the manure may be slightly lower when raising potatoes than corn, our preliminary data show some yield, grade, and size grade advantages when manure was included in the system. In both Experiment 1 and 2, the manure-treated plots resulted in the highest yield and grade. Results of the soil and plant tissue analysis have helped confirm the appropriate equivalency of manurial N and P to potatoes. Our preliminary evaluations have not shown any increases in scab or tuber decay associated with the manure applications. Tuber solids, however, were significantly lower when manure was the nutrient source compared to an approximately equivalent amount of available nutrients from commercial fertilizer. After only 1 year of study, we did not uncover any apparent production problems associated with using manure in a potato production system.

Establishment of the 2001 Crop Year Experiments

A second year of crop experiments was established at both Antigo and Rhinelander following similar protocols and treatments as those used in 2000 but on a new plot area. In addition, the manure treatments from a portion of Experiment 2 at Antigo in 2000 were used to evaluate the influence of time of manure application prior to potato planting on potato diseases in 2001. Application in the fall of 1999, fall of 2000, and spring of 2001 allows us to include application timings of 18, 6, or 1 month(s) before planting in the experiment. Table 7 shows the dates of the various operations on these experiments to date for this year. Table 8 presents the analytical results of the manure that was spread in preparation for the 2001 crop season at both locations.

Experiments 1a and 1b evaluate the apparent nitrogen and phosphorus availability from dairy manure to potatoes. As was done the previous season, liquid dairy manure from the Purina dairy was applied in the fall of 2000 using a liquid manure spreader truck to 18 x 50 ft strips at rates of 0, 10, or 20 thousand gallons/acre. Results from the manure treatments are being compared with those obtained from N or phosphate fertilizer treated plots where five rates of N or five rates of P_2O_5 were used. Treatments are similar to those used in 2000. In the spring, a broadcast application of 400 lb/acre of 0-0-60 was applied preplant. Potatoes (cv. Snowden) were planted using 550 lb/acre 2-2-10 starter fertilizer as a carrier for Admire (Colorado potato beetle control). Nitrogen applications were split 33% at emergence as $(NH_4)_2SO_4$ and 67% at hilling as NH_4NO_3. Phosphate applications were applied preplant broadcast as 0-46-0. All plots were replicated four times, in randomized complete blocks.

Suction cup lysimeters were installed at a depth of 3 feet in row 2 of the high manure treatment plots, the high rate fertilizer treatment plots, and the untreated control plots. Soil water samples are being extracted about every 2 weeks throughout the season. Potato petioles are again being sampled (25 petioles/plot) at about 30, 45, 60, and 75 days after emergence to assess the plant nitrogen and phosphorus status. Prior to planting, soil samples were taken to a depth of 2 feet in 1-foot increments (6 cores per plot) for the nitrogen part of the experiment and to a depth of 1 foot only (12 cores/plot) for the phosphorus component. Two sets of mid-season samples (0 to 1 foot) are also being taken from the plots in Experiment 1A. Post-harvest samples will be taken from all plots (0 to 1 foot for P, 0 to 3 feet for N).

Average total nitrogen, phosphate, and potash content of the manure applied to these experiments in the fall of 2000 at Antigo was 28.1 lb N, 11.5 lb P_2O_5, and 23.2 lb K_2O per 1000 gallons. Little variation existed between the four samples taken.

Experiment 2 evaluates the influence of a low (10,000 gallon/acre) or high (30,000 gallon/acre) rate of fall manure at Antigo and spring-applied manure at Rhinelander on the incidence and severity of potato scab for several potato varieties compared to the amount of scab found on unmanured areas. Varieties used are Russet Norkotah, W-1151R, Snowden, and Superior.

Whole plant dry weights (vegetation, tubers, and roots) are being taken from 6 plants/pot (early season) or 4 plants/pot (later season) several times during the growing season at Antigo only. This will allow us to evaluate the pattern of nutrient uptake from both fertilizer and manure for the several varieties. The last sampling will be taken just before vine kill.

Analysis of the spring-applied manure used at Rhinelander was 22.3 lb N, 7.8 lb P_2O_5, and 21.6 lb K_2O per 1000 gallons. The Antigo applications were made the same day as those of Experiment 1 and analyses are give above.

Experiment 3 evaluates whether time can moderate the influence of manure application or potato disease incidence and severity. This experiment, which is now in place where Experiment 2 was for the 2000 growing season, has had manure applied 18 months, 6 months, and 1 month before potato planting. A high manure application rate (30,000 gallons/acre) was used. Since the plots that had received manure in the fall of 1999 have raised a crop of potatoes after that application, only second-year availability (approx. 10%) could be expected on these plots. Therefore, fertilizer at the rate of 170 lb N/acre and 74 lb P_2O_5/acre was applied to compensate

for the nutrients previously removed. The no manure control plots received 254 lb N/acre and 187 lb P_2O_5/acre. For the 2001 growing season, this field was planted with the same four varieties used in Experiment 2.

Plot diagrams and treatment lists for the various experiments are appended.

August to October Plan of Work:

Samples will continue to be collected through the end of September, including one more petiole sampling, two more soil samples, and four more water samplings for Experiment 1 at Antigo. Experiment 2 at Antigo will have two or three more whole plant samplings as well as two more soil samplings. Harvest occurs in late September, at which time tubers will be sampled for solids, evaluated for diseases and hollow heart, and then analyzed for nutrient content. This will be done for all experiments as well as harvest soil samples.

Table 1. Effect of dairy manure and fertilizer N rates on petiole NO_3-N levels on several sampling dates at Antigo, WI, 2000.

N rate	N source	7 July (30 dae)†	21 July (44 dae)	8 August (60 dae)	20 August (75 dae)
lb/acre		---------- % ----------			
0	Control	1.67	0.42	0.11	0.09
60	Fertilizer	1.71	1.21	0.43	0.26
120	Fertilizer	2.17	1.62	1.21	0.64
180	Fertilizer	2.36	1.85	1.25	0.62
240	Fertilizer	2.33	1.56	1.32	0.97
327	Manure	2.40	1.41	0.85	0.34
654	Manure	2.78	1.68	1.41	0.85
Pr > F		<0.01	<0.01	<0.01	<0.01
$LSD_{0.05}$		0.54	0.53	0.57	0.41

† dae, days after emergence.

Table 2. Effect of fertilizer or manure N rates on soil NO_3-N levels taken at four times during the season at Antigo, WI, 2000.

N rate	N source	Soil depth 0 to 1 ft	1 to 2 ft	2 to 3 ft	Profile total
lb/acre		---------- ppm	----------	----------	lb/acre
		Pre-season (11 May 2000; 0 to 2 ft)			
0	Control	12.3	3.1	--	61.6
327	Manure	38.1	3.2	--	165.1
654	Manure	33.0	8.4	--	165.5
Pr > F		0.3	<0.01	--	0.03
LSD0.05		18.7	2.6	--	77.2
		Mid-season (7 July 2000; 0 to 1 ft)			
0	Control	15.6	--	--	62.4
60	Fertilizer	34.4	--	--	137.6
120	Fertilizer	32.1	--	--	128.4
180	Fertilizer	48.1	--	--	192.4
240	Fertilizer	27.5	--	--	110.0
327	Manure	13.7	--	--	54.8
654	Manure	55.9	--	--	223.6
Pr > F		0.04	--	--	0.04
$LSD_{0.05}$		27.4	--	--	109.5
		Mid-season (8 August 2000; 0 to 1 ft)			
0	Control	4.9	--	--	18.0
60	Fertilizer	9.0	--	--	36.0
120	Fertilizer	12.3	--	--	49.2
180	Fertilizer	20.5	--	--	82.5
240	Fertilizer	18.8	--	--	75.2
327	Manure	29.3	--	--	117.2
654	Manure	19.1	--	--	76.4
Pr > F		0.31	--	--	0.30
$LSD_{0.05}$		21.3	--	--	85.0
		Harvest (13 October 2000; 0 to 3 ft)			
0	Control	14.1	6.4	3.1	94.4
60	Fertilizer	20.4	10.9	3.1	138
120	Fertilizer	19.6	8.4	4.2	129
180	Fertilizer	24.7	16.8	5.5	188
240	Fertilizer	37.8	19.1	14.6	286
327	Manure	15.9	7.9	3.4	109
654	Manure	27.3	26.8	10.0	256
Pr > F		0.12	0.03	<0.01	0.01
$LSD_{0.05}$		16.1	12.5	4.0	108

Table 4. Effect of dairy manure and fertilizer phosphate rate on petiole total P levels at Antigo, WI, 2000.

Nutrient rate	Nutrient source	7 July	21 July	8 August	20 August
lb/acre		---------- % ----------			
0	Control	0.405	0.319	0.190	0.176
60	Fertilizer	0.472	0.304	0.196	0.182
120	Fertilizer	0.423	0.342	0.199	0.195
180	Fertilizer	0.472	0.354	0.199	0.198
240	Fertilizer	0.505	0.361	0.195	0.200
327	Manure	0.460	0.320	0.202	0.204
654	Manure	0.503	0.346	0.199	0.211
Pr > F		<0.01	0.33	0.91	0.15
$LSD_{0.05}$		0.52	NS†	NS	0.27

† NS, not significant.

Table 5. Effect of manure rate on preplant soil test NO_3-N levels taken on 10 May for Experiment 2 at Antigo and Rhinelander, WI, 2000.

	Antigo		Rhinelander	
Manure rate	0 to 1 ft	1 to 2 ft	0 to 1 ft	1 to 2 ft
1,000 tons/acre	---------- NO_3-N (ppm) ----------			
0	20.8	8.0	4.0	2.6
10	29.7	11.3	26.3	8.4
30	60.8	9.7	40.0	10.1
Pr > F	<0.01	0.38	<0.01	0.29
$LSD_{0.05}$	15.1	NS †	10.5	NS

† NS, not significant.

Table 6. Effect of manure on mid-season soil test NO_3-N levels taken 11 July for Experiment 2 at Antigo and Rhinelander, WI, 2000.

Nutrient source †	Variety	Nitrate-N (0 to 1 ft) Antigo	Rhinelander
		ppm	
100% fertilizer	R. Norkotah	58.0	91.0
	Norland/W-1151R ‡	50.2	84.5
	Snowden	51.5	88.3
	Superior	62.1	84.0
67% fertilizer 33% manure	R. Norkotah	58.1	86.1
	Norland/W-1151R	80.8	73.3
	Snowden	47.5	67.5
	Superior	46.3	79.8
100% manure	R. Norkotah	86.4	71.3
	Norland/W-1151R	76.8	66.3
	Snowden	83.4	63.9
	Superior	84.0	70.1
Statistical significance (Pr > F)			
Nutrient source (NS)		<0.01	0.17
Variety (V)		0.79	0.83
NS x V		0.39	0.99
Main effects			
Nutrient source			
Fertilizer		55.5	86.9
Fertilizer+manure		58.1	76.7
Manure		82.7	67.9
$LSD_{0.05}$		15.8	20.0
Variety			
R. Norkotah		67.5	82.8
Norland/W-1151R		69.3	74.7
Snowden		60.8	73.2
Superior		64.1	78.0
$LSD_{0.05}$		NS §	NS

† Manurial nitrogen rate applied = 294 lb/acre of available N based on a 30% availability in the first year. Fertilizer was applied at 294 lb N/acre.

‡ Norland at Antigo and W-1151R at Rhinelander.

§ NS, not significant.

Table 7. Chronology table for manure potato experiments at Antigo and Rhinelander, WI, 2001.

Antigo — Experiments 1a and 1b:		
Manure application		17 November 2000
Fertilizer applications —	Preplant	15 May 2001
	Starter (500 lb 2-2-10/acre)	15 May 2001
	Emergence nitrogen	4 June 2001
	Hilling nitrogen	21 June 2001
Planting		15 May 2001
Emergence		9 June 2001
Lysimeter installation —		4 June 2001
	Water sample #1	13 June 2001
	Water sample #2	21 June 2001
	Water sample #3	5 July 2001
	Water sample #4	16 July 2001
	Water sample #5	24 July 2001
Petiole samples —	Sample #1	5 July 2001
	Sample #2	16 July 2001
	Sample #3	24 July 2001
	Sample #4	
Leaflet petiole		24 July 2001
Soil samples —	Pre-fertilizer treatment (0 to 1 and 1 to 2 ft)	15 May 2001
	Mid-season #1	5 July
	Mid-season #2	†
	Post-harvest (0 to 1, 1 to 2, and 2 to 3 ft)	
Antigo — Experiment 2:		
Manure application		17 November 2000
Fertilizer applications —	Preplant (400 lb)	15 May 2001
	Starter (580 lb 2-2-10/acre)	15 May 2001
	Emergence nitrogen	4 June 2001
	Hilling nitrogen	21 June 2001
Planting		15 May 2001
Emergence		9 June 2001
Whole plant samples —	Sample #1	21 June 2001
	Sample #2	5 July 2001
	Sample #3	24 July 2001
	Sample #4	
	Sample #5	
	Sample #6	
Leaflet petiole		24 July 2001
Soil samples —	Preplant (0 to 1 and 1 to 2 ft)	15 May 2001
	Mid-season (0 to 1 ft)	

— continued —

Table 7. (continued).

Antigo — Experiment 3:		
Manure application		17 November 2000
Fertilizer applications —	Preplant (400 lb)	16 May 2001
	Starter (580 lb 2-2-10/acre)	16 May 2001
	Emergence nitrogen	4 June 2001
	Hilling nitrogen	21 June 2001
Planting		16 May 2001
Emergence		9 June 2001
Leaflet petiole		25 July 2001
Soil samples —	Preplant (0 to 1 and 1 to 2 ft)	16 May 2001
	Mid-season	25 July
Rhinelander — Experiment 2:		
Manure application		1 May 2001
Fertilizer applications —	Preplant	14 May 2001
	Starter (580 lb 2-2-10/acre)	14 May 2001
	Emergence nitrogen	5 June 2001
	Hilling nitrogen	21 June 2001
Planting		14 May 2001
Emergence		6 June 2001
Leaflet petiole		24 July 2001
Soil samples —	Preplant (0 to 1 and 1 to 2 ft)	14 May 2001

† Where dates are not shown, these samples have not yet been taken.

Table 8. Average manure analytical results for applications made for the 2001 crop season at Antigo and Rhinelander, WI.

Location	Experiment	Type of application	Dry matter	Total N	NH_4-N	P_2O_5	K_2O
			% ----------	----------	lb/1000 gal	----------	----------
Antigo	1a and 1b	Fall 2000	5.1	2.8	11.51	23.22	
Antigo	2	Fall 2000	5.1	2.8	11.24	27.78	
Antigo	3	Fall 1999	6.0	3.2	13.05	25.97	
		Fall 2000	5.1	3.0	10.83	22.61	
		Spring 2001		4.3	1.9	8.44	21.95
Rhinelander	2	Spring 2001		4.5	1.9	7.85	21.61

Table 3. Lysimeter water nitrate-N samples as affected by manure or fertilizer applications at various times at Antigo, WI, 2000.

N rate	N source	16 June Range	16 June Mean	23 June Range	23 June Mean	7 July Range	7 July Mean	21 July Range	21 July Mean
lb/acre		ppm							
0	Fertilizer	7.4-17.0	12.2	6.6-22.1	14.3	8.3-21.4	12.6	7.2-17.0	12.6
240	Fertilizer	--	--	5.6-15.0	10.8	9.7-15.4	12.3	6.8-18.4	13.3
327	Manure	10.0-25.7	15.7	14.3-32.0	22.6	13.4-28.5	18.9(3)†	8.7-28.0	17.3(3)
654	Manure	3.3-19.1	11.8	5.2-18.3	12.7	7.4-83.0	32.3	16.1-40.0	26.0
Pr > F			0.38		0.47		0.39		0.22
$LSD_{0.05}$			NS‡		NS		NS		NS

N rate	N source	9 Aug Range	9 Aug Mean	20 Aug Range	20 Aug Mean	8 Sept Range	8 Sept Mean
lb/acre		ppm					
0	Fertilizer	1.7-10.9	7.4(3)	5.7	5.7(1)	--	--
240	Fertilizer	6.8-18.4	11.8(3)	19.2	19.2(1)	1.8-20.5	8.17(3)
327	Manure	14.3-37.1	25.7(3)	36.6-101.4	68.9(2)	15.4	15.4 (1)
654	Manure	48.6	48.6(1)	3.5	3.6(1)	51.6-129.7	90.6 (2)
Pr > F			0.10		--		--
$LSD_{0.05}$			24.0		--		--

† The numbers in parentheses are the number of lysimeters from which samples were collected for that treatment. Where no number is shown, samples were collected from all four replications.

‡ NS, not significant.