MANURE MANAGEMENT AND POTATO PRODUCTION

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With the recent expansion of the dairy industry in Idaho, field crops with highest nutrient removal potential (corn silage, alfalfa hay, and small grain crops) receive the majority of dairy waste applications in the state. However, as dairies have expanded into prominent potato growing regions, more and more potato growers are planting into fields with extensive and even recent manure applications. It is critical for the growers to fully understand the potential benefits and issues associated with growing potatoes in fields with histories of manure applications to serve the greatest benefit to the grower, the consumer, and the environment. The purpose of this discussion is to 1) summarize research that has been done outside of Idaho on manure application to potato fields, and 2) to present our research findings on this topic.

MANURE AND COMPOST LONG_TERM RESIDUAL EFFECTS

The residual effects of manure applications on tuber yield have been examined in a small number of studies. Dawson and Kelling found that yields were reduced with a recent application of liquid dairy manure application, but yields of potatoes increased over the next two year when grown on the same site. Sharma and Grewal (1986) and Conn and Lazarovits (1999) did not detect any residual effects on potato yield over 3 years after manure applications. In contrast, plots receiving manure applications for 20 years at 15 tonnes manure ha^{-1} significantly increased barley yields in comparison to control plots (Hall, 1905).

To determine the residual effects of manure applications in Idaho, a two-year study looked at potato production on a field that previously received manure, compost, and phosphorus fertilizers applications. Specifically, Russet Burbanks potatoes were planted into a 2 acre ARS agricultural field that had previously received applications of fresh solid dairy waste, composted solid dairy waste, inorganic P fertilizers, and/or no P source in the fall for three consecutive years (2003, 2004, and 2005). Chemical sources of N, P, and K were applied to the field in 2006, 2007, 2008 and 2009, based on the needs of the crop. Potatoes were planted in this field in 2008 and 2009. While residual effects of manure and compost applications significantly increased yield in 2008, they did not significantly effect yields in 2009 (table 1). Soil nitrate concentrations followed a similar trend, with residual effects of manure applications significantly increasing soil nitrate concentrations in 2008 but not in 2009 (table 2). Soil potassium and phosphorus followed similar trends in 2008 and 2009 (table 2). These results suggest that plant available nitrogen originating from manure and compost may have the greatest influence on yield

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in comparison to the effects of altering phosphorus or potassium levels. Tubers from the control plots showed a trend ($p<0.10$) for higher glucose levels (data not shown). There were no other noticeable differences in processing quality between the treatments. The presence of *E. coli* 0157:H7 was not detected on the surface of five potatoes selected in any of the treatments. Also, these treatments had no significant effect on coliform counts on the surface of five potatoes from each plot.

Table 1. Total yield, marketable yield, culls, and yield of US#2 grade (cwt/A). Values in the same column followed by the same letters are not significantly different at $p \leq 0.05$

Treatment	Total Yield cwt/A)		US#1 (cwt/A)	
	2008	2009	2008	2009
Manure	494a	428	333	345
Compost	487a	365	319	305
Fertilizer	412b	452	271	390
Control	349b	329	199	268
LSD $p \leq 0.05$	70.9	NS	NS	NS

Table 2. Effects of historical nutrient field treatments on soil chemical properties.

Treatment	NO3-N (ppm)		Olsen P (ppm)		K (ppm)	
	2008	2009	2008	2009	2008	2009
Manure	43.3 a	19.0	19.8 a	23.2 a	204 a	182 a
Compost	31.0 b	13.7	17.3 a	20.7 ab	170 a	162 a
Fertilizer	26.3 b	12.6	22.3 a	16.7 b	130 b	107 b
Control	22.5 b	11.1	5.0 b	4.7 c	128 b	110 b
LSD $p \leq 0.05$	12.0	NS	11.2	4.9	34.3	45.3

RECENT MANURE APPLICATIONS

Several studies on recent applications of cattle, dairy, and farmyard derived manure (planting within 6 months after application) to potatoes in northern United States and southern Canada have shown significant potato yield increases in comparison to non-limiting fertilizer applications (Dawson and Kelling, Holliday et al. 1965, Black and White, 1973, Curless et al., 2004). These studies suggest that factors beyond nutrient content were involved in the yield increases. Grandy et al. (2002) found that while soil bulk density was not affected with these manure applications, the soil carbon content increased 28 and 46% and medium and large aggregate content increased on potato cropping rotation fields receiving 16 tonnes cattle manure ha^{-1} for 5 and 6 years prior,. Conversely, Lee and MacDonald (1977) and Hall (1905) did not detect potato yield changes with cow and farmyard manure applications compared to fertilizer applications. Conn and Lazarovits (1999) did not detect potato yield increases with cow manure application of 100 tonnes ha^{-1} in comparison to control plots not receiving any fertilizers.

In 2009, Russet Burbank potatoes were planted into a certified organic field in Kimberly, Idaho, after a spring barley cover crop (table 3). Fresh dairy manure was spring-applied at a rate of 8.9 wet tons/acre and incorporated to a 6-inch soil depth prior. While not statistically significant, yields did increase by 37 cwt./acre with the spring-manure application, illustrating that recent manure applications may increase tuber yield in Southern Idaho.

Table 3. Total yield, marketable yield, culls, and yield of US#1 grade (cwt/A). Values in the same column followed by the same letters are not significantly different at $p \leq 0.05$.

Preplant treatment	**Preplant rate (ton dry matter/ acre)**	**Preplant rate (total lb N/acre)**	**Total Yield (cwt/A)**	**US#1 (cwt/A)**	**Petiole NO3 7/14/09 (ppm)**	**Petiole NO3 7/27/09 (ppm)**
Dairy manure	3.1	54	296 a	260 a	875 ab	1275 a
None	0	0	259 a	234 a	575 a	1575 ab

NUTRIENT CYCLING

Nutrient cycling and accumulations in potato production systems are also of great interest to growers, as applications of fertilizers often need to be adjusted to compliment the nutrient supply from a manure source. Curless et al. (2004) estimated 62% of manure P to be available to the potato. They also found luxury consumption of fertilizer P by potato plants but not for manure P. Finally, it should also be noted that Curless et al. (2004) found that potato petiole nitrate concentrations were significantly lower for manure treated plants than for nitrogen fertilized plants, while yields were significantly higher with manure applied treatments, suggesting that petiole nitrate targets for inseason N fertilizer applications may need to be adjusted for manured soils. In estimating long-term release of N from dairy manure applications, Klausner et al. (1994) used decay principles to predict nitrogen availability from dairy manure to be 21, 9, 3, 3, and 2% for 1, 2, 3, 4, and 5 years following dairy manure applications under New York growing conditions, respectively. However, decay constants of dairy manure-nitrogen have not been established specifically for irrigated, cool climate calcareous soils, as are found in Idaho.

To determine effects of phosphorus and salt in dairy waste on soluble salt and phosphorus concentrations in potato field soils and corresponding potato tuber yields, 50 potato fields throughout South Central Idaho were soil sampled in 2009. The cooperator's fields had received different fertilizer treatments including manure (14 fields), lagoon water (10), both lagoon water and manure (5), compost (6), and conventional fertilizer only (15). Field and background soil samples (with minimal disturbance) were collected. Tuber yield data is currently being collected from cooperators. Preliminary soil data shows a potential accumulation of calcium (Ca), magnesium (Mg), sodium (Na), and phosphorus (P) on fields receiving compost, manure, and/or lagoon water applications in comparison to fertilizer only, with minimal effect on electrical conducitivity (Table 3). Significant potassium accumulations were detected only on fields that have received fresh dairy manure applications.

Table 3. Contribution of fertilizer or dairy waste applications on soluble salts and Olsen P concentration from 50 cooperators' fields in South-Central Idaho. Background values from neighboring non-agricultural fields have been subtracted.

Treatment	**E.C.**	**Ca**	**Mg**	**K**	**Na**	**Olsen P**
	dS/m	-------------------------mmol/L-----------------------				----ppm--
Fertilizer only	0.40	0.22	-0.12	-0.82	0.45	14.1
Compost	0.53	6.78	2.56	-0.60	2.56	43.6
Lagoon water	0.66	3.14	1.90	-0.05	2.24	36.2
Manure	0.42	3.81	1.73	0.27	1.87	64.1
Lagoon water + Manure	0.54	6.76	2.73	1.16	2.74	47.7

POTATO TUBER QUALITY

Shifts in tuber quality and crop toxicities may also be anticipated due to an overabundance of specific nutrients that are not typically found in potato fields. Dawson and Kelling found that tuber solids decreased with liquid dairy manure applications (93,500-2,805,000 l ha^{-1}) in comparison to fertilized plot at two locations, suspecting an accumulation of salts as the cause. Black and White (1973) found that starch content was not affected in the first 8 years of yearly manure applications (9 tonnes ha^{-1}) to potato-oat-alfalfa rotations, but significantly decreased tuber starch content in the ninth year. While the cause was not identified, the author suspected potassium accumulations, as increasing amounts of potassium fertilizers had lowered starch content in another treatment used in this study. Manganese toxicities have also been attributed to cow manure applications (Lee and MacDonald, 1977), although this was identified only under very acidic soil conditions (soil pH < 4.8).

SUSCEPTIBILITY TO DISEASE AND E. COLI

Scab, sclerotia, verticillium wilt, and pathogenic bacterial persistence are major concerns associated with potato production on manured fields, as manure is often suspected to provide optimal conditions for these diseases, disorders, and bacteria. Dawson and Kelling showed that scab incidence increased with liquid dairy manure applications (93,500-2,805,000 l ha^{-1}) in only one of four site-years in comparison to fertilized plots. Blodgett (1940) showed that the combination of lime and manure increased scab from 0.3 to 63% on acidic soils, while manure applications alone had no significant effect. Adversely, Conn and Lazarovits (1999) found the scab incidence was actually reduced 2 and 3 years after cattle manure had been applied at a rate of 100 tonnes ha^{-1} at one of two sites, suggesting that the reduction in soil pH may have been the cause of the scab reduction. In one study, sclerotia incidence reduced by 10% in manure plots comparison to fertilized plots (Blodgett, 1940). In another study, incidence of verticillium wilt was reduced at one of two sites 1 year after application, but not the 2nd or 3rd years (Conn and Lazarovits, 1999). The seasonal difference may have been related to a subsequent decrease in nematode populations and/or a documented increase in soil microbial populations. Finally, Entry et al. (2006) found greater incidence of Enterococcus and fecal coliform in fresh potato skins and potato rhizosphere on plots receiving dairy manure solids applications in comparison to dairy compost, fertilizer, and control treatments, while no E. coli was detected in any of the treatments.

SUMMARY

Based on information from the literature and research that conducted in Idaho, it is apparent that manure applications can be potentially beneficial to potato production when applied at agronomic rates. More information is needed on manure applications in extreme excess of viable amounts taken up by the plant in order to more closely address the issue of recent and long-term manure applied fields that Idaho potato growers may be facing in years to come, if not already.