#1818 EFFECTS OF A SINGLE ADDITION OF COMPOST ON POTATO YIELDS WHEN NITROGEN AND PLANT AVAILABLE WATER ARE NOT LIMITING

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Abstract

In 2001, nine field plots at the University Horticulture Research Center in South Burlington, VT were amended with compost at a rate of 0 kg·ha^{-1}, 7,344 kg·ha^{-1}, or 14,688 kg·ha^{-1}. A split-plot design was used and replicated three times at the site. Compost rates were the main plot treatments. Each main plot was comprised of a 24 m double row planting. Plantings of potato (*Solanum tuberosum* L.) cultivars 'Russet Burbank' and 'Butte Russet' were replicated twice in each plot. Subplots consisted of four 4.8 m replications bordered on either end by a 0.6 m section of guard plants. Nitrogen levels were adjusted via fertigation to bring all treatments to similar levels of potential available N. All treatments received the same amount of water during nutrient application. Irrigation based on 65% PAW for all treatments began on August 2 and continued through the month of August. Soil moisture readings were taken daily, summed for each treatment, and irrigation was made based on a 65% PAW threshold for each individual compost treatment. All potatoes were individually graded based on USDA standards. The amount of irrigation water required to maintain 65% PAW was ~23.0% less in the 14,688 kg·ha^{-1} compost treatment than in the zero kg·ha^{-1} treatment. The addition of compost had no significant effect on total yield of marketable potatoes, but compost effects on tuber number (P=0.0026), number of culls (P=0.0152), and total weight of culls (P=0.0256) were significant. The addition of compost significantly increased tuber number, the number of culls, and the total weight of culls. 'Butte Russet' yielded approximately 22.7% significantly more saleable tubers by weight than 'Russet Burbank'. Interaction effects were not significant.

Introduction

Production of potatoes and profitability relies on the crop making efficient use of available space, water and nutrient resources. Production practices to achieve optimum profitability may vary with cultivar, anticipated tuber use, growing conditions, as well as input costs compared to anticipated return (Waterer, 1997). Fertilization of potato crops in general, and with N in particular, has long been recognized as a vital step in increasing the yield of tubers per unit area (Shukla and Singh, 1977).

Initial N requirements of a potato crop can be met by soil N that is present at planting as well as by microbial decomposition of incorporated cover crops or green manures. In many cases soil N can not sufficiently meet total seasonal N requirements creating the need for supplemental additions of N (Vos, 1999).

Research has shown that the proper use of seasonal applications of N has the potential to optimize potato yield and quality by encouraging early tuber growth and maintaining maximum growth prior to harvest (Kleinkopf and Westermann, 1993). High N levels can cause excessive vegetative growth and can also delay tuber initiation, which could ultimately lead to yield reduction and delayed maturity. Excessive top growth due to high levels of early season N can also deplete soil moisture reserves that could have been better used later in the season to support tuber growth (Waterer, 1997). Organic nutrient sources, such as solid manures and compost amendments, have the potential of releasing nutrients over a longer period of time due to the slow rate of mineralization of the organic fraction. Compost amendments also increase the water holding capacity of the soil (Gagnon et al., 1998). This coupled with irrigation management can potentially reduce soil nutrient leaching, and increase yield as potatoes are sensitive to moisture fluctuation. It has been illustrated that soil moisture may be the most prominent factor in potato production as temporary dryness can reduce yield (Kalra and Singh, 1975).

This study was conducted to examine the effects of varying compost amendment rates on tuber yield and quality response of potato when nitrogen was optimal at minimum for all treatments and when soil moisture levels were maintained at optimum levels for growth from tuber initiation through the tuber bulking growth stage.

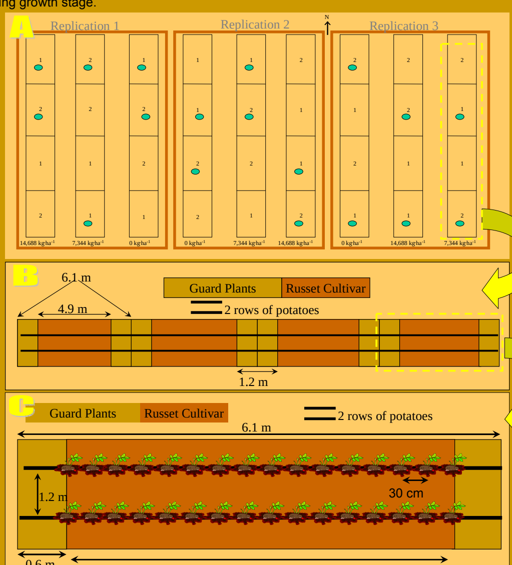

Figure 1. Experimental Design. **A.** Three replicate blocks showing cultivar location (1='Russet Burbank'; 2='Butte Russet') and amendment rate distribution. Blue circles indicate locations of soil moisture readings. **B.** Blow-up of a single treatment illustrating spacing and location of guard plants and double rows of potatoes in each treatment. **C.** Illustration of a single cultivar block within a treatment. Two blocks were used per treatment to minimize field variability and seed piece spacing was 30cm with 1.2m between rows.

Figure 2. A. Amendment treatment rates pre-incorporation. **B.** Creation of furrow for planting of seed pieces. Seed piece spacing was 30cm. **C.** Picture of treatment blocks with 2.4m buffer of annual ryegrass (*Poa sp.*) seeded at a rate of 13.7 kg·ha^{-1}. 'Butte Russet' is pictured in flower. **D.** Digging of potatoes with potato digger 14d after vine killing. 'All Blue' potatoes were used as guard plants and also aided in digging. Once 'All Blue' potatoes were noticed on the conveyor the tractor was stopped and the conveyor was allowed to clear. Digging was then resumed leaving a 1-2m area between sub-blocks. Tubers were the placed into labeled polyester bags and placed into a root cellar for sorting and grading. Western rows were dug prior to eastern rows.

Materials and Methods

The trial was conducted on a Deerfield loamy fine sand at the Horticulture Research Center, Univ. of Vermont in South Burlington, Vermont. Initial soil pH was 7.1 with 3.4% organic matter (Table 5). Elemental sulfur (90%) was applied prior to planting at a rate of 0.9 kg per 9.3 m² to lower pH to target 6.1.

Compost was applied in May 2001, at the rate of 0, 7,344 and 14,688 kg·ha^{-1} fresh weight basis (Figure 2A; Table 2). A split-plot design was used with 3 replications (Figure 1). Main plot treatment was compost amendment rate and split-plot effect was cultivar. Each replication contained 3, 2-row blocks each having a compost amendment treatment. Each 2-row block was 24m long with rows spaced 1.2m on center and contained 2 randomized sub-blocks 4.9m long of each russet cultivar. (Sub-blocks were used to eliminate field variability and for piece of mind as no vegetable crops had ever been grown at the site. For statistical analysis the sub-blocks were combined for each russet cultivar). 'All Blue' guard plants were used at the end of each Russet sub-block and were 0.6 m long (Figure 1). Tuber seed pieces were planted on May 21 at 30cm spacing giving approximately 4,409 seed pieces·ha^{-1} where the average seed piece weight was 63g giving 281 kg·ha^{-1} of seed potato. Seed pieces were covered with 10cm of soil directly after planting in a 19cm deep furrow (Figure 2B) and were hilled on June 28 and July 18. Treatments were separated by a 2.4m wide area planted with annual ryegrass (*Poa sp.*) at a rate of 13.7 kg·ha^{-1}. Disease and insect pests were managed following organic production guidelines.

Metanaturals 16-0-0 (Bella Via, LLC., Rohnert Park, CA) liquid organic injectable fertilizer was applied through drip irrigation by a Dosmatic Advantage A40 inline fertilizer injector. Potatoes were fertilized with total minimum N from all sources being 40.4 kgN·ha^{-1} (0 kg·ha^{-1} treatment). 28.6 kgN·ha^{-1} was applied to the 0 kg·ha^{-1} treatment and 14.3 kgN·ha^{-1} was applied to the 7,344 kg·ha^{-1} treatment via fertigation. Total N was expected to be 44.4 kgN·ha^{-1} for the 7,344 kg·ha^{-1} treatment. No additional fertilizer was added to the 14,688 kg·ha^{-1} treatment and total N was expected to be at 48.5 kgN·ha^{-1} (Figure 3). Treatments not receiving fertigation were irrigated upon completion of injection for the amount of time that it took to inject a 300 ppm N nutrient load to the respective treatment(s). There were 15 fertigations. The drip tape had emitters every 30.5 cm with an output of 1.7 L • min-1 • 30.5 m at a line pressure of 55.2 kPa. Each amendment treatment rate had individual main irrigation lines with a stop-valve and one lateral irrigation line at each hill. Drip tape was placed on top of the hill prior to the second hilling and buried by approximately 5cm of soil.

Irrigation monitoring and management was initiated on August 2 and was terminated on August 31. Irrigations were made when plant available water (PAW) dropped below 65% by treatment. Soil moisture levels were measured daily using a ThetaProbe (TP) TDR moisture sensor calibrated for each treatment. Moisture readings were taken in the center of the hill for each cultivar for each treatment replicate (18 readings) (Figure 1A). When PAW was below 65%, based on the mean of treatment replicates, irrigation was initiated for 4-h.

Tubers were harvested on September 27 using a commercial potato digger (Figure 1D). Tubers were individually sized and graded by market class based on USDA Standards for Grades of Potatoes (USDA, 1997). Unmarketable tubers were graded as "cull" if tubers failed to meet guidelines. A total of 9,070 tubers were individually graded with a total weight of 1,192kg.

Statistical analysis was preformed via SAS analytical software using PROC GLM for a split-plot design and Tukey's mean comparison test. Significance is indicated when P <0.05. Interactions were tested and were not significant. (Badger, 2002).

Table 1. Nitrogen credits used for experiment. Metanaturals 16-0-0 (Bella Via, LLC., Rohnert Park, CA) liquid organic fertilizer was applied through drip irrigation. Minimum N from all sources was 40.4 kgN·ha^{-1} (0 kg·ha^{-1}). 28.6 kgN·ha^{-1} was applied to the 0 kg·ha^{-1} treatment, 14.3 kgN·ha^{-1} was applied to the 7,344 kg·ha^{-1} treatment, and no additional fertilizer was added to the 14,688 kg·ha^{-1} treatment. Total N was 44.4 kgN·ha^{-1} for the 7,344 kg·ha^{-1} treatment, and 48.5 kgN·ha^{-1} for the 14,688 kg·ha^{-1} treatment. Treatments not receiving fertigation were irrigated for the amount of time that it took to inject 300 ppm N.

Source of N or N Credit	Amount
Soil organic matter	6.2 kgN·ha^{-1}
Annual ryegrass cover	5.5 kgN·ha^{-1}
7,344 kg·ha^{-1} compost	18.4 kgN·ha^{-1}
14,688 kg·ha^{-1} compost	36.8 kgN·ha^{-1}
Metanaturals Liquid N	0-28.6 kgN·ha^{-1}
TOTAL	40.3 kgN·ha^{-1} minimum

Table 2. Nutrient analysis of dairy manure compost used in experiment. Compost used was produced by Champlain Valley Farm Crafted Compost (Charlotte, VT). Inputs were mostly dairy cattle manure and bedding, and was composted out-of-doors in windrow form. Nutrient analysis was by saturated media extract, performed by the UVM Ag. Testing Labratory.

pH	8.6
NO_3-N	179.0 ppm
NH_4-N	16.8 ppm
P	39.9 mg·kg^{-1}
K	2397.0 mg·kg^{-1}
Ca	53.1 mg·kg^{-1}
Mg	100.2 mg·kg^{-1}
Soluble Salts	11.7 ms cm

Results and Discussion

Compost significantly increased tuber number, number of culls, and total weight of culls, but did not increase total marketable yield by weight (P=0.4049, Table 3). Marketable tubers by number increased as compost treatment rate increased (P=0.0026), but a similar trend was not present for marketable weight. This indicates that tubers on average were smaller for the higher treatment rates, which may be a varietal response and may vary from cultivar to cultivar. This may benefit Vermont growers if they market smaller tubers. When looking at the grade class US#1 there was no significant differences between compost amendment rates (P=0.2792), but there was a significant difference between cultivars (P=0.0079). 'Butte Russet' yielded more than 'Russet Burbank' (data not shown), and this trend also exists when looking at total marketable yield by weight (P=0.0355, data not shown). Cull weight (P=0.0256) and tuber number (P=0.0152) increased significantly when comparing the 14,688 kg·ha^{-1} treatment to the 0 kg·ha^{-1} treatment. It is important to note that the increase in culls is after the fact that all of the treatments produced the same marketable yield.

Table 3. Yield parameters by treatment for 2001 compost study at UVM. Displayed are tuber number·ha^{-1} and weight (kg·ha^{-1}) for marketable and cull yield results by treatment.[z]

	Marketable		Cull	
Treatment	tuber number·ha^{-1}	weight (kg·ha^{-1})	tuber number·ha^{-1}	weight (kg·ha^{-1})
0 kg·ha^{-1}	284,785 a	39,171.69 a	73,719 a	10,045.96 a
7,344 kg·ha^{-1}	331,175 b	40,665.96 a	105,813 a b	15,189.47 a b
14,688 kg·ha^{-1}	345,050 b	43,068.13 a	130,620 b	18,951.10 b

[z] Mean separation by Tukey's via SAS. Significance is indicated by different letters when P<0.05

An increase in compost did reduce water applications by ~23% when the 14,688 kg·ha^{-1} treatment was compared to the 0 kg·ha^{-1} treatment. On Julian day 223 the 14,688 kg·ha^{-1} was the first treatment to not need irrigation to maintain 65% PAW and there was separation between the treatments. The other treatments reached the same level the following day and alternated on a day-to-day basis until day 229 (Figure 3), and when daily irrigation amounts were summed the 14,688 kg·ha^{-1} reduced total irrigation by 6,812 liters or ~23% (Table 4).

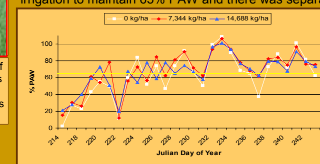

Figure 3. Soil moisture status during tuber bulking. Julian days are displayed where day 214 is August 2 and day 243 is August 31. The yellow line indicates 65%PAW. Irrigations where made for 4h when PAW was below 65% based on the mean per treatment (n=3). On day 223 the 14,688 kg·ha^{-1} treatment was the first to not need daily irrigation to remain at 65% PAW. The other treatments then followed and alternated on a day-to-day basis for nearly one week.

Table 4. Total water applied (liters·treatment^{-1}) by treatment showing percent water applied where the 0 kg·ha^{-1} is 100%. The 14,688 kg·ha^{-1} treatment saved approximately 23% of the applied water when compared to the 0 kg·ha^{-1} treatment to maintain 65% PAW Total water savings was approximately 6,812 liters of water savings.

Treatment	Water applied (liters·treatment^{-1})	Percent Water Applied
0 kg·ha^{-1}	29,518	100%
7,344 kg·ha^{-1}	24,976	~85%
14,688 kg·ha^{-1}	22,706	~77%

Increasing amendment rate also impacted soil physical and chemical properties. Increase in amendment rate increased soil organic matter (SOM), and many soil nutrients (Table 5). The increase in SOM is an important factor in the overall health of the soil. It is interesting that the 0 kg·ha^{-1} treatment depleted SOM by 0.2% for a single season, which overtime could have a detrimental impact on production land due to a loss in the organic fraction while also decreasing soil moisture holding capacity.

Table 5. Analysis of soil from treatment plots amended with one application of dairy manure compost at different rates compared to preseason measurements. Values shown for post season are means of treament replicates ± standard error. Anlalysis completed by the UVM Ag. Testing Lab, Burlington, VT.[z]

		Post Season by Amendment Treatment		
	Preseason	0 kg ha^{-1}	7,344 kg ha^{-1}	14,688 kg ha^{-1}
pH	7.1	6.5 ±0.1	6.9 ±0.1	6.8 ±0.2
N (%)	n/a	0.2 ±0.01	0.2 ±0.01	0.2 ±0.01
P	5.8	6.8 ±0.58	14.9 ±2.73	23.1 ±6.02
K	178.0	64.8 ±19.07	166.8 ±33.64	281.7 ±70.29
Ca	1955.0	1454.4 ±115.52	1537.9 ±209.11	1607.2 ±254.76
Mg	116.0	104.1 ±11.88	146.6 ±13.49	183.3 ±53.19
Org matter (%)	3.4	3.2 ±0.1	3.7 ±0.2	3.9 ±0.1

[z] Values in PPM unless otherwise indicated. n/a = data not taken.

Conclusions and Future Directions

The results of this study indicate that the 14,688 kg·ha^{-1} dairy manure compost amendment treatment rate produced the same marketable yield as the 0 kg·ha^{-1} treatment, received no supplemental fertilization, reduced water application by approximately 23%, and improved soil physical properties. It is important to remember that the compost used in this experiment does not represent all composts. Varying nutrient content, input materials, and composting methods could prove to be an important factor in end product quality and deserve more research attention.

Using dairy manure compost may be a way to reduce soil nutrient leaching by using farmyard waste in non-raw form while increasing the overall health of the soil. Recycling of nutrients and limiting degradation of freshwater resources needs to be investigated further.

In Vermont there is an abundance of sources for dairy manure as well as many diversified farms, but in locations where such abundance does not exist 14,688 kg·ha^{-1} of compost could prove to be quite costly. On the other hand, most Vermont farmers do not pay for water rights or usage. In locations where such costs are imposed there is potential for savings during dry years. The effects of compost during wet seasons also deserves research attention.

Currently in the 2002 season this experiment is being replicated following the same protocol. Improvements include an increase in soil moisture readings where each individual row is being irrigated to maintain 65% PAW during tuber bulking (72 total readings; 4 per row), soil temperature data is being taken for each treatment, and ammonia and nitrate content are being analyzed on a monthly basis for each treatment replicate to monitor N levels throughout the season.

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