Urine as fertilizer: Maximizing hay yield and enriching low-N composts

2014 Annual Report

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Summary

The Rich Earth Institute is pioneering the use of sanitized human urine as an innovative and sustainable fertilizer. Wide-scale reuse of urine as fertilizer would provide a stably-priced, locally produced, and sustainable source of fertilizer for farms, while directly alleviating the growing problem of nutrient pollution of surface waters by septic systems and wastewater treatment facilities.

In the third season of field trials using urine as fertilizer, the Rich Earth Institute collected approximately 4,500 gallons of urine for use as fertilizer on hay. In order to refine the previous year's study on yield and the effect of diluting urine at the time of application, 1,717 gallons were sanitized and applied to expanded test plots on two farms. Results confirmed previous findings that diluted and undiluted urine are both effective fertilizers, increasing yield in second cut hay. Data also showed that urine diluted 50/50 with water produced moderately higher yields than undiluted urine. Full statistical analysis of both trials is underway and will be included in the final report.

The bench-scale composting trial is not complete, for reasons described below. Results will be included in the final report.

In a related but separate project, the Institute began EPA-funded field trials to determine the persistence of residual pharmaceuticals from urine-based fertilizers in vegetable crops, soil, and groundwater. This two-year project, (performed in partnership with the University of Michigan, University at Buffalo, Brown and Caldwell engineering firm, and Hampton Roads Sanitation District in Virginia,) will help determine whether there is any need to reduce pharmaceuticals in urine before it is used as fertilizer.

The Institute also conducted a formal farmer survey sent to the Pasture Calendar list and the Grass Farmers Association to learn about farmer interest and capacity for using of urine as fertilizer. Analysis of the 51 responses will be included in the final report.

Objectives/Performance Targets

Urine collection commenced in March, following a public “Urine Donor Kick-Off” event held in Brattleboro and attended by a standing-room-only audience of over 200 people, including urine donors from the previous year and interested farmers. Institute staff presented a summary of the previous year's work, an explanation of the project's rationale, and an outline of upcoming projects. Our partners at Best Septic Services of Westminster brought a specially converted urine-collecting portable toilet, which was used to collect urine throughout the event. It was customized with a decorative and informative vinyl wrap. Examples of urine diverting toilets for residential installation were also on display.
The depot where participants bring collected urine was upgraded for efficiency and ease of use in March with the addition of a new self-service electric pump station designed and built by the Institute. It allows urine donors to easily and hygienically pump out their own containers. This pump station has remained in use to the present time, requiring only minor modifications to the automatic electric switching mechanism.
Delays in the state permitting process for the redesigned pasteurizer precluded its use to prepare urine for the 2014 growing season. Although though the final design cannot be built until the permit is approved, we built and tested a prototype of the heat exchanger and determined the heat recovery efficiency between effluent and influent urine to be approximately 75%, sufficient to meet our anticipated fourfold increase in processing capacity. The State still has not issued the new permit, but projections by the permitting office suggest it will be ready in time for the 2015 season. We will begin upgrading the pasteurizer during the current SARE project period, even if the final permit is not yet in hand, and then make any required adjustments once the permit is written, in order to have the pasteurizer ready for the new season.

All urine used in the 2014 season was treated through the long-term storage method (>30 days at or above 20°C). Approximately 1000 gallons of urine were taken to Fair Winds Farm and 1500 gallons to Whetstone Valley Farm and enclosed in purpose-built, unheated greenhouses made of clear plastic film stretched over wooden frames. As in 2013, electronic temperature sensors were submerged in the tanks and connected to a datalogger which recorded time-stamped temperature readings for periodic retrieval, the results of which are shown in Figure 1. Both greenhouses performed adequately, producing a sanitized product for use by mid-July, which was compatible with the fertilizing needs of second cut hay on these farms. For fertilizer application earlier in the season, pasteurization would be a better method.

Field trials

The original proposal called for only two replicates of each treatment at Fair Winds Farm, but we increased the number to three in order to increase statistical significance. 811 gallons of urine fertilizer were applied

on 7/29/2014. Treatments included undiluted urine, a 50/50 urine/water mix, or no fertilizer. UVM extension testing reported nutrient concentrations in the urine of 6.304 g/L total N, 0.374 g/L total P, and 1.370 g/L total K. Soil moisture in the top six inches (as determined by air drying at room temperature) averaged 17%, with a standard deviation of 0.54%. Dominant species were perennial grasses timothy, brome, orchardgrass, quackgrass, and reed canarygrass, with scattered red clover and vetch growing in Quonset and Warwick soils.

906 gallons were applied at Whetstone Valley Farm on 8/15/14. Each treatment was done in three replicates, including the same treatments as at Fair Winds Farm with the addition of a synthetic fertilizer treatment (urea, triple superphosphate, and KCl) with total NPK levels matched to the quantities applied to the urine-treated strips. UVM extension testing reported nutrient concentrations in the urine of 5.381 g/L total N, 0.329 g/L total P, and 1.300 g/L total K. Soil moisture in the top six inches (as determined by air drying at room temperature) averaged 31%, with a standard deviation of 1.8%. Dominant species were perennial grasses timothy, orchardgrass, and reed canarygrass, with scattered red clover, growing in Marlow fine sandy loam.

Urine fertilizer application at Hogget Hill Farm was omitted because the farmer needed to fertilize before we had enough sanitized urine available. Hogget Hill was the least important site because the other two trials included replicates and multiple treatments, while Hogget Hill was to be a simpler demonstration with no replicates.

Compared to 2013, the urine fertilizer application process was much faster due to a faster transfer pump. A 180 GMP gas-powered Honda pump transferred urine and dilution water from the storage tanks to the applicator roughly 25 times faster than the 7 GPM pump used in 2013. At this rate, the shortest pumping time required per 1000 gallons, (enough to fertilize an acre of hay,) is six minutes.

With pumping time reduced, the time bottleneck became the speed of the applicator. The gravity-fed applicator boom and hoses delivered liquid to the ground at about 25 gallons/minute, requiring about 40 minutes to apply 1000 gallons. Using a powered pump would increase the application speed. Increasing the tank size (currently 200 gallons) would save time by reducing the number of trips required.

Hay was baled at Fair Winds Farm on 10/12/14 and from Whetstone Valley Farm on 11/11/14. Yield figures are shown in Figures 2 and 3.

Composting

Upgrades to the Institute's compost incubator (allowing precise monitoring and logging of oxygen consumption and ammonia emission) took longer than anticipated, due to shortage of available time during the field season and unanticipated performance limitations of the ammonia sensors available within the project's budget. An alternative method for ammonia monitoring (via sulfuric acid trap and periodic titration) has been established and tested.

Results from the composting portion of the project will therefore not be available until the final report.

Accomplishments/Milestones

Throughout 2014:

The Rich Earth Institute's work generated regional, national, and international media attention including: online articles on NPR’s “The Salt”, National Geographic, Modern Farmer, BBC Mundo (Spanish) and Grist, television coverage by Vermont Public Television, and radio interviews on VPR, the CBC, and the Australian Broadcasting Corporation. Interest in separating urine from the waste stream for beneficial reuse

in agriculture is growing.

March–May: Urine collection, transport

* Urine donor kick-off event with standing-room audience engaged full community, including interested farmers on 3/28/14
* Self Service urine pump added to urine depot and donors began to supply urine
* Home collection pump-out route initiated with Best Septic from 10 homes that used 55 gallon barrels for winter collection
* Existing tanks at Fair Winds Farm filled with urine on 4/27/14. Storage greenhouse constructed around tanks on 4/4/14.
* Greenhouse constructed at Whetstone Valley Farm on 5/21/14.
* Ten year permit application submitted to VT Watershed Management for mobile urine pasteurizing unit.
* Strong community support emerged through application process; Rich Earth Institute's Urine Nutrient Reclamation Project project included in the Windham Regional Plan and the Windham Solid Waste Management District's Solid Waste Implementation Plan (SWIP).
* Extension of Insignificant Waste Management Event Approval (IWMEA) permit submitted
* Twelve 275 gallon palletized storage tanks delivered to Whetstone Valley Farm. Filled as urine became available.

June-July: Urine treatment

* Receipt of IWMEA extension permit for summer trials
* Test strips marked on both farms.
* Public education outreach at Strolling of the Heifers parade. Parade float pulled by participating farmer. 10 portable urine-only toilets collected urine at the Expo after the parade.
* Due to time demands from fieldwork and unanticipated complications in composting incubator upgrades, initiation of bench scale compost trials delayed.

July–August: Urine application after first cutting of hay

* Samples of urine from both farms sent to UVM for nutrient analysis on 7/21/14.
* Urine applied at Fair Winds Farm on 7/29/14.
* Urine applied at Whetstone Valley Farm on 8/14/14 –later than expected due to the participating farmer's cutting schedule.
* Provided 10 portable toilets and educational booth at SolarFest in Tinmouth Vermont--275 gallons collected. 7/18-7/22/14
* University of Michigan documentary crew filming onsite August 4-6

September–November: Hay harvested , weighed, and sampled

* Hay cut, dried, baled, and weighed at Fair Winds Farm. (Baled 10/12/14 and weighed 10/17/14)
* Hay cut, dried, baled, and weighed at Whetstone Valley. (Baled 11/11/14, weighed 11/14/14) –later than expected due to farmer's cutting schedule
* 28,000 gallons of underground storage made available to Rich Earth Institute.
* Urine depot moved indoors so that participants can continue to collect and donate throughout the winter.
* Grass Farmers Survey sent to New England Farmers via UVM extension email list on 10/7/14. 51 survey respondents.

December: Data Analysis and Compost Trials

* Social Research Committee conducts preliminary analysis of Grass Farmers survey.
* Total urine collected in 2014 over 4,500 gallons.
* Development of compost incubator and instrumentation continues. Method developed to measure ammonia emissions from compost after electronic sensors prove inadequate.
* Composite hay samples prepared for third-party forage quality analysis.
* Complete statistical analysis is awaiting the return of forage quality analysis results (including dry mass fraction).

Still to be completed:

* Statistical analysis of field trial results
* Third-party analysis of forage samples
* Bench-top compost trials
* NOFA/Mass conference presentation, 1/10/2015
* Building Energy conference presentation, Boston 3/4/2015

Impacts and Contributions/Outcomes

Data from the Whetstone Valley Farm field trial showed a moderate difference between the two urine treatments. Strips fertilized with a 50/50 urine/water solution yielded 16% more hay than strips fertilized with pure urine. In terms of the increase in yield compared to control strips, the 50/50 urine/water treatment produced a yield increase 30% larger than that produced by the pure urine treatment.

Data from Fair Winds Farm showed a yield increase from the fertilizer applications. The average yield of 50/50 diluted strips was higher than on undiluted strips, but variability within each treatment was high.

Average yields and standard deviations are shown in Figures 2 and 3. Complete statistical analysis will be included in the final report.

These results indicate that while undiluted urine is an effective fertilizer, 50/50 dilution of urine with water at the time of application is a beneficial practice. But because doing so doubles the volume of liquid that must be transported and applied, dilution is not realistic in all settings. A practical way in which dilution could be achieved without any added labor or fuel cost would be by mixing urine with lower-strength liquid dairy manure prior to application.

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Attachments:

Photos of Rich Earth Institute activities: http://mysare.sare.org/mySARE/assocfiles/994153photos.jpg
Figure 2: Yield averages and standard deviations, Whetstone Valley Farm:
http://mysare.sare.org/mySARE/assocfiles/994472Figure 2 Whetstone Valley Farm yield.png
Figure 1: Stored urine temperatures, Whetstone Valley Farm:
http://mysare.sare.org/mySARE/assocfiles/994472Figure 1 Temperature.gif
Figure 3: Yield averages and standard deviations, Fair Winds Farm:
http://mysare.sare.org/mySARE/assocfiles/994472Figure 3 Fair Winds Farm yield.png

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