UNIVERSITY OF WISCONSIN SYSTEM
SOLID WASTE RESEARCH PROGRAM
Student Project Report

Hugelkultur Gardening Technique Does not Result in Plant Nutrient Deficiencies and is a Potential Source Reduction Strategy for Yard Trimmings Wastes

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Abstract: 13.3 million tons of yard trimmings wastes – consisting of leaves, grass clippings, brush, and tree trimming wastes – are landfilled every year. Moreover, increasing financial pressure on municipalities and increasing waste processing costs are endangering many bans on yard trimming waste landfilling. As such, source reduction of yard trimming wastes has become a primary goal in managing this form of municipal solid waste. In this study, the hugelkultur method of raised bed gardening was piloted as a method for yard trimmings waste source reduction. In addition to calculating the yard trimmings waste diversion potential of the hugelkultur method, plant tissues of three crops – lima beans, *Phaseolus lunatus*; kale, *Brassica oleracea*; and okra, *Abelmoschus esculentus* – were analyzed for nutrient deficiencies. Although statistical power of this study was small, the preliminary data suggest that no nutrient deficiencies developed as a result of the hugelkultur method. Meanwhile, the project diverted 11.25 tons of yard trimmings waste. While more long-term studies focused on soil fertility effects are needed before wider-spread application of the hugelkultur method as a waste diversion scheme, in the short term it appears to be a meaningful form of yard trimmings waste minimization at the community scale.

Introduction:

As of 2009, the United States generated 243 million tons of municipal solid waste per year, of this 13.7% consisted of "yard trimmings" including grass, leaves, brush, and tree trimming wastes (Brown et al. 1998; EPA 2010). Of the 33.2 million tons of yard wastes produced in 2009, 19.9 million tons (59.9%) were recovered through recycling and composting programs; the remainder was landfilled (EPA 2010). The proportion of municipal yard trimming wastes that is landfilled is currently changing in complex ways: while the overall quantity of yard trimming wastes that are produced is on the rise, more states are passing legislation banning the landfilling of yard trimmings wastes (USCC 1993; Brown et al. 1998; EPA 2010; Buckner 2010). These yard trimmings landfill bans are largely due to landfill space shortages and the high costs associated with waste transport to regional landfill sites and apply 23 U.S. states and 50% of the country's population and provide an impetus for municipalities to develop composting programs for yard trimming wastes (Buckner 2010, and EPA 2010). As a result, nearly 3,000 yard trimmings composting programs now exist (Buckner 2010, and EPA 2010); however, significant costs associated with the development and management of these programs have spurred multiple states to attempt to repeal their yard trimmings landfill bans (Haaren 2010). The unrest surrounding yard trimmings landfill bans suggests that alternative waste management methods may be necessary in order to simultaneously address the environmental concerns over landfilling yard trimmings as well as the fiscal concerns of municipalities. Source reduction or the prevention of yard trimmings wastes before it enters the waste management stream could be a solution by reducing the yard trimmings waste load and subsequent cost of processing.

Source reduction is considered the most important step of the EPA's integrated waste management strategy (EPA 2010). Examples of yard trimmings source reduction activities could include backyard composting, retaining grass clippings on the lawn, etc. The advantage of source reduction is that waste is managed at the residential, institutional, or commercial level before it ever enters the formal waste management stream, and there is no subsequent cost associated with the management of that waste (EPA 2010). One of the main disadvantages of source reduction is that it depends on the "voluntary" (i.e. unpaid) participation of the residential, institutional, and commercial sectors. In the case of yard trimmings, the residential sector generates as much as 60% of the total waste load with an annual yard trimmings production rate of 57 lbs per capita (WI data), and consequently the residential level represents the bulk of source reduction opportunities (WDNR 2010). This being said, few homeowners have the space, wherewithal, or desire to construct backyard composting systems competent to handle their total yard trimming waste load.

In situ co-utilization may be a way to supplement backyard composting such that source reduction of yard trimmings wastes is more appealing to home-owners and more effective overall. Co-utilization itself is the process of combining two or more by-products or wastes in order to produce a specialty soil; "in situ" implies that the process of combining would take place on the same site that the waste was produced (Brown et al. 1998). Hugelkultur – or mound culture – is an example of an in situ co-utilization technique that is garnering popularity among permaculture enthusiasts and home gardeners. A centuries old Eastern European technique, hugelkultur consists burying woody debris, brush, grass trimmings, and other leaf wastes, covering this with topsoil, and then growing vegetable crops or landscaping on top of the resultant raised garden bed (Holzer 2004; Miles 2010). The technique is intended to mimic the forest nutrient cycle and is purported to have multifold benefits such as retaining soil moisture, enhancing microbial populations, and improving soil aeration, and overall increased soil fertility (Brown et al. 1998; Holzer 2004; Miles 2010). If true, hugelkultur could offer an important tool in the source reduction of residential yard trimmings with the added incentive of improving garden soils for home-owners; however, the paucity of literature on hugelkultur coupled with the fact that burying large amounts of high carbon wood and brush could result in nitrogen immobilization and a resultant loss in soil fertility tempers any undue optimism about hugelkultur as a silver bullet for soil improvement yard trimmings source reduction (Brown et al. 1998; Havlin et al. 2005). Would incorporating large amounts of yard trimmings wastes result in improved soil fertility? Or just in large amounts of buried yard trimmings? In order to crudely assess the effectiveness of hugelkultur, kale, lima beans, and okra were grown on two identical garden plots – one prepared as a hugelkultur raised bed with the other as a control – and compared plant tissues across beds for signs of nutrient deficiencies.

Location and Limitations:

F.H.King Students for Sustainable Agriculture is a student organization founded in 1979 that encourages education and hands-on experience with small-scale sustainable agriculture on its 2-acre student farm. The produce grown on the student farm is harvested bi-weekly and is distributed to UW-Madison students and staff free-of-charge and to area food pantries. The garden is located within the Lakeshore Nature Preserve, which covers 300 of the 933 acres of the University of Wisconsin-Madison campus (University 2006) and is a recreational and educational site for UW-Madison students and staff as well as the greater Madison community.

Because much of the harvesting at F.H.King is volunteer-based and subject to "harvester variation," obtaining consistent week-to-week yield data for the research plots of the current study was impossible. The fact that F.H.King plots are also harvested unwarrantedly by gardeners in the adjacent community gardens compounded the difficulties with collecting consistent yield data.

Materials and Methods:

Municipal yard trimmings were obtained from several sources. Wood chips and brushwood were provided by the Lakeshore Nature Preserve as part of their invasive species management plan; as such, these wastes, consisted primarily of common buckthorn (*Rhamnus cathartica*) and Norwegian maple (*Acer platanoides*). Leaf mulch was obtained from the nearby Shorewood Hill Neighborhood; leaf mould was the result of one year's storage of leaf mulch at the F.H.King Student Farm. Finished compost was produced on site with biodegradable municipal waste obtained through the F.H. King Full Cycle Freight bicycle composting program. Seed was provided by Olds Garden Seed, Co., Madison, WI.

A 50 ft. x 50 ft. garden plot at the F.H. King Students for Sustainable Agriculture Student Garden, was divided into two 25ft. x 50ft. parcels. The parcels were identical in slope, pedology, cropping history, and fertility management. The northmost plot was amended as follows: the topsoil was removed to a depth of 16 in. The exposed argillaceous B-horizon was loosened further to a depth of 8 in. and covered thinly with a layer of corn stover and buckthorn and Norwegian maple brush. This was subsequently covered to a depth of 8 in mixed buckthorn and Norwegian maple woodchips and then covered in 8 inches of leaf mould. The leaf mold was dressed with an inch layer of finished compost, and the original topsoil was then replaced. On the control bed, one inch of finished compost was applied to the soil surface; the soil was subsequently loosened to a depth of 12 in.

Fig1: Installation of hugelkultur bed. Two F.H.King Students for Sustainable Agriculture Students spreading wood chips for the foundations of a quadrant of hugelkultur bed.

Fig2: Hugelkultur and control beds four weeks after installation. The left bed is raised although it has settled as soil has migrated into the yard trimmings mat. Lima beans are seen growing toward the back of the plot.

Both control and hugelkultur beds were planted with identical crops at identical locations within the bed. The crops planted were lima beans, *Phaseolus lunatus* (Henderson Bush); kale, *Brassica oleracea* (Red Russian); and okra, *Abelmoschus esculentus* (Clemson Spineless). With the exception of the okra, all crops were planted during the week of the 4th of June according to CIAS Guidelines (CIAS 2011). The okra was planted during the week of the 25th of June. After planting, crops were not given subsequent fertilizer treatments and were watered using dripline irrigation. Garlic (Elephant, New York White, and German Extra Hardy) was planted in succession to the okra during the week of October the 29th according to CIAS guidelines (CIAS 2011).

Kale, lima beans, and okra plants were harvested for tissue analysis. Ten individual plants from each treatment were randomly selected for harvest. In the case of the okra, two adult leaves including the entire petiole were harvested per plant. For the lima beans, any juvenile bean pods were removed, and the entire plant was sampled. With the kale, the entire plant was sampled. Samples were oven dried before being ground and submitted to the University of Wisconsin-Madison Soil and Plant Analysis Laboratories, Verona, WI (SPAL 2013). Nutrient levels were corrected for ash content.

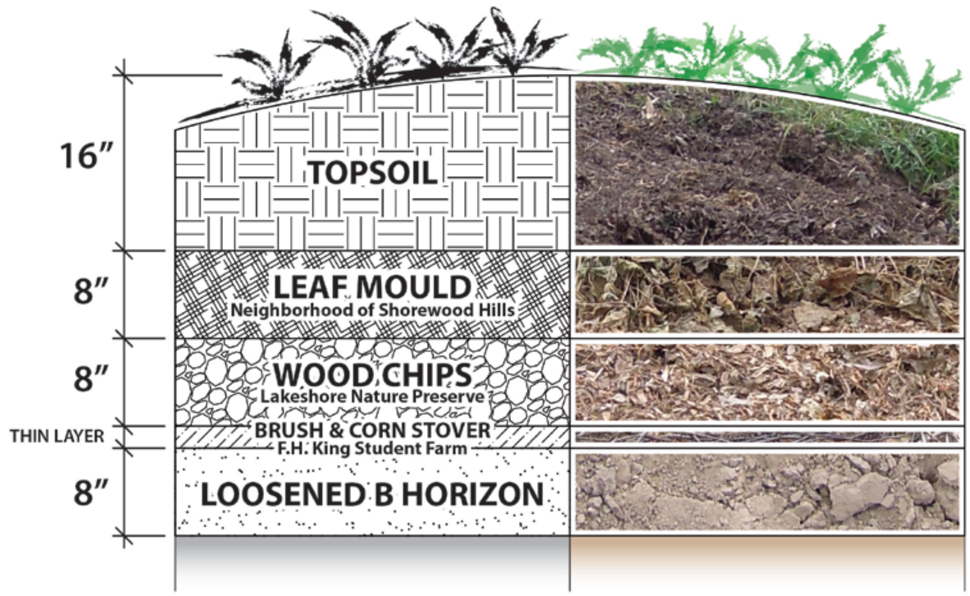

Fig3: A cartoon of a hugelkultur raised bed juxtaposed with a dissection of one of the actual study beds. Sources for introduced yard trimmings wastes are stated in reduced font.

Results:

In the hugelkultur treatment plot, 60 cubic yards of yard trimmings waste were incorporated. Assuming bulk densities for wood chips are 450lbs/yd^3 and for leaf mulch is 300 lbs/yd^3, this corresponds to an incorporation rate of 13500 lbs of wood chips and 9000 lbs of leaves in a 1250 ft^2 area or 39 tons/acre (Rynk et al. 1993). Seedling emergence was observed to be not as consistent as that of the non-raised bed. Between treatments there was no observable difference in plant height. However, it was difficult to determine the degree of these differences because both plots were vandalized in August. The experimental design was observational without replicates that permit statistical analysis and results are discussed in this light.

Among the primary macronutrients N, P, and K, and the secondary macronutrients Ca, Mg, and S there was no clear trend between the raised bed (RB) and control treatment groups and between species (cf. Fig. 1, Appendix). N was the only nutrient that was consistently higher across species in the RB treatment group; however, the difference in percent composition of N varied from 2.4% in okra to 15.5% in kale to 17.8% in lima bean. The largest difference in percent composition was for P in okra in which the RB okra had 25.3% greater concentration of

P. The smallest difference was for Ca in lima beans, in which Ca levels in the RB treatment was 19.1% lower than that of the control.

Among the micronutrients Zn, B, Mn, Fe, Cu, Al, and Na kale exhibited higher levels under RB conditions for every nutrient except Na (cf. Fig. 2, Appendix); however, there was a large difference in Fe levels between the RB and NRB treatments among okra and lima beans (-40% and -65.1%, respectively). Likewise there was a large difference in Al levels between the RB and NBR treatments (-57.9% for okra and -60.4% for lima beans). Levels of Mn and B in lima beans were also much lower (-39.3% and -27.8%) in the RB treatments.

Fig4: A cartoon of the hugelkultur raised bed including the calculated inputs of yard trimmings waste and labor hours and the total amount of municipal solid waste diverted over the course of a season. In the foreground is photograph of a profile of the layer of yard trimmings inputs after four months. Note advanced state of decomposition.

Discussion:

This study demonstrates that it is possible to intensively garden on a hugelkultur bed over a single season without deficiencies in the major macronutrients N, P, K. It also demonstrates that the installation of a hugelkultur bed with the present methods can divert a sizeable amount of waste – 11.25 tons of waste in our study – before it enters the waste stream. This corresponds to 395 times the per capita production of yard trimmings waste for the state of Wisconsin (WDNR 2010). The short duration of this study, however, limit any claims about the long-terms fertility impact of this gardening method, and the limited number of plant species analyzed limit any claims about its applicability.

Perhaps the most interesting outcome of this pilot study is that there were no observed nitrogen deficiencies among the three crops planted despite the incorporation of carboniferous materials. Given the high C:N ratios of wood chips and leaves (560 and 80, respectively), we would expect N immobilization due to microbial activity and consequent N deficiency in the raised bed crops (Rynk et al. 1993; Havlin et al. 2005). This deficiency, however, was not observed. While this could be due to plant roots colonization only extending into the layer of replaced topsoil, the elevated levels of N in RB treatments suggest that there is some increased availability of N. A recent nutrient analysis of the leaf mulch source for this project (Wepfer et al. 2012) reports a C:N ratio of 14.43 in the Shorewood Hills leaf mulch piles. Such as ratio would be comparable to that of a mature soil (Havlin 2005). If this is the case, the assumption that the raised bed inputs were high carbon would be inaccurate, and there would be no reason to expect N deficiency.

While no chlorosis symptoms were observed between RB and NRB treatments, the lower levels of Fe observed among RB lima beans and okra could be potentially problematic, especially because the levels observed in RB okra was below the sufficiency level of 50ppm (Havlin et al. 2005). While increasing soil organic matter content is expected to increase Fe availability in calcareous soils such as the dolomitic soils underneath the F.H.King garden, the large organic matter inputs may have resulted in a microbial bloom, increasing competition over already scarce Fe(III) between rhizosphere microbes and the plants themselves (Havlin et al. 2005, and Leamanceau et al. 2009). The fact that kale did not experience lower levels of Fe under the RB treatment, however, indicates that a more complex form of interaction may be at play.

Due to the limited parameters of this study, it is impossible to say how beneficial the method of hugelkultur is over conventional techniques in organic gardening. This is in part due to site selection and inability to obtain reliable yield information. This being said, the treatment did not result in major nutrient deficiencies, and did represent a sizeable diversion of yard trimmings wastes. While more long-term studies on nutrient mobility would be necessary to determine the lasting effects on soil fertility, the hugelkultur raised bed method in community gardens may be a suitable form of yard trimming waste minimization in the short term.

<u>Future Directions</u>:

In addition to assessing the effects of the hugelkultur method over a longer period of time and across a wider variety of species, future studies could include more extensive life cycle analysis (Fava 1991) in order to assess the carbon sequestration potential of the hugelkultur method in an urban agricultural setting. A recent study in Sutton, UK (Kulak 2013) has indicated that urban agricultural spaces have the greatest greenhouse gas offsetting potential of any form of urban green space; however, this study did not take into consideration the potential of urban agricultural spaces for waste minimization at the community level and may consequently be underestimating the potential of such forms of land use. A study assessing the carbon offsets as well as carbon emissions of various composting methods such as the hugelkultur method would help to define the role alternative agricultural methods can play in reducing the carbon footprint of food production in urban areas. Moreover, such an analysis of municipal solid waste minimization via *in situ* co-utilization on urban agricultural spaces may also help to inform urban land use policy and subsequent planning (Lal 2007).

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Appendix:

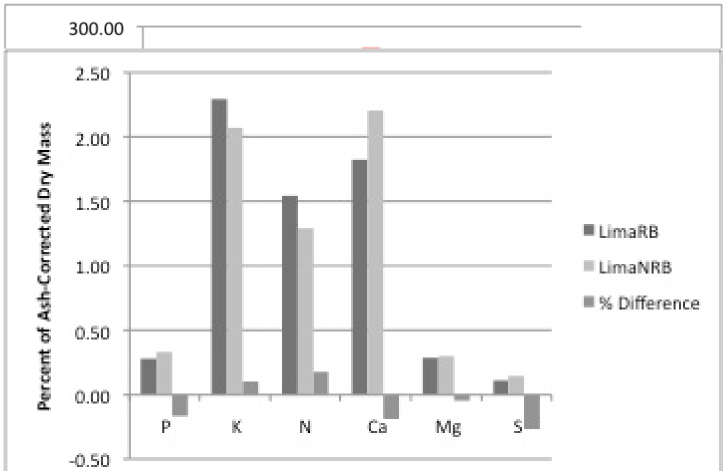

Fig. 2a: Ash-corrected dry mass composition for lima beans (above ground tissue only) grown on raised bed (RB) and non-raised bed (NRB) treatments. RB Lima beans exhibit higher levels of Na, but lower levels of Zn, B, Mn, and Cu, and greatly lower levels of Fe and Al. All tissue analysis performed at the UW-Madison Soil and Plant Analysis Lab, Verona, WI.

Fig. 1a: Percent of ash-corrected dry mass for lima beans (above ground tissue only) grown on raised bed (RB) and non-raised bed (NRB) treatments. RB Lima beans exhibit higher levels of N and K, but lower levels of P, K, Ca, Mg, and S. All tissue analysis performed at the UW-Madison Soil and Plant Analysis Lab, Verona, WI.

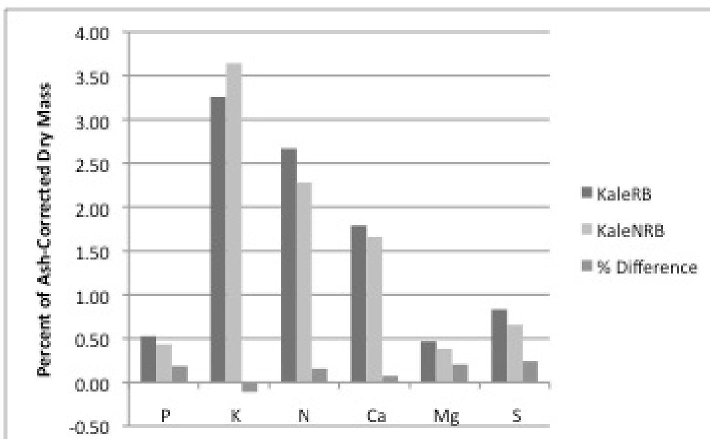

Fig. 1b: Percent of ash-corrected dry mass for kale (above ground tissue only) grown on raised bed (RB) and non-raised bed (NRB) treatments. RB kale exhibit higher levels of N, P, Ca, Mg, and S but lower levels of K.

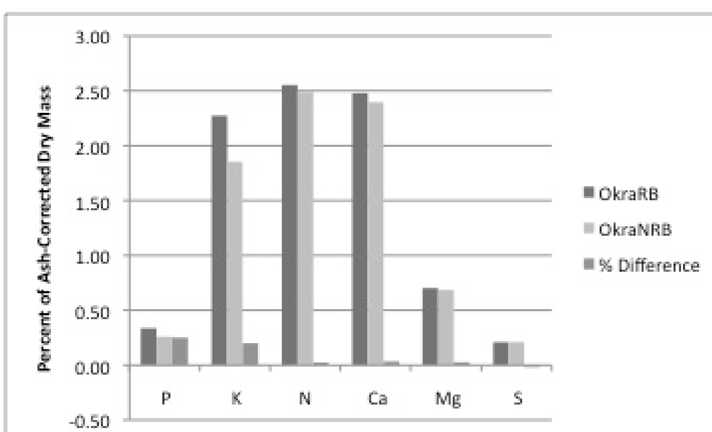

Fig. 1c: Percent of ash-corrected dry mass for okra (above ground tissue only) grown on raised bed (RB) and non-raised bed (NRB) treatments. RB Okra exhibit higher levels of N, K, Ca, Mg, S, and P.

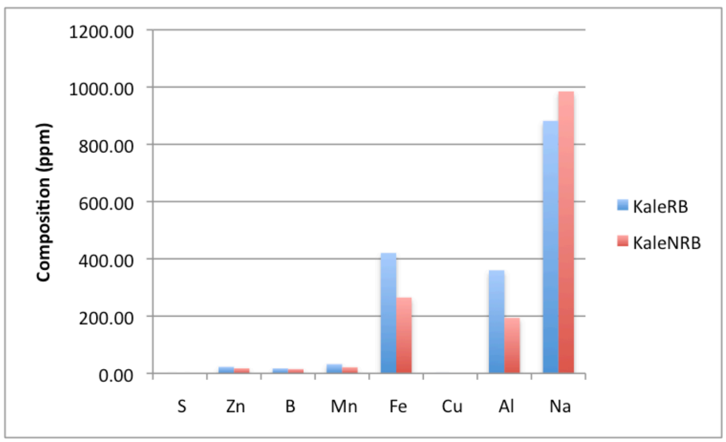

Fig. 2b: Percent of ash-corrected dry mass composition for kale (above ground tissue only) grown on raised bed (RB) and non-raised bed (NRB) treatments. RB kale exhibit higher levels of Fe and Al, but lower levels of Zn, B, Mn, and Na.

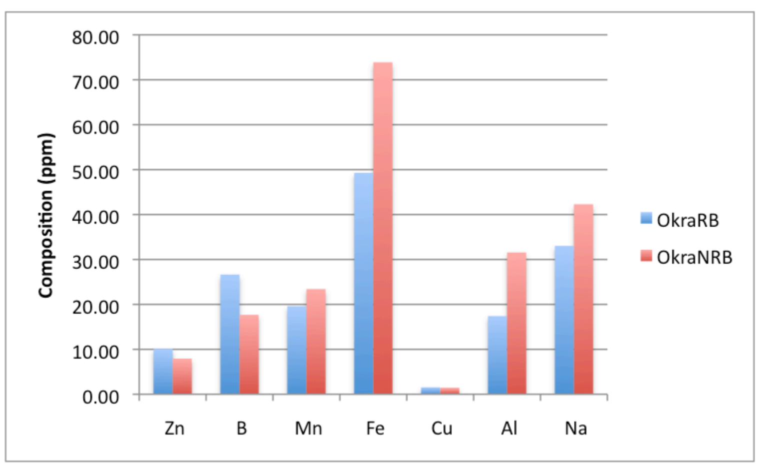

Fig. 2c: Percent of ash-corrected dry mass composition for okra (above ground tissue only) grown on raised bed (RB) and non-raised bed (NRB) treatments. RB okra exhibit higher levels of B and Zn, but lower levels of Mn, Fe, Al, and Na.