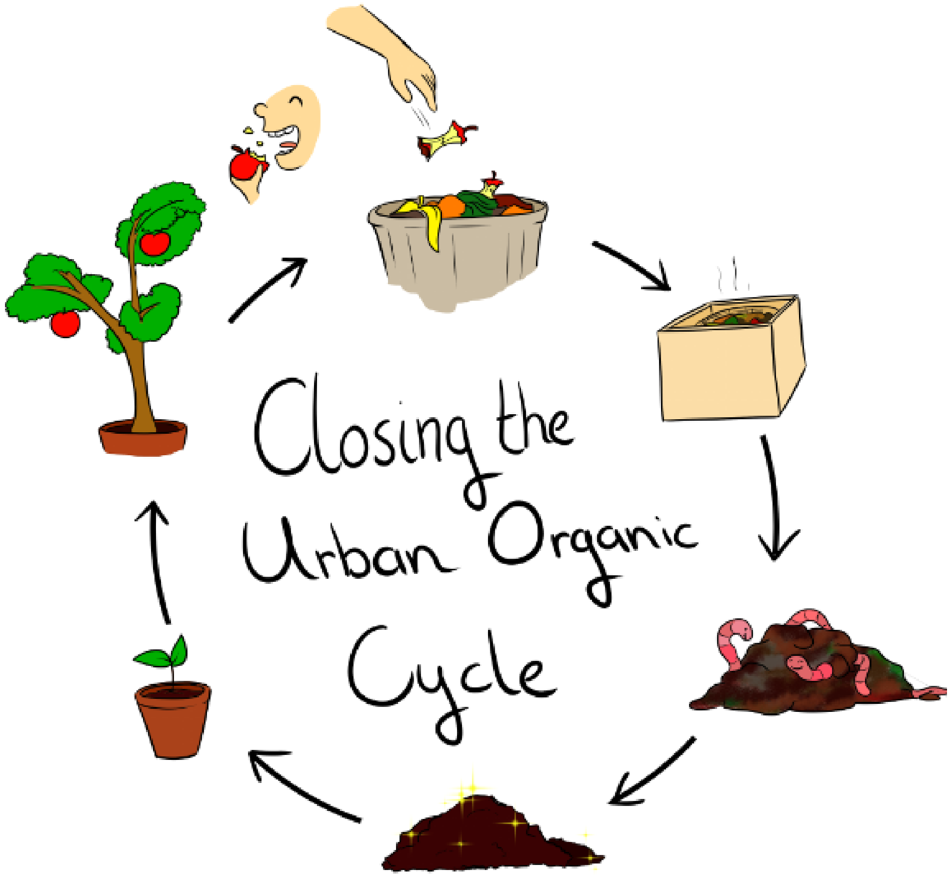
From degradation to creation: closing the urban organic cycle

Research on: i) valuation of organic residues trough vermicompost optimization, ii) soil improvement, iii) plant development and iv) drought resilience

Marissa Verhoeven



From degradation to creation: closing the urban organic chain

Research on: i) valuation of organic residues trough vermicompost optimization, ii) soil improvement, iii) plant development and iv) drought resilience.

Research report

Client:	Permaculture Living Laboratory (PERMALAB), HortaFCUL, cE3c research group, Faculty of Science, University of Lisbon
Conducted by:	Marissa Verhoeven
Team:	Silvia Bacci Matias Mesa Garcia Florian Ulm Miguel Costa
Contacts:	Gil Penha-Lopes David Avelar
Motive project:	This project will be conducted as a research internship for Marissa Verhoeven
Supervising teacher:	Geert Peeters
Location:	Faculty of Sciences, University of Lisbon, Lisbon, Portugal
Year:	2019

CONTENTS

Abstract 4

1. Introduction 5

2. Transforming waste into black gold. 7

   2.1 Material and methods 7

      2.1.1 Data analysis 8

   8

   2.2 Results 8

   2.3 Discussion 9

3. Growing on gold; from seed to flower 10

   3.1 Material and methods 10

      3.1.1 Data analysis 11

   3.2 Results 12

      3.2.1 Germination 12

      3.2.2 Growth 13

      3.2.3 Bloom 14

   3.3 Discussion 14

4. Conclusion 16

References 17

Appendix 19

   Appendix I 19

   Appendix II 19

   Appendix III 20

   Appendix IV 20

   Appendix V 21

Abstract

This research has been conducted to contribute to the Faculty of Science University of Lisbon's (FCUL) sustainability by closing the organic cycle and revaluing organic waste into fertilizer. First, the optimization of the process used at the FCUL to transform organic waste into vermicompost has been studied. Temperature measurements of composting organic waste have been taken 3 times a week from 10 different samples of a period of 15 weeks to determine how long the organic waste needs in the normal composting stage before it can move on to the vermicomposting stage. The gained results show a drop in temperature at day 21 on average, indicating the composting stage has finished. In this way a lot of vermicompost is produced which then can be used as organic fertilizer for plants. Since little is known about at which quantities of vermicompost plants thrive the best in different stages of their development, another research has been conducted. Lupine, rocket and carrot seeds have been sown in various ratios of vermicompost:soil (100:0, 75:25, 50:50, 25:75, 0:100), duplicated 4 times. They have been monitored, measured and analyzed for the following parameters: germination, length of leaves, amount of leaves and drought resilience For the germination stage of the plants the different soil ratios didn't give any significant differences although results suggest it might vary between species. For the vegetal stage of the plant development the optimum amount of vermicompost also differs between species but overall a minimum of 50% would be best. For rocket the optimum lays around 75% vermicompost while that for lupine ranged from 75%-0%. Carrot shows an optimum ranging from 100%-25%. The examination of drought resilience, measured by the bloom of rocket, shows that a treatment of 100% vermicompost gives a significant larger water retainment than the other treatments. The general conclusion is that it's possible and important to close the urban organic cycle, by valuating the organic residues trough vermicompost optimization and use of the vermicompost in soil improvement to have better plant development and increase its drought resilience.

1. Introduction

Every year enormous amounts of organic waste are generated. In Europe alone, annually up to 88 million tons of food are wasted, of which around 53% comes from households (Stenmarck et al, 2016). Dealing with this amount of waste leads to costs estimated at an amount of 143 billion euros each year. To produce large quantities of food a lot of land with fertile soil is needed, but while the food demand grows the soil fertility decreases (European Commission, 2006; Godfray et al, 2010). Studies show that between 1 and 6 billion hectares worldwide are estimated to suffer from land degradation (Gibbs and Salmon, 2015) reducing crop yields and overall nutritional value in plants leading to food insecurity (Lal, 2009). Fertile soil does not only establish higher yields and nutritional value in food production (Ulm et al, 2018), but it can significantly affect plant-pollinator interactions by directly influencing pollinator nutrition and overall performance and better pollination can lead to better yields (Cardoza et al, 2012) in a cycle of positive feedback. To still be able to produce food on degraded lands, farmers in the current industrial paradigm need artificial ways such as inorganic fertilizers to enrich the soil (Ritchie, 2017). There is a gap in the cycle; on one hand massive amounts of organic matter are thrown away and on the other hand (chemical) fertilizers are produced in large amounts to meet the demand.

There are, however, more natural and efficient ways of regenerating soil in which the biological cycle is mimicked (biomimicry) such as composting and vermicomposting. Vermicompost is essentially made up out of the droppings of earthworms feeding on organic waste (Huang et al, 2014; Lalander et al, 2015). This form of compost does not only provide the necessary macro- and micro-nutrients which plants need for their development (Atiyeh et al, 2000a, b), but also increases the exchange capacity (EC) and has water retaining properties (Ngo et al, 2012; Zhao et al, 2017). Just as with compost, vermicompost can be produced at home. Moreover, vermicomposting takes less space in comparison with composting and is more efficient. (Lleó et al, 2013). Working according methods like biomimicry corresponds with permaculture designs such as sustainable urban agriculture, in which the goal is to create a human living environment in a way that is both ecologically and economically sustainable (Mollison, 2013).

The Faculty of Science's permaculture project HortaFCUL aims to study and contribute to the University of Lisbon's sustainability. The main source of organic waste comes from the canteens at the faculty which produce food for around 5383 students and 683 staff (2018/19), thus, a lot organic waste is generated. HortaFCUL wants to value this organic waste by first composting it and then make it into vermicompost which, among other things, can be used to enrich the soil at the experimental community garden PermaLab and at the faculty gardens and orchards. This is already being done for almost 20% of the organic waste suitable for vermicomposting and experiments are running to optimize the process to make this 100% as soon as possible. However, this process has never been monitored to pinpoint when the composting process slows down enough and gets below 25 C^{o} for the organic matter to be in the right conditions and have the right temperature to add worms and start vermicomposting (Reinecke, 1992).

In conclusion, vermicompost has a lot of benefits both regarding its chemical aspects as well as production methods. It is generated by transforming food waste and provides all the nutrient needed in food production which would solve two problems at the same time. Despite all these benefits there is little known about the effects of different quantities of vermicompost on plant development, both in large- and small-scale agriculture. The few studies that have been conducted focused only on large-scale agriculture with relatively low amounts of vermicompost, up to 20% (Atiyeh et al, 2000b). However, when vermicompost is produced in abundance, for example at home or in community gardens like the PermaLab, it is useful to know which quantity of vermicompost gives optimal results. At which quantities do plants benefit the most and where is the limit after which plants could suffer damage from excess amounts of nutrition? Is there a different influence between the phenological states of the plant and in which ways is this noticeable?

The optimal amount of vermicompost fertilizer is a knowledge gap that HortaFCUL aims to fill. In this study an experiment was set up to determine at what ratio vermicompost:soil plants gain optimal benefits from the use of vermicompost. Seeds will be planted in different treatments and the whole process from germination till the production of flowers and fruits will be monitored. Different parameters such as germination rate, length of leaves and presence of flowers will be used to determine the quality of the plants development.

2. Transforming waste into black gold.

Valuation of organic residues trough vermicompost optimization

The organic waste from the canteens first undergoes normal composting. In this time bacteria, fungi and other microorganisms break down a lot of the matter so it is later easier to digest by worms(Sharma & Gargab, 2018). This process of transforming organic waste into young compost (stage 1) and this compost into vermicompost (stage 2) was closely measured in this study. To have the process function at its optimal rate temperature measurements were taken to know when the temperature of the composted organic waste (end of stage 1) drops below 25 C^{o} so the added worms have the optimum conditions to thrive (Reinecke, 1992).

This states the research question: How long it takes composting organic waste to receive worms? In other words; after what time does the temperature of the composting organic waste drop below 25 C^{o}?

2.1 Material and methods

The material used for composting consisted of organic waste from the canteens of the Faculty of Sciences, University Lisbon (FCUL). The organic waste includes fruit and vegetable scraps, coffee grounds and egg shells in which the ratios differ from time to time. The waste was collected between 0 and 60 hours after it was produced. The waste was put inside nets which were then directly placed in insulated cubic containers with a volume of 0,125m^3 (0.5minner dimensions). The containers were made from ROOFMATE™ Extruded polystyrene foam insulation sheets of 5 cm thickness, which were joined using polyurethane foam adhesive spray and sealed with acrylic. In these cubic containers the organic waste had a composting time depending on the temperature development. Every Monday, Wednesday and Friday the temperature was measured by hand with a compost temperature measurer of the brand JARDI éco (figure 2.1, Appendix I) to determine when the composting was finished. In this process the temperature measurer would be stuck in the middle of the nets 4 times, of which the highest measured temperature would be noted. When the temperature dropped below 25 C° (Reinecke, 1992) the organic material was taken out and transferred to crates in which the red wiggler worms (*Eisenia fetida*) were added for the vermicomposting to start. This process has been replicated 10 times, with 3 measurements per week over a period of 15 weeks.

Figure 2.1, example of how the measurements will be taken in the insulated cubic containers filled with organic waste.

2.1.1 Data analysis

The means and standard deviation of temperature measurements have been calculated, plotted and analyzed in Excel to develop composting metabolism curves.

2.2 Results

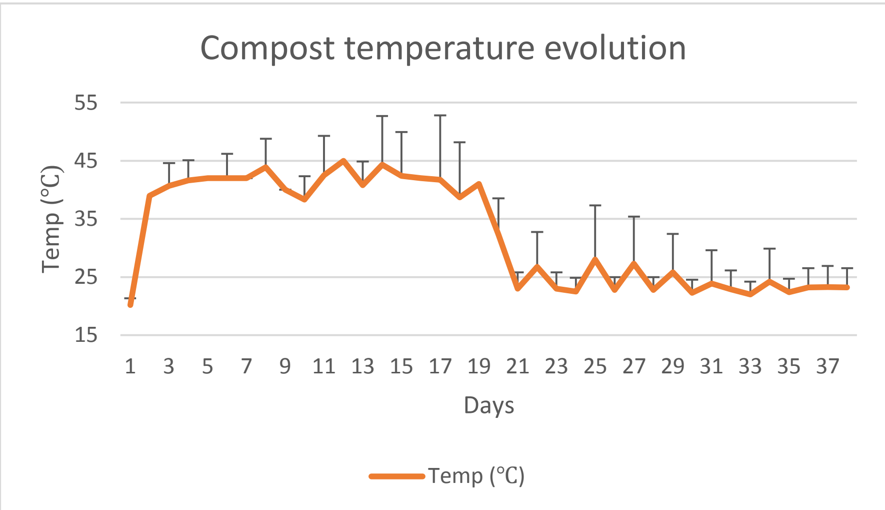


Figure 2.1, Line shows the average temperature of compost for 10 replicates over a period of 40 days, whiskers show the STD

During the first days, the temperature of the compost ranged from a means of 20 degrees to around 45 degrees. The measurements show a drop of about 20 degrees from day 19 to 21 (figure 3.1). At day 21 the temperature has gone below 25 which means the compost is suitable for vermicomposting. The total means of STD is nearly 5 days.

2.3 Discussion

At day 21 the temperature had gone below 25 which means the compost is suitable for vermicomposting, so the worms could be added. The total means of STD, however, is nearly 5 days. This means there is a fluctuation in temperatures between the different boxes. This could be explained by the different input in each box. The food waste produced per box came from the same source and is about the same, but there were slight changes in composition. For example, one day there could be more acidic waste, such as orange and lemon peels, and other days more alkaline waste such as banana peels and coffee grounds. Furthermore, weather circumstances and seasonal changes could've had an influence. Even though the boxes are well isolated, it could be that periods of cold, rain or heat had influence on the temperature. However, the high STD shouldn´t be a problem in practice as the measurements have always been taken in the middle of the compost where the temperature has it´s maximum. The optimum temperature for worms lays around 23 C^o and the maximum temperature after which they will stop functioning lays around 35 C^o (Reinecke, 1992) which decreases their survival rate. Furthermore, the worms will be free to move to the outer layers to escape potential undesired heat.

3. Growing on gold; from seed to flower

Soil improvement and its influence on seed germination, plant development and drought resilience

3.1 Material and methods

Five different species of plants were used as bioindicators while plant growth and development were measured. The following ratios have been examined:

A. 100:0
B. 75:25
C. 50:50
D. 25:75
E. 0:100 (control)

These 5 treatments were replicated 4 times to ensure reliable results.

The vermicompost which will be used for the experiment was produced with the food scraps from the canteens at the university of Lisbon. The food scraps have first had 40 days of composting followed by 2-3 months of vermicomposting. The vermicompost has been separated from the worms by hand and mixed in a concrete mixer to create a homogeneous mixture. The used soil consists of clay to resemble average poor garden soils. The first 4 weeks a net has been put around the pots to prevent the seeds and seedlings from being eaten by birds.

The mixtures of different ratios were contained in plastic pots of $0.011m^3$ (bottom diameter: 18cm, top diameter: 30cm, height: 25cm) which were set up according to a Latin square (Appendix II) at the PermaLab at the University of Lisbon (Appendix III).

In every pot several species of plants have been sown according to the layout of figure 3.1: lupine (*Lupinus albus*), wild carrot (*Daucus carota*), basil[1] (*Ocimum* basilicum) and rocket (*Eruca sativa*). For every species per pot 5 seeds were sown of which only one with the best growth rate was kept. The remaining seedlings were cut by the stem 4 weeks after sowing. However, all seeds were included in the germination count. So, in total 80 seeds were sown of which after 4 weeks only 20 remained. The plants were watered by hand with the same amounts of water and no additional fertilizer has been added during the experiment.

For the first 4 weeks every Monday, Wednesday and Friday the following parameter was measured:

- Total count of germinated seeds

After 10 weeks (calendar week 20), at the end of the experiment the following parameters were measured:

- Length of leaf (the longest leaf was measured from stem to top)
- Count of leaves (for the lupine the hands of leaves were counted as one single leaf)
- Drought resilience[2]

[1] The basil is not concluded in the rest of the report as the seedlings had disappeared during the experiment.

[2] A period of drought simulated by 5 days without watering was induced. After this period of drought, the plants were observed whether they had started blooming or not. The longer time it takes for the plants to bloom, the better the drought resilience (Farooq et al., 2009).

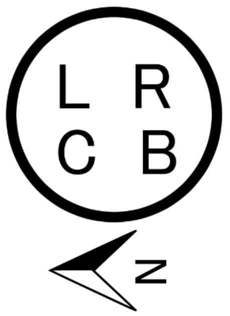


Figure 3.1, layout of seeds in pot. L: Lupinus albus, R: Eruca sativa, C: Daucus carota and B: Ocimum basilicum. The northic Arrow indicates in what way the pots are positioned on the field.

3.1.1 Data analysis

To examine which treatment (independent variable) has had significant (<0,05) influence on the different parameters (dependent variables) a multivariate statistic Post Hoc test in SPSS has been used to analyze the data.

3.2 Results

3.2.1 Germination

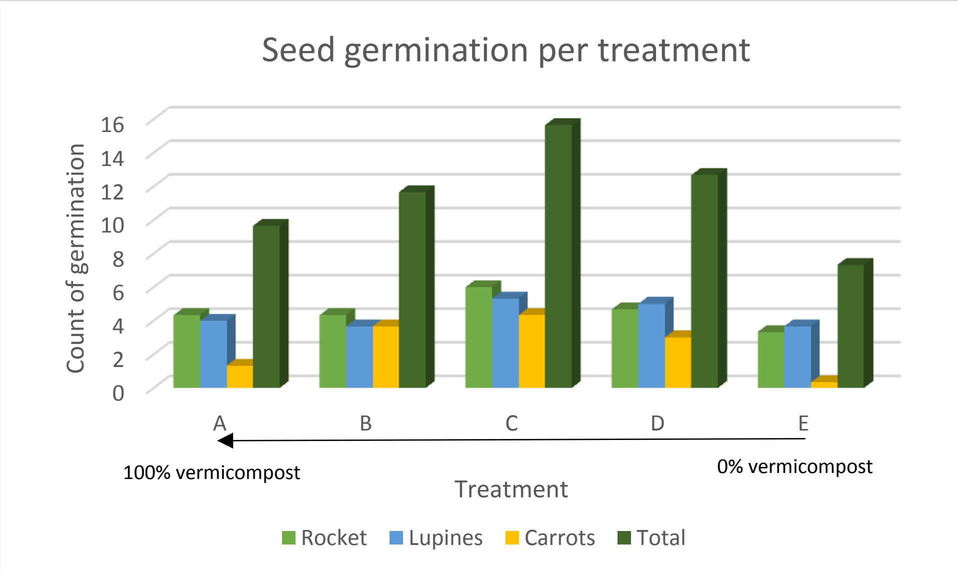


Figure 2.1, Number of germinated seeds for the different plant species (rocket, lupine, carrot) and the total over the experiment treatments with different ratios of vermicompost:soil. A=100:0, B=75:25, C=50:50, D=25:75, E(control)=0:100. For every plant species, a total of 20 seeds were grown.

The total of germinated seeds doesn't show a significant difference. However, if we look specifically at the germination of carrot seeds we see that treatment E (0% vermicompost) gives a significantly lower germination rate compared with B, C and D (75, 50 and 25% vermicompost).

3.2.2 Growth

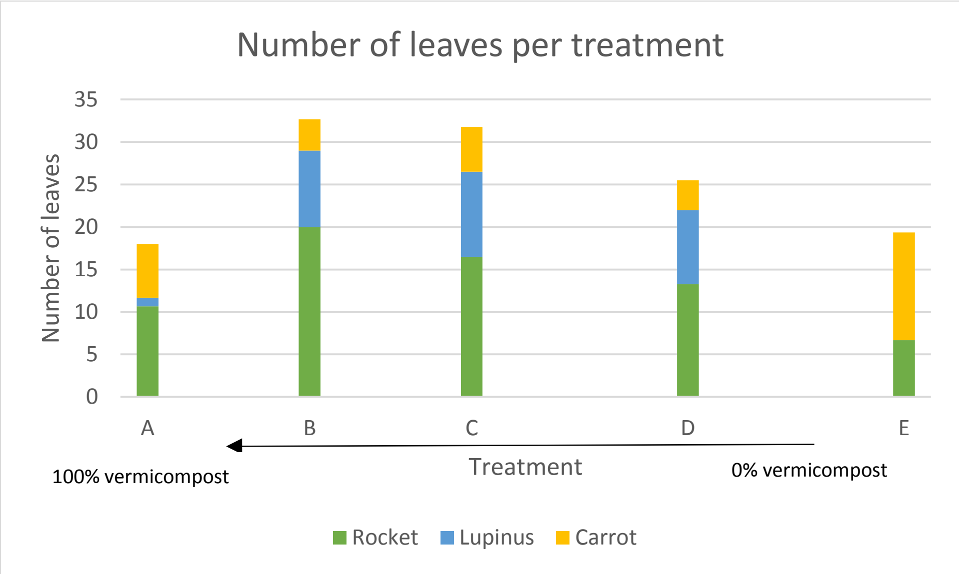


Figure 3.2 Cumulative number of leaves for the different plant species (rocket, lupine and carrot) over the experiment treatments with different ratios of vermicompost:soil. A=100:0, B=75:25, C=50:50, D=25:75, E(control)=0:100.

In treatment A (100% vermicompost) there were significantly fewer lupine leaves compared with all the other treatments. However, significantly more carrot leaves were counted in the same treatment.
Treatment E (0% vermicompost) counts significantly less carrot leaves compared to all treatments, and less rocket leaves compared to treatment B and C. Between treatments B, C and D, no significant differences have been found.

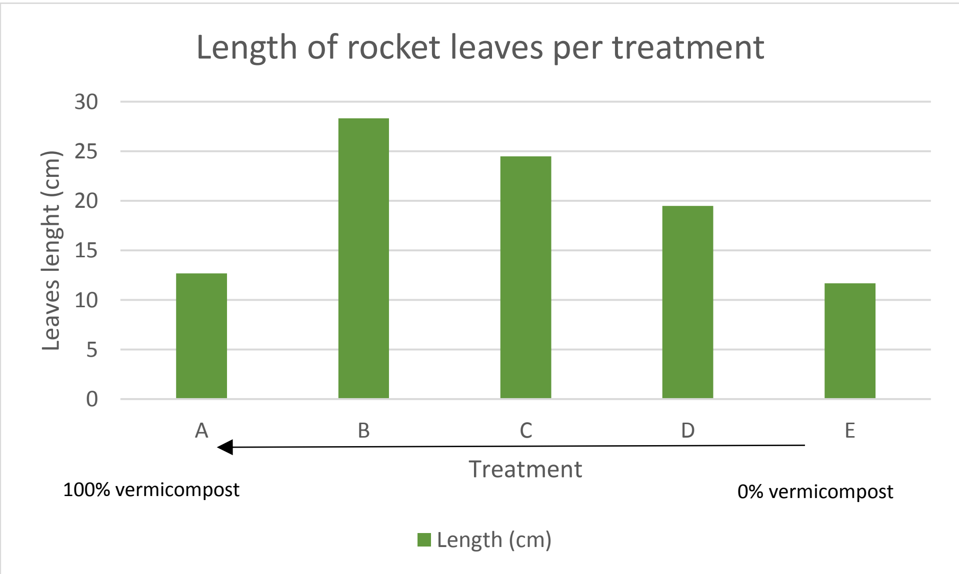


Figure 3.3, Average length of rocket leaves over the expermint treatments with different ratios of vermicompost: soil. A=100:0, B=75:25, C=50:50, D=25:75, E(control)=0:100.

Concerning the length of the leaves, treatment A (100% vermicompost) shows significantly shorter leaves than all other treatments except in comparison with treatment E (0% vermicompost). The longest rocket leaves, with a means of 28,33 cm, were those of the plants in treatment B. They show significantly longer leaves than treatment A, D and E.

3.2.3 Bloom

In treatment B, C, D (75, 50 and 25% vermicompost) all rocket plants had bloomed after a period of drought. In treatment E 33.3% of the rocket plants had bloomed. In treatment A (100% vermicompost), no rocket plants had bloomed. Thus, in treatment A significantly less (none) rocket plants had bloomed after a period of drought.

3.3 Discussion

The total number of germinated seeds did not show any significant differences as expected since the germination is a phase mostly independent from the soil nutrients. However, the carrot seeds do show a difference in germination between the treatments. Carrot seeds are small and take a long time to germinate (14-21 days) compared to other small seeds such as rocket (5-7 days). This means the seeds are more sensible to external factors such as humidity which is highly correlated with soil organic matter. The clay ground of treatment E might have been too sturdy for the carrots to set roots in. Also, most of the basil seedlings had disappeared from the pots, perhaps eaten by snails (which is why they are not included in the results), chances are that some of the carrot seedlings were eaten as well. Therefore, there will be no conclusions taken from the results of the germination rate of the carrot seeds.

The good growth of the carrot in treatment A might be due to the loose, sandy structure of the vermicompost as carrots prefer loose soil. Yet the lupine didn´t grow too well in treatment A. Lupine is a nitrogen fixator and therefore doesn´t need high nutrient soils but research (Kalra, 2010) shows that vermicompost can have positive influence on the thriving of Rhizobium. This is contradicting with the obtained result. Other research (Prabha, 2010; Sangwan, 2010) shows that vermicompost has positive influence on the plant development of various agricultural plants including nitrogen fixators. This is confirmed by the results obtained in this research concerning the carrot and rockets plants, but once again contradicted by the lupine. Perhaps lupine is more vulnerable to the high concentrations of soluble salts available in vermicompost (Lim, 2015). This could mean that optimum amount of vermicompost variates between plant species. Graph 3.2 and 3.3 show that the optimum amount of vermicompost for rocket would be around 75%, while for lupine it would be less (such as …) to even none at all.

An interesting observation which hasn't been measured was the leaf color of the rocket. The color seemed to variate from darker shades of green with a red hue to bright, almost fluorescent, light green. These changes in chlorophyll could be linked to the different soil treatments especially concerning drought resilience. Further research could be conducted to determine this possible connection.

As excepted the plants in treatments with 100% vermicompost (treatment A) produced significantly less flowers during the period of drought. This means that vermicompost has better water retaining properties than normal clay soil due to its physical structure (Ngo et al, 2012; Lim, 2015; Zhao et al, 2017). Furthermore, the high amount of readily available nutrients could have something to do with it; a recent study (Kaur, 2018) shows that seeds which were pre-soaked in 80-100% vermicompost tea had a significant later blooming and fruiting time.

4. Conclusion

Regarding the valuation of organic waste in an efficient way (research question 1); after 21 days the temperature of the composting organic waste drops below 25 C^0 which is the optimal time to add worms and optimize the process. Although the temperature might still variate around this number, this shouldn´t be a problem for the worms. This means the optimal way to transform organic residues in a highly valuable product is a two steps process: Stage 1 takes in average 21 days of composting the residues in a closed box; from experience stage 2 takes around 30 days to transform this young compost into mature vermicompost (figure 4.1).

Concerning the optimum amount of vermicompost for the germination, vegetal development and resilience of plants (research question 2) there are more complex answers. For germination in general there are no differences although this might vary between species. A follow-up research focusing specifically on the germination of carrot seeds in different ratios of vermicompost:soil is suggested.

The amount of vermicompost where rocket produces the most and longest leaves is around 75% (treatment B). The optimum amount of vermicompost for the vegetal stage of the lupine was found at a wider range; 75-0% (treatment B-E). The carrot showed significantly more leaves at 100% (treatment A) vermicompost, but also did well down to 75, 50 and 25% (treatment B, C and D). The general conclusion is the more vermicompost, the better, but too much can be counterproductive for some species.

As for the drought resilience it was found that vermicompost amount plays an important role on buffering the water scarcity effect. With 100% vermicompost (treatment A) the rocket plants produced significantly less flowers during an induced period of drought. This study corroborates that vermicompost has better water retaining properties than regular clay soil which is backed up by multiple studies. It would be interesting and relevant to follow up this study to better understand the effect of soil organic matter in the resilience of the plants.

The general conclusion is that it's possible and important to close the urban organic cycle, by valuating the organic residues trough vermicompost optimization and use of the vermicompost in soil improvement to have better plant development and increase its drought resilience.

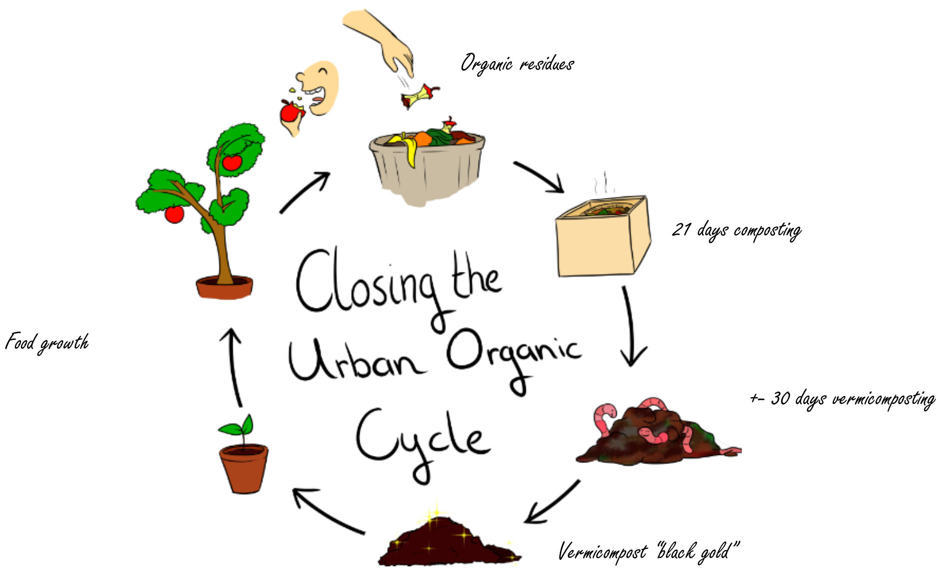


Figure 4.1 Visual representation of the organic cycle at the University of Lisbon

References

Atiyeh, RM., Arancon, NQ., Edwards, CA., Metzger, JD. (2000a). Influence of earthworm-processed pig manure on the growth and yield of greenhouse tomatoes. Bioresour Technology. Volume 75: 175-180.

Atiyeh, RM., Subler, S., Edwards, CA., Bachman, G., Metzger, JD., Shuster, W. (2000b). Effects of vermicomposts and composts on plant growth in horticultural container media and soil. Pedobiologia. Volume 44: 579-590.

Cardoza, Y. J., Harris, K. G., and Grozinger, C. M., (2012). Effects of Soil Quality Enhancement on Pollinator-Plant Interactions. Hindawi Publishing Corporation, Psyche. Volume 2012: 8p.

European Commission (2006). Impact assessment of the thematic strategy on soil. http://ec.europa.eu/environment/soil/three_en.htm Consulted at 25-02-2019.

Farooq, M., Wahid, A., Kobayashi, N., Fujita, D., Basra, S. M. A. (2009). Plant drought stress: effects, mechanisms and management. Agronomy for Sustainable Development. Volume 29: 185-212.

Gibbs, H. K. & Salmon, J. M. (2015). Mapping the world's degraded lands. Applied Geography. Volume 57: 12-21.

Godfray, J., Charles, H., Beddington, R. J., Crute, R. I., Lawrence, H., Lawrence, D., Muir, F. J., Pretty, J., Robinson, S., Thomas, M. S., Toulmin, C. (2010). Food security: The challenge of feeding 9 billion people. Science. Volume 327: 812-818.

Huang, K., Li, F., Wei, Y., Fu, X., Chen, X. (2014). Effects of earthworms on physicochemical properties and microbial profiles during vermicomposting of fresh fruit and vegetable wastes. Bioresoure Technology. Volume 170: 45-52

Kaur A, Singh B, Ohri P, Wang J, Wadhwa R, Kaul SC, et al. (2018) Organic cultivation of Ashwagandha with improved biomass and high content of active Withanolides: Use of Vermicompost. PLoS ONE 13(4): e0194314. https://doi.org/10.1371/journal.pone.0194314

Kalra, A., Chandra, M., Awasthi, A. et al. (2010). Natural compounds enhancing growth and survival of rhizobial inoculants in vermicompost-based formulations. Biol Fertil Soils. Volume 46: 521.

Kirk, W.D.J & Howes, F.N (2012). Plants for bees: a guide to the plants that benefit the bees of the British Isles. International Bee Research Association, Cardiff, Great Brittain, 311p.

Lal, R. (2009). Soil degradation as a reason for inadequate human nutrition. Food Secur. Volume 1: 45 -57.

Lalander, CH., Komakech, AJ., Vinnerås, B. (2015). Vermicomposting as manure management strategy for urban small-holder animal farms. Waste Management. Volume 39:96-103

Lleó, T., Albacete, E., Barrena, R., Font, X., Artola, A., Sánchez, A. (2013). Home and vermicomposting as sustainable options for biowaste management. Journal of Cleaner Production. Volume 47: 70-76

Mollison, B. (2013). Introduction to Permaculture. Tagari Publications, Tasmania, 225p.

Ngo, P.T., Rumpel, C., Doan, T.T., Jouquet, P. (2012). The effect of earthworms on carbon storage and soil organic matter composition in tropical soil amended with compost and vermicompost. Soil Biol Biochem. Volume 50: 214-220

Prabha, K.P. Loretta, Y.L, Usha, R.K. (2008). An experimental study of vermi-biowaste composting for agricultural soil improvement. Bioresource Technology. Volume 99: 1672-1681

Reinecke, A. J., Viljoen, S. A., & Saayman, R. J. (1992). The suitability of Eudrilus eugeniae, perionyx excavatus and Eisenia fetida (Oligochaeta) for vermicomposting in southern africa in terms of their temperature requirements. Soil Biology and Biochemistry. Volume 24(12): 1295–1307.

Ritchie, H. (2017) How many people does synthetic fertilizer feed? https://ourworldindata.org/how-many-people-does-synthetic-fertilizer-feed Consulted at 19-02-2019

Sangwan P, Garg VK, Kaushik CP. (2010). Growth and yield response of marigold to potting media containing vermicompost produced from different wastes. Environmentalist. Volume 30: 123–130.

Sharma, K., Gargab, V. K. (2018). Comparative analysis of vermicompost quality produced from rice straw and paper waste employing earthworm Eisenia fetida. Bioresource Technology. Volume 250: 708 -715.

Stenmarck, A., Jensen, C., Quested, T., Moates, G. (2016). Estimates of European food waste levels. FUSIONS, Stockholm, 80p.

Lim, S.L., Wu, T.Y., Lim, P.N., Shak, K.P.Y., (2015). The use of vermicompost in organic farming: overview, effects on soil and economics. SCI. Volume 95: 1143-1156

Ulm, F., Avelar, D., Hobson, P., Penha-Lopes, G., Dias, T., Máguas, C., Cruz, C. (2018). Sustainable urban agriculture using compost and an open-pollinated maize variety. Journal of Cleaner production. Volume 212: 622-629

Zhao, H.T., Li, T.P., Zhang, Y., Hu, J., Bai, J.C., Shan, Y.H., Ke, F. (2017). Effects of vermicompost amendment as a basal fertilizer on soil properties and cucumber yield and quality under continuous cropping conditions in a greenhouse. J Soils Sediments. Volume 17: 2718-2730

Appendix

Appendix I

A section of the datasheet which has been used for the temperature measurements of the compost.

Box 1					
Date	1/3/2019	4/3/2019	6/3/2019	8/3/2019	11/3/2019
Day of measurement	0	3	5	7	10
Temperature C°					

Box 2					
Date	6/3/2019	8/3/2019	11/3/2019	13/3/2019	15/3/2019
Day of measurement	0	2	5	7	9
Temperature C°					

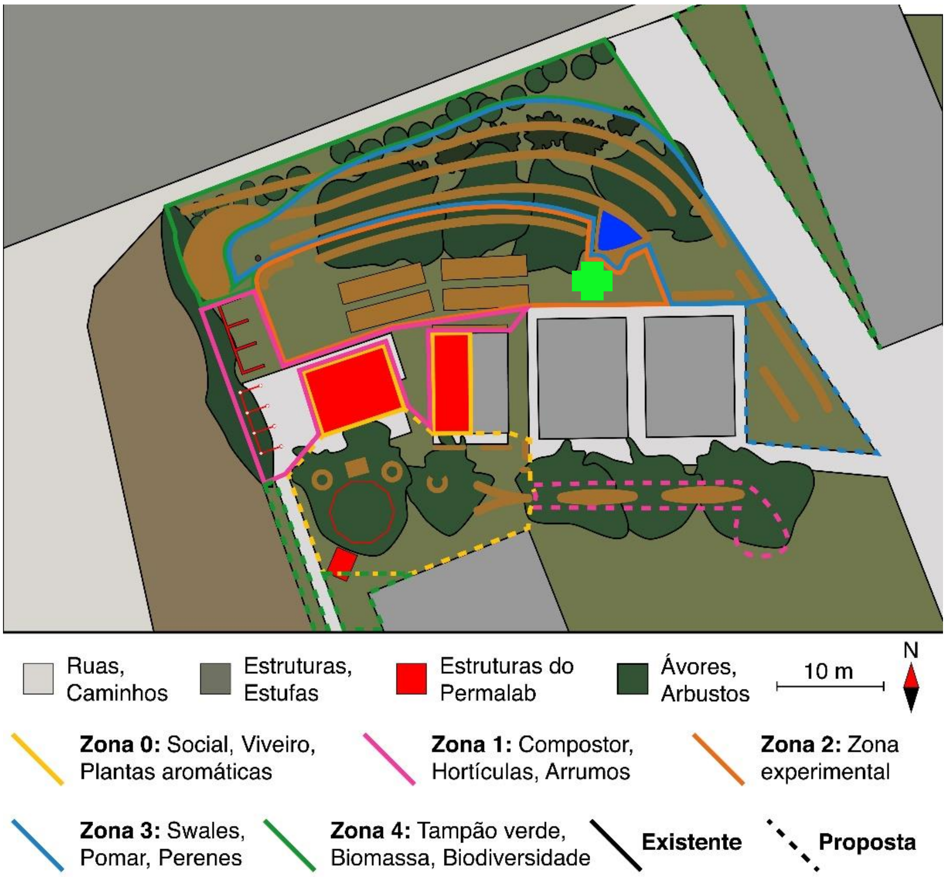
Appendix II

Latin square set-up of the plant development experiment + picture. The letter (A, B, C, D, E) represents the treatment as described at the material and methods, the number represents which replicate it is.

1A	1E	1D	1C	1B
2B	2A	2E	2D	2C
3C	3B	3A	3E	3D
4D	4C	4B	4A	4E
5E	5D	5C	5B	5A

Appendix III

PermaLab at the University of Lisbon. Bright green cross marks research area.



Appendix IV

An example of treatment A (left) compared to an example of treatment D (lright pot) after 5 days of induced drought.

Appendix V

The significances (<0.05) between the treatments for the number of leaves counted per species:

Carrot: A a, B bcd, C abcd, D dbc, E e
Lupine: A a, B bcde, C bcde, D bcde, E bcde
Rocket: A acde, B abcd, C abcd, D abcde, E ade

The significances (<0.05) between the treatments for the lenght of leaves concerning the rocket:

A ae, B bc, C bcd, D cd, E ae