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DIFFERENT COMPOST CHARACTERISTICS AND FERTILISER POTENTIAL

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KARIMÄKI, KAISA:
Eri kompostien ominaisuudet ja lannoitepotentiaalit

Opinnäytetyö 40 sivua, joista liitteitä 2 sivua
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Kompostien käyttö lannoitteena voi olla ympäristölle hyödyllistä, sillä sen avulla tärkeitä ravinteita voidaan kierrättää takaisin luontoon. Kompostien hyötykäyttöön vaikuttaa myös niiden helppokäyttöisyys. Opinnäytetyön tarkoituksena oli arvioida eri kompostien ominaisuuksia ja käytettävyyttä lehtimangoldin kasvatuksessa kontrolloiduissa olosuhteissa. Lehtimangoldi vaatii korkean typpipitoisuuden kasvattaakseen suuret lehdet, joten käytetty kompostien määrä arvioitiin niiden typpipitoisuuksista. Kasvatuskokeessa käytetyt kompostimateriaalit olivat bioreaktorilla käsitelty käymäläjäte (Green Good -komposti), kuivakäymäläkomposti ja matokomposti keittiön biojätteestä. Viitenäytteinä kasvatuskokeessa oli yleislannoite Kekkilän Kesäkukkalannoite sekä lannoittamaton näyte.

Noin kahden kuukauden kasvatuksen jälkeen näkyviä eroja kasvien välille oli syntynyt ja koska kasvutila alkoi loppua, kasvatuskoe päätettiin. Kaikki kasvit punnittiin sekä mitattiin, ja saaduista tuloksista huomattiin, että kuivakäymäläkompostin kasvit olivat kasvaneet parhaiten, sillä kuivakäymäläkompostin kasvit olivat 2,2 cm korkeampia kuin toiseksi korkeimmat näytteet ja tuorepainoltaan ne olivat 29,69 g painavampia kuin toiseksi painavimmat näytteet. Tulos oli myös huomattavissa kasveja katsomalla. Lannoittamattomilla näytteillä oli painavimmat ja pisimmät juuret, mutta lehtikasvullisesti ne jäivät muita huomattavasti pienemmiksi.

Kompostien mikrobiologiset tulokset osoittivat, että näytteissä ei ole E. coli -bakteeria eikä salmonellaa. Tämä tarkoittaa, että kompostit ovat Maa- ja metsätalousministeriön asetuksen 24/2011 mukaisia. Kuivakäymäläkomposti oli hankalinta käyttää, koska se oli epätasaista laadultaan ja erittäin kevyttä. Matokomposti oli homogeenisempää sekä kosteampaa, joka teki sen levityksestä helpompaa. Green Good -komposti oli sähköisen oloista, ja siinä oli epämiellyttävä haju. Prosentuaalisesti Green Good -komposti sisälsi eniten typpeä ja matokomposti vähiten, mutta kuivakäymäläkomposti oli parasta lannoitteena. Kaikki lannoitetut näytteet kasvoivat paremmin kuin lannoittamattomat, ja kuivakäymäläkompostilla lannoitetut näytteet kasvoivat paremmin kuin yleislannoitteella lannoitetut.

Asiasanat: komposti, lannoittaminen, ominaisuudet

ABSTRACT

Tampereen ammattikorkeakoulu
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KARIMÄKI, KAISA:
Different Compost Characteristics and Fertiliser Potential

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Usage of compost as a fertilizer can be environmentally profitable when the compost contains required nutrients and is easy to use. Using compost as a fertilizer results in nutrients circling back to nature, instead of being disposed of. The work was done to assess the usability and effects of different compost materials when growing silver beet (*Beta vulgaris L. Cicla groups*) in controlled conditions. Silver beet requires higher amounts of nitrogen and the used materials amounts were assessed based on their nitrogen amounts. Silver beet is used as a vegetable and it is grown for its big leaves. The used testing materials were bioreactor treated dry toilet manure, dry toilet compost, vermicompost made of kitchen biowaste, store bought general fertilizer (Kekkilän kesäkukkalannoite) and non-fertilized samples as control samples. General fertilizer was used as one material to see if the compost material had anywhere near the same effect.

After approximately two months, visible results were seen in the silver beet and the silver beets were running out of proper space to grow, the experiment was finished. After weighing and measuring the plants, Dry Toilet samples had clearly done better than the other samples. They were on average 2,2 cm taller than the second tallest samples and they had 29,69 g higher average fresh mass than the second heaviest samples. Non-fertilized samples grew the biggest roots but the smallest leaves.

Material testing of the used composts showed that the compost materials are safe to use in terms of allowed microbes, as there is no E. coli or salmonella present (Decree 24/2011). As for the usability, Dry Toilet -compost was the hardest to handle due to its inconsistent composition and light weight. Green Good -compost seemed electric and sticky. It also had a bad odor which made it unpleasant to use. Green Good -compost contained the highest amount of nitrogen whereas vermicompost contained the lowest. Overall Dry Toilet -compost worked best as a fertilizer.

Key words: compost, fertilizer, characteristics

CONTENTS

1 INTRODUCTION

Fertilizing is an essential part of agriculture as all crops need a specific amount of nutrients to grow and to produce good yields. Smaller scale growing, such as greenhouses, need fertilizers as well to ensure proper growth. Fertilizing provides required nutrients for the plants grown when the growing medium does not have enough. The most important nutrients are nitrogen (N), phosphorus (P) and potassium (K). Nitrogen is mainly used by the plants for leaf-growth, so when growing leafy plants, such as silver beet, nitrogen is the main nutrient to consider (Zhao, D. Reddy, K. Kakani, V. Reddy, V.R. 2004). All plants have different nutrient requirements and needs. Compost can be used as a fertilizer if it has enough nutrients or it can be used to enhance the growing medium. The most nutrient rich composts are from slaughter waste, and municipal waste (Taavo, T. 2013).

Using municipal waste as composting material can be tricky due to bacteria and other harmful substances in the raw-material. Compost can be sanitized if the composting temperatures are high enough and other factors are also suitable. Compost requires temperatures of 55°C for three days to sanitize. Higher temperatures might kill useful bacteria. (Taavo, T. 2013).

When considering how profitable and easy it is to use a material as a fertilizer, physical properties must be considered. Moving bigger amounts may cost more and heavy substances can be hard to handle. The weight and volume of the material are then crucial. Handling of the product should be as easy as possible. Very dry and light materials may be harder to handle in large scale facility outdoors as they can spread due to wind.

The purpose of this work is to see how different types of compost affect the growth of silver beet grown in supervised and controlled conditions. Growing of the crops will be closely monitored along with the growing conditions. The used compost materials will also be studied for their other properties, such as dry matter content, loss on ignition and bulk density. The usability and other small observations of the different composts will be assessed as well during the experiment. Other tests for bacteria and such may also be conducted.

2 METHODS

2.1 Experimental setup

The experiment was conducted in the green house of TAMK (Tampere University of Applied sciences). The testing was done by using ten balcony boxes, eight of which were the same size and yellow, and two which were smaller and white, as seen in Picture 1. The smaller boxes were used for the non-fertilized samples. The volume of the yellow boxes was 13 liters and the volume of the white boxes was 10 liters. The boxes were set on the green house table and seventeen silver beet, (*Beta vulgaris L. Cicla groups*), seeds were planted in two rows in each yellow box. The smaller white boxed had fourteen seeds planted in both. The amount of seeds planted in the smaller boxes were lower so the amount and volume was comparable with all boxes. The amount of seeds in total were estimated so that each seedling would have enough room to grow. The required growing space for a silver beet is approximately 50 cm apart (Wade, S.) but this was not possible in the provided conditions, so a bit smaller space was given. The growth of the silver beets was monitored frequently and the results recorded.

Picture 1. Experiment set up at TAMK green house. (Photo: Kaisa Karimäki 2017)

The testing included five different treatments and all treatments had two replicas. The testing samples were Green Good, Dry Toilet compost, Vermicompost, a general fertilizer (Kekkilän kesäkukkalannoite) and non-fertilized samples. All materials are listed in Table 1.

Table 1. Used testing materials.

Name	**Material/process**	**Origin**	**Amount used in total, g**
Green Good	Bioreactor treated dry toilet manure	Green Good machine, Hiedanranta	Box 1: 28,81 Box 2: 28,80
Dry Toilet	Dry toilet compost	TAMK dry toilet	Box 1: 90,21 Box 2: 90,20
Ver-micompost	Kitchen bio-waste in ver-micomposter	TAMK	Box 1: 139,23 Box 2: 139,22
General fertilizer	Kekkilän kesäkukkalannoite. N-P-K: 19-4-20	Store bought	Box 1: 5,80 Box 2: 5,81

The testing area was constantly monitored for temperatures and the TAMK green house has automated blinds to control the amount of light coming in. The testing area was placed in the corner of the green house to ensure the plants would not be harmed by other activities in the green house. The moisture levels of the plants were also monitored to ensure they got enough water.

2.1.1 Testing medium

The testing medium, where the seeds were planted, was a mixture of fine sand and peat. The ratio of sand and peat was made to be 50:50. The testing medium was a mixture of sand and peat to ensure that the nitrogen needed by the plants was mainly coming from the fertilizers, not the testing medium. The peat used in the growing medium was also tested for nitrogen. According to Wade, S. (2009) silver beets grow best in sandy loams and they require quite big amounts of nitrogen.

As the growing medium was slightly acidic, the pH was altered by adding lime into the mixture. The starting pH was around 4,9 and it was risen to 6,5 by adding 325 ml of lime into each yellow box and 225 ml of lime into both of the white boxes.

2.1.2 Fertilizing

All the samples were fertilized twice, once before the planting and once during growth. The amounts of compost used for fertilizing were calculated by using the total nitrogen amounts of all samples obtained from the total Kjeldahl nitrogen measurements. The amounts of nitrogen in all used samples was the same, the amounts were taken from the Silver beet growing by Wade S. (2009).

The compost amounts for each box were calculated by assessing the area of the box to be 0,11 m^2 and the needed nitrogen values being 3 g/m^2 and 7 g/m^2. The amount of nitrogen needed per box before the seeds were planted was therefore 330 mg and the nitrogen needed during the growth was 770 mg. Amounts of compost and fertilizer needed were calculated by the total nitrogen needed divided by the total nitrogen of each sample obtained from Table 4. The amount of general fertilizer that was needed was checked from the box. The amounts of added compost before the experiment are presented in Table 2. and the compost amounts added during the experiment are in Table 3.

The fertilizer in both times was put in a small ditch that was dug in the middle of the box. The ditch was then covered and the soil was watered. Spreading of the fertilizers throughout the boxes would have disturbed the seedlings.

Table 2. Amounts of compost and fertilizers added 29.3.2017

Sample/box	Mass, g
GreenGood 1	8,65
GreenGood 2	8,64
Dry toilet 1	27,08
Dry toilet 2	27,07
Vermicompost 1	41,78
Vermicompst 2	41,78
General fertilizer 1	1,75
General fertilizer 2	1,75

Table 3. Amounts of compost and fertilizers added 25.4.2017

Sample	**Mass, g**
GreenGood 1	20,16
GreenGood 2	20,16
Dry toilet 1	63,13
Dry toilet 2	63,13
Vermicompost 1	97,45
Vermicompst 2	97,44
General fertilizer 1	4,05
General fertilizer 2	4,06

2.2 Nitrogen

2.2.1 Kjeldahl method

Total nitrogen of all three composts were analyzed by using the Kjeldahl method. The method measures organically bound nitrogen in ammonium (Hoegger, R. 1998.). The nitrogen analysis was done before the start of the experiment to determine the amounts of compost needed for each treatment. The samples analyzed in Kjeldahl were Dry Toilet compost, vermicompost, Green Good compost and peat.

The total Kjeldahl nitrogen levels measured from the different composts are presented in Table 4. The measured nitrogen values were consistent for each replica. It is clearly visible that the most nitrogen was in the Green Good samples, and Dry Toilet samples had the second most nitrogen. Vermicompost had less nitrogen per kg than peat that was used in the growing medium. Average nitrogen percentage obtained from the Kjeldhal measurement are represented in Figure 1. Green Good has the highest amount of nitrogen present.

Table 4. Total nitrogen levels measured using Khjeldal. Average values calculated.

Sample	N%	g/kg	Average N%	Average g/kg
Green Good 1	3,83	38,3	3,82	38,2
Green Good 2	3,79	37,9		
Green Good 3	3,83	38,3		
Vermicompost 1	0,80	8,0	0,79	7,9
Vermicompost 2	0,76	7,6		
Vermicompost 3	0,80	8,0		
Peat 1	0,94	9,4	0,94	9,4
Peat 2	0,94	9,4		
Peat 3	0,93	9,3		
Dry toilet 1	1,19	11,9	1,22	12,2
Dry toilet 2	1,29	12,9		
Dry toilet 3	1,17	11,7		

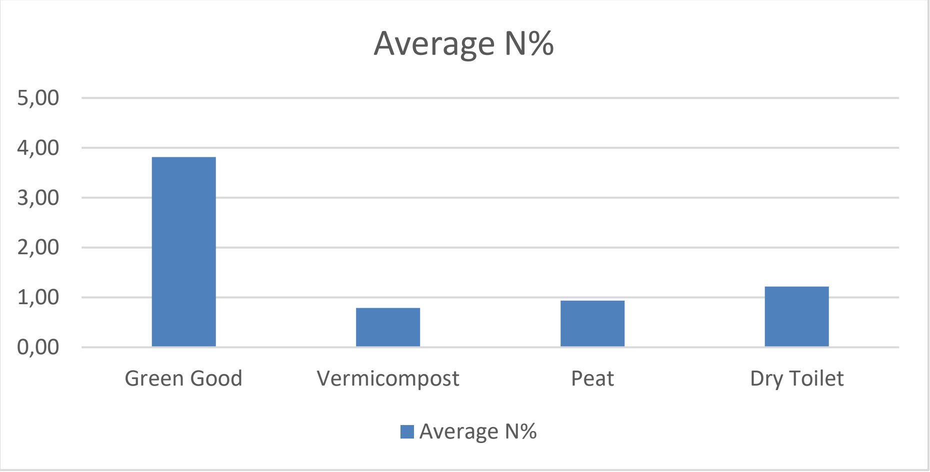

Figure 1. Average nitrogen % obtained using Kjeldahl method.

2.2.2 Total nitrogen using vario TOC select

Nitrogen levels left in the soil after the growing experiment were measured using vario TOC select equipment. The machine can measure total nitrogen levels from liquid or solid samples. The equipment is mainly meant to be used to measure total organic carbon (TOC) and total bound nitrogen (TNb) from liquid samples and only TOC from solid samples. The total nitrogen measured by vario TOC select is more specific than total Kjeldahl nitrogen, since it measures TNb. TNb means nitrogen in the forms of free ammonia, ammonium, nitrite, nitrate and organic compounds (SFS-EN 12260 2004).

The analysis was done by first weighing the dried samples into tin foil cups and pressing the air from the foil cups. The samples were all around 100 mg. The samples were then inserted into the machine's feeding carousel and then all samples were analyzed at once. The machine analyses the samples by burning them at around 950°C and then analyzing the gas formed. The machine is mainly used for the analysis of total organic carbon (TOC) which was not analyzed this time. The equipment was calibrated using standardized soil before the start of the analysis. The equipment gives the results in a ready table with the TNb %.

The small amount and size of the needed samples made it hard to get homogenous samples as the grain size differed within the samples. As the samples were not that homogenous enough, two replicas were made from each sample, ten samples in total.

2.3 Dry matter content

Dry matter content of used fertilizers is measured to see how much moisture the samples have. Most measurements done to the composts are after they are dried. The dry matter content of each compost sample was analyzed using standard SFS-EN 15934:2012, method A.

The analysis was done by first drying the crucibles at 105°C for 30 minutes. The crucibles were then cooled down and approximately 1 gram of sample was measured into the crucibles. The samples were then dried at 105°C for 1,5 hours. The crucibles with the samples were then weighed and dry matter content was calculated using Formula 1.

$$w_{dm} = \frac{(m_c - m_a)}{(m_b - m_a)} * 100 \tag{1}$$

Where,

w_{dm} is dry matter content in percent, %
m_a is the mass of empty crucible, g
m_b is the mass of crucible with the sample, g
m_c is the mass of the crucible with the dried sample, g

2.4 Loss on ignition

Loss on ignition is analyzed to see how much organic material is in the compost and how much of it is minerals.

The analysis of loss on ignition was done according to standard SFS-EN 15935:2012. The samples were dried with the same procedure as the dry matter content and then ignited in a furnace at 550°C for 2 hours. The ignited samples were then cooled down and weighed. Loss on ignition was calculated using Formula 3.

$$LOI = \frac{(m_c - m_d)}{(m_c - m_a)} * 100 \tag{3}$$

Where,

LOI is loss on ignition, in percentage %
m_a is the mass of empty crucible, g
m_c is the mass of the crucible with the dried sample, g
m_d is the mass of the crucible with the ignited sample, g

2.5 Bulk density

Bulk density is a measurement of how much particles by weight are in a specific volume. The higher the bulk density is, the more material is in a space. Bulk density can be measured as either loose or tapped since the procedure will affect the results. When let fall loose, the particles will settle further from each other and when tapped, they will be packed closer together, thus affecting the bulk density.

The bulk density in this case was measured by applying the Standard SFS-EN 1236 which is meant for loose bulk density measurement. The standard was applied to suit the laboratory equipment at hand. The testing was done by using a regular A4 paper that was then made into a funnel. The reason for the use of the paper as a funnel was the particle size of the testing materials. The funnel was then inserted on top of a 250ml graduated cylinder and the sample was poured into the funnel. The sample was then let to flow into the cylinder. The weight of the sample was measured and the bulk density was calculated by using Formula 2. The testing was repeated twice for each sample.

$$\rho = \frac{m}{V} \tag{2}$$

Where,

ρ is bulk density in kg/m^3

m is the mass of the sample in kg

V is the volume of the sample in m^3

3 RESULTS

3.1 Different tests on the compost materials

Dry matter content of compost, loss on ignition (LOI %), and bulk density (loose) were done for all compost materials used during the experiment. The compost materials were also sent to the KVVY laboratory for microbiological testing. The results from the testing can be found in Appendix 1.

3.1.1 Dry matter content of compost

The obtained dry matter values in percent are shown in Table 5. The values obtained from the analysis are similar with values obtained from dry matter content apparatus. The highest dry matter content was in the Dry Toilet compost samples. It was clear that Vermicompost was the most wet.

Table 5. Dry matter content of compost results.

Sample	Dry matter, %
Green Good 1	92,5
Green Good 2	92,5
Dry toilet 1	94,1
Dry toilet 2	93,8
Vermicompost 1	38,5
Vermicompost 2	37,1

3.1.2 Loss on ignition

Values obtained from the loss on ignition analysis are shown in Table 6. The results show that Green Good samples had the most organic matter and Vermicompost had the least. Biggest value difference was with the Dry Toilet samples where the result had a difference of 9,3 %.

Table 6. Loss on ignition as percent

Sample	LOI, %
Green Good 1	83,8
Green Good 2	83,0
Dry toilet 1	66,6
Dry toilet 2	75,9
Vermicompost 1	52,5
Vermicompost 2	53,7

3.1.3 Bulk density

Bulk density was measured and the results are presented in Table 7. The highest bulk density was analysed for Vermicompost and the lowest on Dry Toilet samples. These values are consistent with Dry Matter since Vermicompost samples were much more saturated with water, making them heavier.

Table 7. Bulk density measured, presented as kg/m^3

Sample	kg/m^3
GreenGood 1	312
GreenGood 2	316
Dry toilet 1	284,8
Dry toilet 2	287,2
Vermicompost 1	483,2
Vermicompost 2	474,4

3.2 Growth experiment

As the growth experiment resulted in quite big amount of data, it is divided into pictures describing the results and tables and figures where measured results are recorded.

3.2.1 Pictures of the experiment

The growth of the crops was monitored weekly and the results were recorded. At first 17 seeds were planted in each yellow box and 14 seeds in both white boxes. In the beginning, the seedlings were left to grow in peace but after three weeks, few of the seedlings were taken out to provide enough space for the seedlings left, and to ensure each box had the same number of seedlings. Twelve seedlings were left in each yellow box and ten seedlings in both white boxes. At the end of the experiment, the length of each plants tallest leaf and roots were measured. The number of leaves per plant were also counted and recorded as well as the biomass of all plants.

Picture 2. represents each sample (Green Good 1-2, Dry Toilet 1-2, Vermicompost 1-2, General fertilizer 1-2 and No fertilizer 1-2) after the seedlings have surfaced. At this point, no visible variation between treatments was seen. Most of the planted seeds germinated, some had two seedlings surfacing from one seed.

Picture 2. All boxes with seedlings 12.4.2017. (Photo: Kaisa Karimäki 2017)

Picture 3. represents the silver beet plats before they were taken out and measured. The experiment finish was decided to be 25.5, making the growing period to be approximately two months. The experiment was finished since there were visible differences between treatments and the silver beets would have slowly run out of space to grow. Visible differences in height, condition and width can be easily seen from the picture. Dry Toilet treatment is visibly doing the best. The leaves are clearly the tallest and very bushy. No fertilizer 2 has clearly the smallest leaves and it does not look bushy at all.

Picture 3. All treatments on 25.5.2017. (Photo: Kaisa Karimäki 2017)

Pictures 4 to 8 below represent samples taken from each treatment. Each picture has a sample from replica one and replica two. The biggest amounts of dirt were cleaned from each plant to see the roots properly. Cleaning the roots was done by shaking the excess dirt of and then rinsing the roots to get the rest of the dirt off. Some soil is still left in the roots because more thorough cleaning could have caused a lot of breakage of the tallest roots. The root material is quite thing and it broke off easily.

Picture 4. represents Green Good samples. The samples had lengthy roots but not very bushy. The main root in most of the plants was thick and strong. The leaves on both Green Good samples were quite narrow. The stems on most of the plants were quite thin which caused the Green Good samples to fall down a few times during the experiment.

Picture 4. Examples of Green Good 1 (left) and Green Good 2 (right). (Photo: Kaisa Karimäki 2017)

Picture 5. represents Dry Toilet samples. The samples had long and bushy roots along with sturdy stems. The leaves of Dry Toilet samples were quite wide and long. The Dry

Toilet samples had sturdy and healthy feeling and looking plants. Dry Toilet samples were harder than Green Good samples to clean due to very bushy roots. Shaking them did not help clean off the soil and washing did not remove any of the soil.

Picture 5. Examples of Dry Toilet compost 1 (left) and Dry Toilet compost 2 (right). (Photo: Kaisa Karimäki 2017)

Picture 6. represents Vermicompost samples. Vermicompost samples had very wrinkly and quite narrow leaves but very steardy stems. The roots had a nice long and wide main root. The roots were also quite bushy and clearly very healthy. Cleaning of the Vermicompost samples was as hard as cleaning of the Dry Toilet samples.

Picture 6. Examples of Vermicompost 1 (left) and Vermicompost 2 (right). (Photo: Kaisa Karimäki 2017)

Picture 7. represents General fertilizer samples. General fertilizer 1 plants grew quite straight and they had very strong stems. The plants from General fertilizer 1 grew in a close cluster making them easier to handle. General fertilizer 2 had a bit weaker stems but still strong. The leaves on General fertilizer 1 were a bit bigger than General fertilizer 2 but overall both were quite narrow and wrinkly. The roots on both General fertilizers were bushy and the main root in the middle was not very strong or long.

Picture 7. Examples of General fertilizer 1 (left) and General fertilizer 2 (right). (Photo: Kaisa Karimäki 2017)

Picture 8. represents No fertilizer samples. The samples had very bushy and long roots but most of the stems were quite narrow and weak. A few of the plants had stronger stems. The plants grew quite messy, meaning that the stems went in all directions. This made handling and measuring the plants quite hard. The leaves remained quite skimpy and a few even had discolouring. The leaves were narrow and wrinkly.

Picture 8. Examples of No fertilizer 1 (left) and No fertilizer 2 (right). (Photo: Kaisa Karimäki 2017)

3.2.2 Tables and figures

Total length

Table 8. represents the measured lengths of each plant. The total length of each plant was measured from the tip of the tallest leaf to the tip of the roots. The average length per box is also represented at the bottom and average length per treatment is shown at the bottom row. Dry Toilet 1 had the tallest plants on average and the average of both Dry Toilets was the highest. Dry Toilet 2 had the tallest plant with the length of 43,5 cm. The average length of the No fertilizer samples was clearly lower than the rest.

Figure 2. represents the content from Table 2. It can be seen from Figure 2, that Dry Toilet has the highest average and No fertilizer has the lowest.

Table 8. Total lengths of each plant and average lengths per treatment.

	Green Good 1	**Green Good 2**	**Dry Toilet 1**	**Dry Toilet 2**	**Vermicompost 1**	**Vermicompost 2**	**General fertilizer 1**	**General fertilizer 2**	**No fertilizer 1**	**No fertilizer 2**
Total lenght, cm	24,5	26,5	35,0	36,0	20,0	28,0	18,0	22,0	21,0	30,0
	31,0	18,5	32,0	28,5	25,0	31,5	21,0	37,0	32,0	22,0
	30,5	31,0	32,0	33,0	24,0	36,0	30,0	30,0	32,0	27,0
	24,5	20,5	31,0	35,0	33,0	30,0	29,0	36,0	32,0	29,0
	30,0	22,0	36,0	27,0	30,0	32,0	30,0	17,0	39,0	30,0
	27,5	35,0	30,0	39,5	31,0	44,0	31,0	31,0	12,0	30,0
	20,0	30,0	38,5	30,5	32,0	36,5	27,0	30,0	27,0	31,0
	34,0	38,0	39,0	35,5	29,0	29,0	29,0	31,0	36,0	30,0
	36,5	37,0	34,0	35,0	30,0	32,0	29,5	38,5	16,0	27,0
	32,0	33,5	37,5	43,5	26,0	31,0	32,0	36,0	29,0	28,0
	32,0	32,0	38,0	33,0	31,0	33,0	39,0	35,0	x	x
	33,0	26,0	18,0	13,0	30,0	32,0	43,0	24,0	x	x
Average, cm	**29,6**	**29,2**	**33,4**	**32,5**	**28,4**	**32,9**	**29,9**	**30,6**	**27,6**	**28,4**
	29,4		32,9		30,7		30,3		28,0	

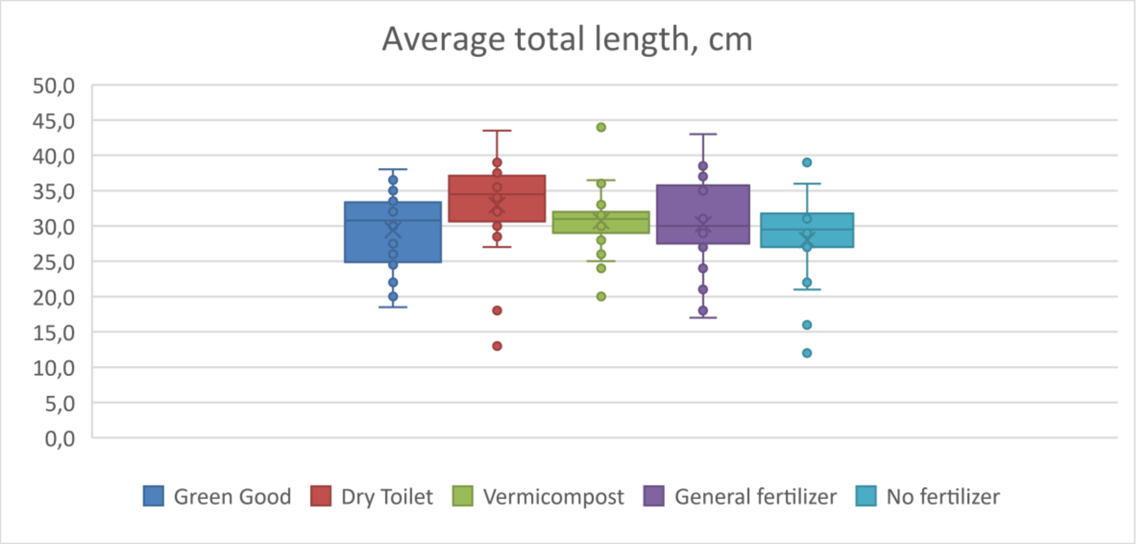

Figure 2. Average total length of silver beets per treatment.

Leaf length

Table 9. represents the measured leaf-length of each plant. The measurement was done from the tip of the tallest leaf to the beginning of the root. The tallest leaf had the length of 31,5 cm and it was measured from Dry Toilet 2. Both Dry Toilets 1 and 2 had the tallest average height. On average, No fertilizer treatments had the shortest leaves. Figure 3. shows the data from average lengths from Table 9. The figure shows that the results are quite similar, but Dry Toilet has a greater average than the rest. No fertilizer average is clearly the lowest.

Table 9. Length of the tallest leaf per plant with average lengths.

	Green Good 1	Green Good 2	Dry Toilet 1	Dry Toilet 2	Vermicompost 1	Vermicompost 2	General fertilizer 1	General fertilizer 2	No fertilizer 1	No fertilizer 2
Tallest leaf, cm	14,0	15,0	23,0	26,0	11,0	15,0	8,0	11,0	14,0	16,5
	22,0	9,5	21,5	18,0	15,5	22,0	11,0	23,0	22,0	13,5
	20,0	21,0	21,0	24,0	16,5	22,0	19,0	20,0	23,0	15,5
	14,5	14,0	22,0	24,0	25,5	19,0	21,0	24,0	21,5	15,0
	16,0	15,0	25,0	18,5	20,0	18,0	20,0	9,0	25,0	17,0
	15,0	23,0	17,5	28,5	22,5	29,0	20,0	21,0	7,0	16,0
	12,0	20,0	27,5	21,5	22,0	26,5	21,0	17,5	18,0	16,0
	19,0	25,0	24,0	24,5	18,0	20,0	28,5	19,0	23,5	15,0
	23,5	26,0	24,0	22,0	19,0	22,0	25,0	28,5	9,0	14,0
	21,0	22,5	26,5	31,5	18,0	20,0	28,0	22,0	18,0	16,0
	21,0	23,0	27,0	24,0	21,5	21,0	28,0	23,0	x	x
	20,5	15,0	10,5	7,5	20,0	19,0	19,0	16,0	x	x
Average, cm	**18,2**	**19,1**	**22,5**	**22,5**	**19,1**	**21,1**	**20,7**	**19,5**	**18,1**	**15,5**
	18,6		22,5		20,1		20,1		16,8	

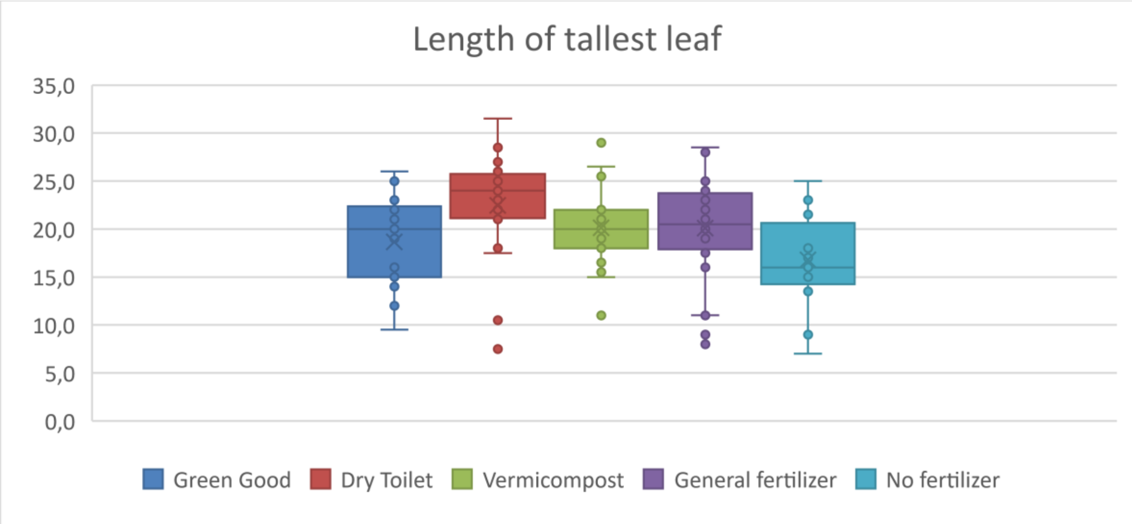

Figure 3. Average length of tallest leaf per treatment.

Root length

Table 10. represents the measured root lengths of each plant. The root length was measured from the beginning of the root to the tip of the root. As seen in Table 10, the longest roots were from General Fertilizer 1 sample (24,0 cm) but on average, No fertilizer 2 had the longest root lengths from all samples. As seen in Figure 4, No fertilizer replicas had the longest roots and General fertilizers had the shortest. All treatments are very similar but No fertilizer has a bit higher average value than the other treatments.

Table 10. Root length of each plant with average lengths.

	Green Good 1	Green Good 2	Dry Toi-let 1	Dry Toilet 2	Vermicom-post 1	Vermicom-post 2	General fertilizer 1	General fertilizer 2	No fer-tilizer 1	No fer-tilizer 2
Root lenght, cm	10,5	11,5	12,0	10,0	9,0	13,0	10,0	11,0	7,0	13,5
	9,0	9,0	10,5	10,5	9,5	9,5	10,0	14,0	10,0	8,5
	10,5	10,0	11,0	9,0	7,5	14,0	11,0	10,0	9,0	11,5
	10,0	6,5	9,0	11,0	7,5	11,0	8,0	12,0	10,5	14,0
	14,0	7,0	11,0	8,5	10,0	14,0	10,0	8,0	14,0	13,0
	12,5	12,0	12,5	11,0	8,5	15,0	11,0	10,0	5,0	14,0
	8,0	10,0	11,0	9,0	10,0	10,0	6,0	12,5	9,0	15,0
	15,0	13,0	15,0	11,0	11,0	9,0	0,5	12,0	12,5	15,0
	13,0	11,0	10,0	13,0	11,0	10,0	4,5	10,0	7,0	13,0
	11,0	11,0	11,0	12,0	8,0	11,0	4,0	14,0	11,0	12,0
	11,0	9,0	11,0	9,0	9,5	12,0	11,0	12,0	x	x
	12,5	11,0	7,5	5,5	10,0	13,0	24,0	8,0	x	x
Average, cm	**11,4**	**10,1**	**11,0**	**10,0**	**9,3**	**11,8**	**9,2**	**11,1**	**9,5**	**13,0**
	10,8		10,5		10,5		10,1		11,2	

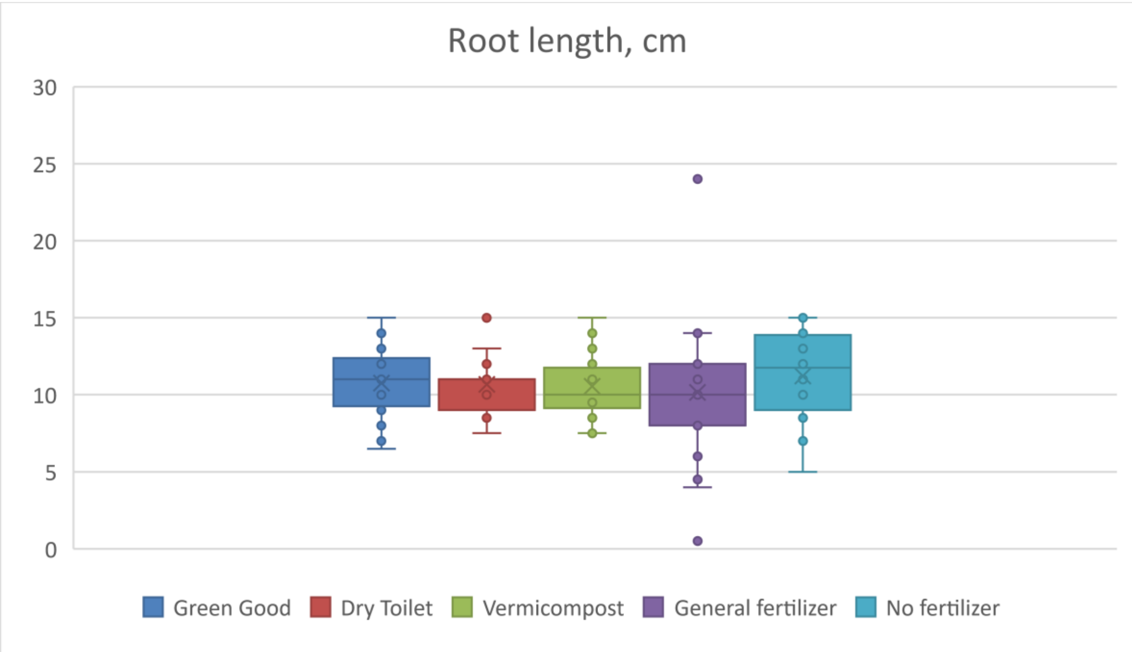

Figure 4. Average root length per treatment.

Number of leaves

Table 11. represents the number of leaves per plant. For all samples, General fertilizer 1 had the most leaves at 8,6. From all treatments, Dry Toilet treatment had on average the greatest number of leaves at 8,3. No fertilizer samples had least leaves per treatment. Only three plants had less than 6 leaves; two of these were from No fertilizer 1. As seen in Figure 5. No fertilizer samples have the lowest average value. Dry Toilet and General fertilizer have very similar values as do Green Good and Vermicompost.

Table 11. Number of leaves per plant.

	Green Good 1	**Green Good 2**	**Dry Toilet 1**	**Dry Toilet 2**	**Vermicom-post 1**	**Vermicom-post 2**	**General fertilizer 1**	**General fertilizer 2**	**No fer-tilizer 1**	**No fer-tilizer 2**
Number of leaves	7	8	7	7	8	6	6	8	5	8
	9	8	10	7	8	8	7	8	8	7
	8	6	10	9	8	8	8	8	9	7
	8	8	9	10	8	8	7	9	5	6
	8	7	10	8	8	7	8	7	8	8
	7	8	8	8	7	8	10	8	8	7
	7	8	8	7	8	8	8	8	8	7
	8	8	10	8	8	8	9	8	7	6
	8	6	9	8	9	10	9	7	7	8
	7	9	9	8	6	8	9	7	8	7
	7	8	6	10	8	7	10	7	x	x
	8	9	5	8	6	8	12	9	x	x
Average	**7,7**	**7,8**	**8,4**	**8,2**	**7,7**	**7,8**	**8,6**	**7,8**	**7,3**	**7,1**
	7,7		**8,3**		**7,8**		**8,2**		**7,2**	

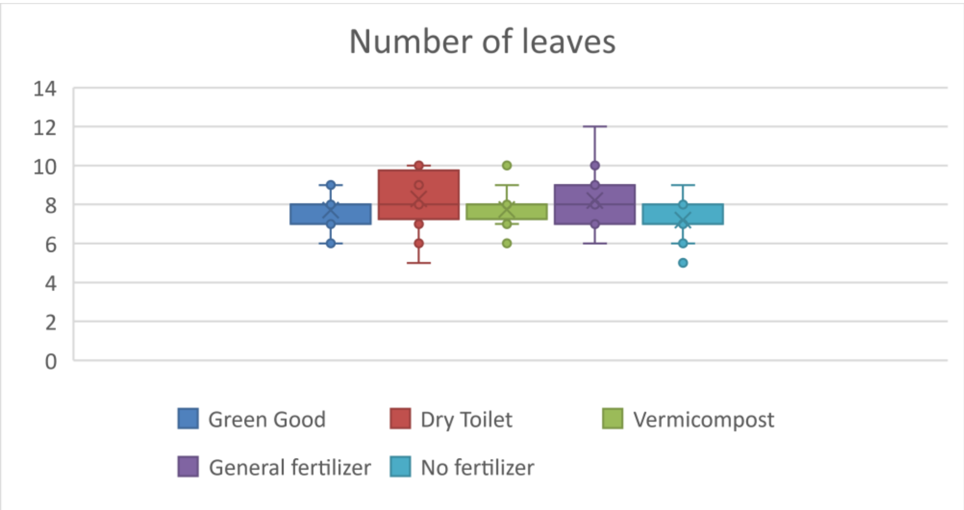

Figure 5. Average number of leaves per treatment.

Fresh masses

Fresh leaf mass, root mass and total masses of each box are represented in Table 12. The plants were weighed on the same day as the experiment was ended and it is possible to see that with the weight of 116,41 g, Dry Toilet 1 had the greatest leaf mass. General fertilizer 1 had the greatest root mass with the weight of 3,15 g. Table 13. has the average values for fresh leaf mass, root mass and total mass per treatment. Figure 6. was made to represent the average values in Table 13. From Figure 6. it is possible to see that the Dry Toilet masses are greater than others and No fertilizer values are clearly lower than the rest. Green Good and No fertilizer masses are quite similar. Figure 7. represents the root masses from Table 13. It can be noted that the Green Good root mass is clearly lower than the rest and General fertilizer and No fertilizer have higher root masses.

Table 12. Fresh masses of plants weighed on 25.5.2017.

	Leaf mass, g	**Root mass, g**	**Total mass, g**	**Total mass per treament**
Green Good 1	53,50	1,38	54,89	121,67
Green Good 2	65,53	1,25	66,78	
Dry Toilet 1	116,41	2,52	118,93	236,73
Dry Toilet 2	115,26	2,54	117,80	
Vermicompost 1	68,47	2,17	70,64	153,65
Vermicompost 2	80,64	2,37	83,01	
General fertlizier 1	99,92	3,15	103,06	177,36
General fertilizer 2	71,61	2,69	74,29	
No fertilizer 1	62,16	2,95	65,11	104,61
No fertilizer 2	36,92	2,58	39,50	

Table 13. Average values obtained from Table 12.

	Av. leaf mass, g	Av. root mass, g	Av. total mass, g
Green Good 1	59,52	1,319	60,84
Green Good 2			
Dry toilet 1	115,84	2,530	118,37
Dry toilet 2			
Vermicompost 1	74,55	2,270	76,82
Vermicompost 2			
General fertlizier 1	85,76	2,917	88,68
General fertilizer 2			
No fertilizer 1	49,54	2,765	52,31
No fertilizer 2			

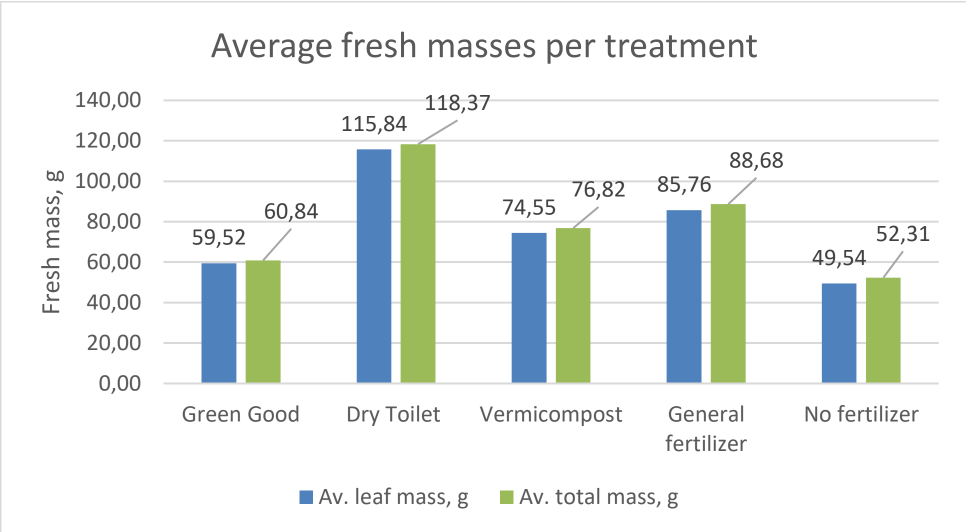

Figure 6. Average values for leaf mass and total mass per treatment.

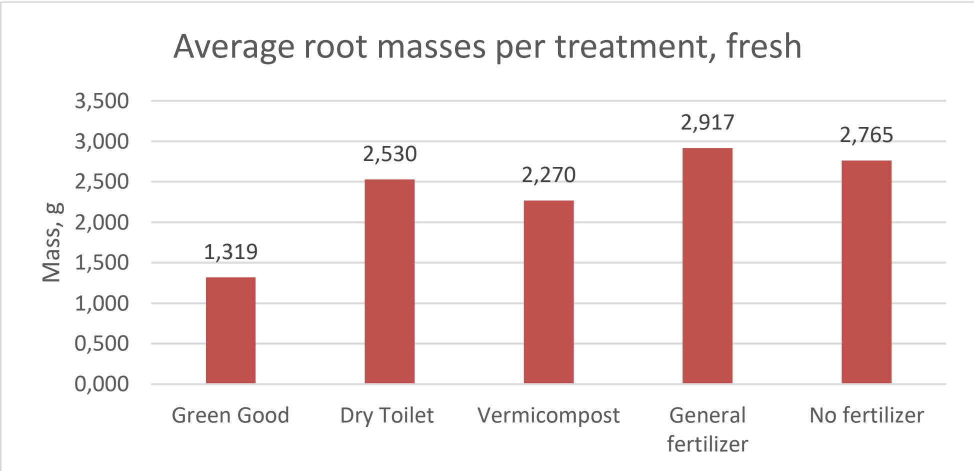

Figure 7. Average root masses per treatment, fresh

Average leaf, root and total masses for one plant were calculated due to different number of plants in No fertilizer treatments. These average values are presented in Table 14. It can be seen from Table 14. that Dry Toilet samples had the greatest leaf masses but on average, No fertilizer 1 samples were heavier than Green Good samples. An average for all treatments was calculated and the results are represented in Figure 8 and 9. Dry Toilet values are much greater for all values but root mass. As seen in Figure 9, Green Good has the lowest root mass.

Table 14. Average fresh leaf mass, root mass and total mass of one plant per treatment.

	Leaf mass/ plant, g	**Root mass/ plant, g**	**Total mass/ plant, g**
Green Good 1	4,46	0,115	4,57
Green Good 2	5,46	0,105	5,57
Dry Toilet 1	9,70	0,210	9,91
Dry Toilet 2	9,61	0,212	9,82
Vermicompost 1	5,71	0,181	5,89
Vermicompost 2	6,72	0,198	6,92
General fertlizier 1	8,33	0,262	8,59
General fertilizer 2	5,97	0,224	6,19
No fertilizer 1	6,22	0,295	6,51
No fertilizer 2	3,69	0,258	3,95

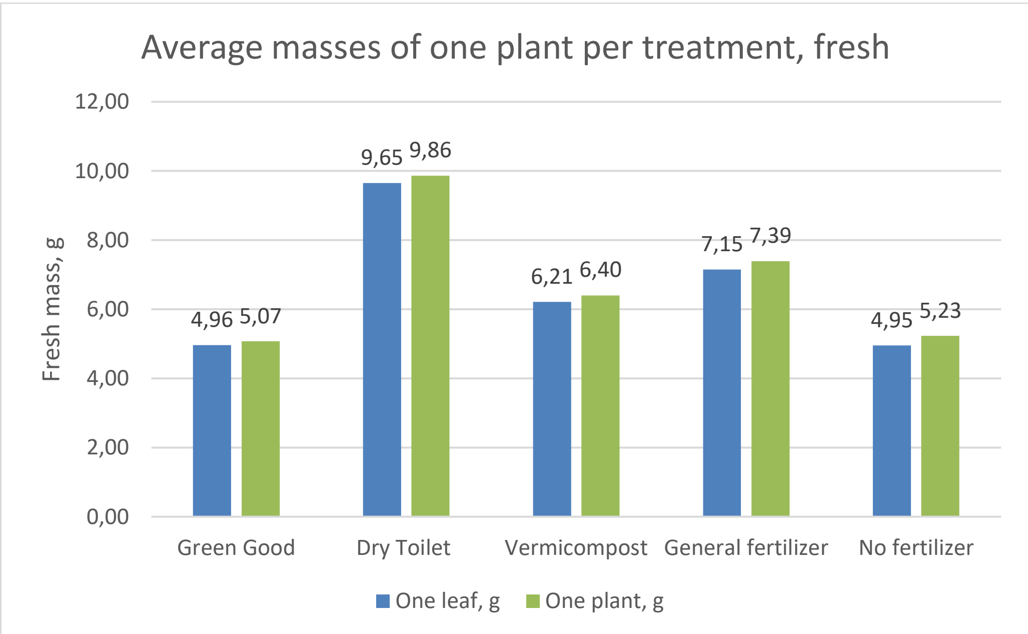

Figure 8. Average mass of one leaf, one root and one plant per treatment.

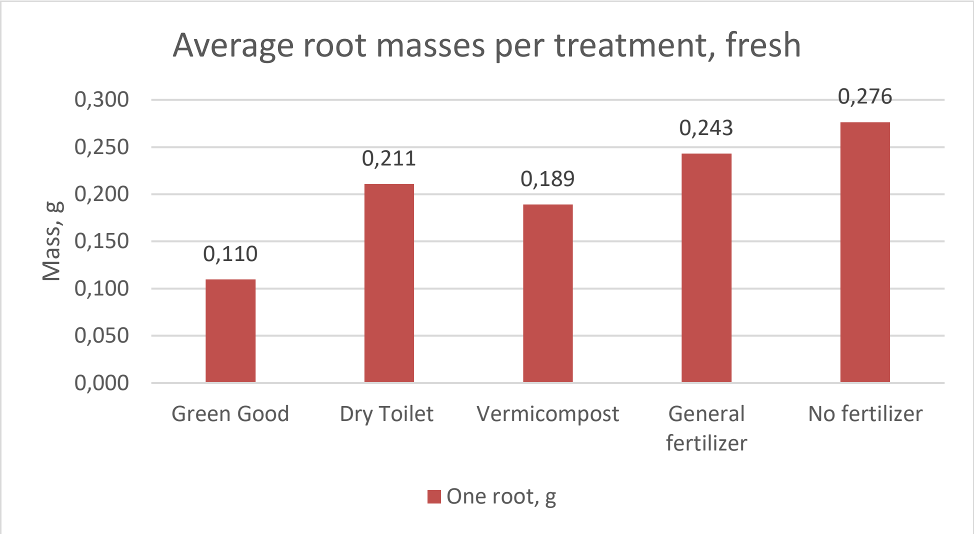

Figure 9. Mass of one root per treatment.

Dried masses

The samples were left to dry at ambient temperature for two days so that dry masses could be measured. The samples were left in open bags and the air in the green house was quite warm. From Table 15. the dried masses of all plants can be seen. After drying, Dry Toilet 2 had the heaviest leaves with the weight of 70,92 g and General fertilizer 2 had the greatest root mass at 0,54 g. In total, Dry Toilet samples had the greatest mass at 133,87 g. Table 16. represents the average values per treatment for values obtained from Table 15. From Table 16, Figure 10. was made and from it, it can be seen that even dried, Dry Toilet samples were heavier than the rest. The average root masses are represented in Figure 11. From the values, it shows that on average, General fertilizers had the heaviest roots and Green Good had the lightest roots.

Table 15. Dried masses of all plants weighed on 27.5.2017.

	Leaf mass, g	Root mass, g	Total mass, g	Total mass per treatment
Green Good1	24,57	0,22	24,79	52,69
Green Good 2	27,74	0,16	27,90	
Dry Toilet 1	62,22	0,34	62,55	133,87
Dry Toilet 2	70,92	0,40	71,32	
Vermicompost 1	35,16	0,47	35,63	73,77
Vermicompost 2	37,76	0,38	38,15	
General fertlizier 1	54,96	0,50	55,46	97,50
General fertilizer 2	41,50	0,54	42,04	
No fertilizer 1	28,98	0,48	29,46	45,40
No fertilizer 2	15,48	0,46	15,94	

Table 16. Average dried masses of all samples.

	Av. leaf mass, g	Av. root mass, g	Av. total mass, g
Green Good1	26,16	0,189	26,34
Green Good 2			
Dry toilet 1	66,57	0,367	66,94
Dry toilet 2			
Vermicompost 1	36,46	0,428	36,89
Vermicompost 2			
General fertlizier 1	48,23	0,523	48,75
General fertilizer 2			
No fertilizer 1	22,23	0,471	22,70
No fertilizer 2			

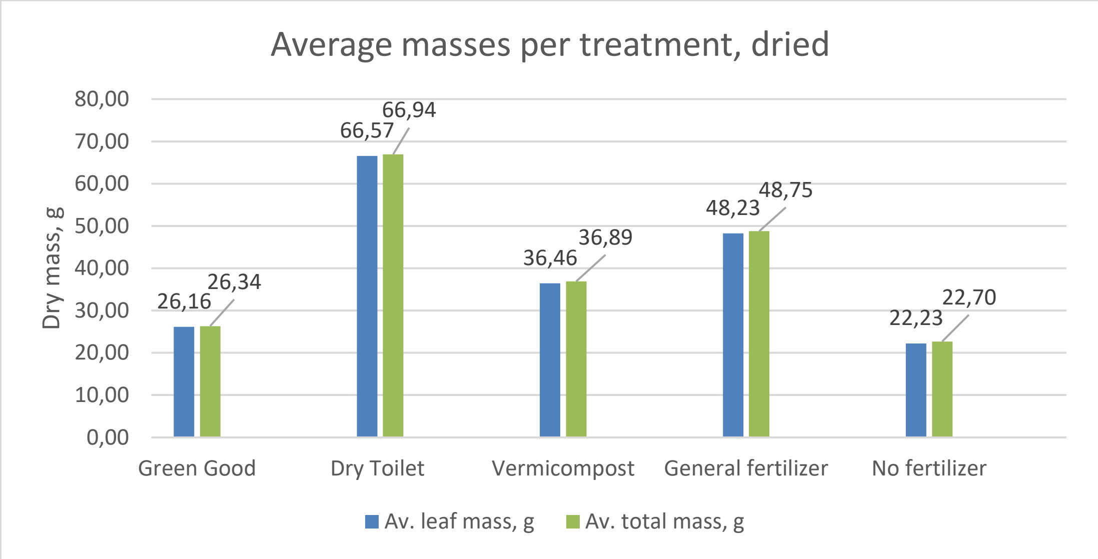

Figure 10. Average values for leaf mass, root mass and total mass per treatment, dried.

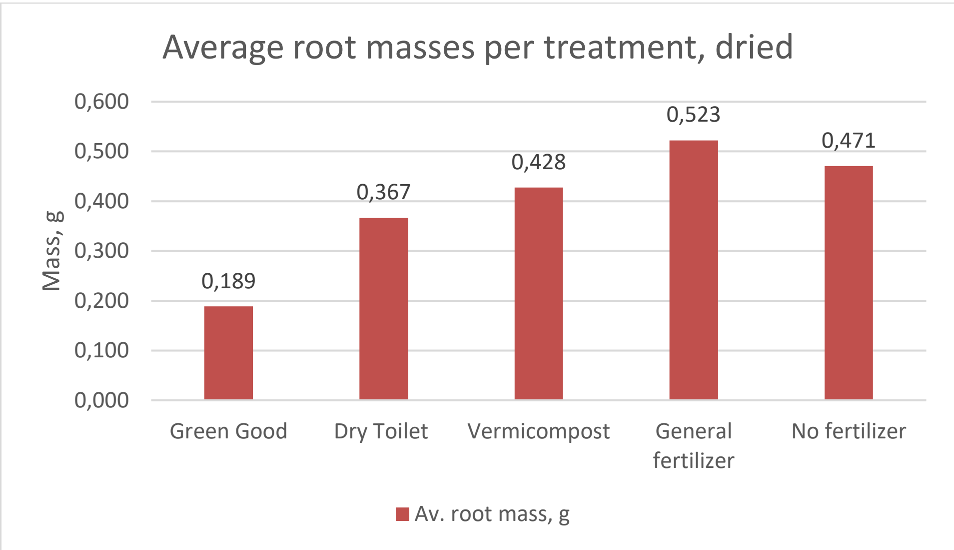

Figure 11. Average root masses per treatment, dried

Average dried leaf mass, root mass and total mass was calculated for one plant per each treatment and they are shown in Table 17. From the table, Dry Toilet 2 has the highest leaf mass and No fertilizer 1 has the highest root mass at 0,048 g. An average per treatment type was calculated for each variable and Figure 12 and 13. were created to represent said values. From Figure 12. Dry Toilet had greatest values. Green Good treatment had lower values than No fertilizers. From Figure 13. it is clear that No fertilizer had the heaviest roots dried.

Table 17. Average dried leaf mass, root mass and total mass of one plant per treatment.

	Leaf mass/ plant, g	Root mass/ plant, g	Total mass/ plant, g
Green Good 1	2,05	0,018	2,07
Green Good 2	2,31	0,013	2,33
Dry Toilet 1	5,18	0,028	5,21
Dry Toilet 2	5,91	0,033	5,94
Vermicompost 1	2,93	0,039	2,97
Vermicompost 2	3,15	0,032	3,18
General fertlizier 1	4,58	0,042	4,62
General fertilizer 2	3,46	0,045	3,50
No fertilizer 1	2,90	0,048	2,95
No fertilizer 2	1,55	0,046	1,59

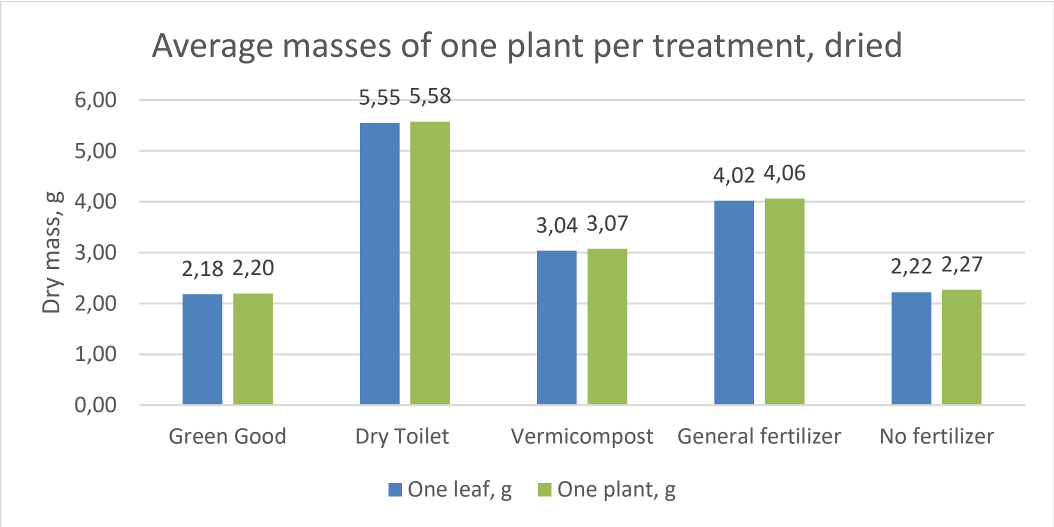

Figure 12. Average mass of one leaf, one root and one plant per treatment. Standard deviation added.

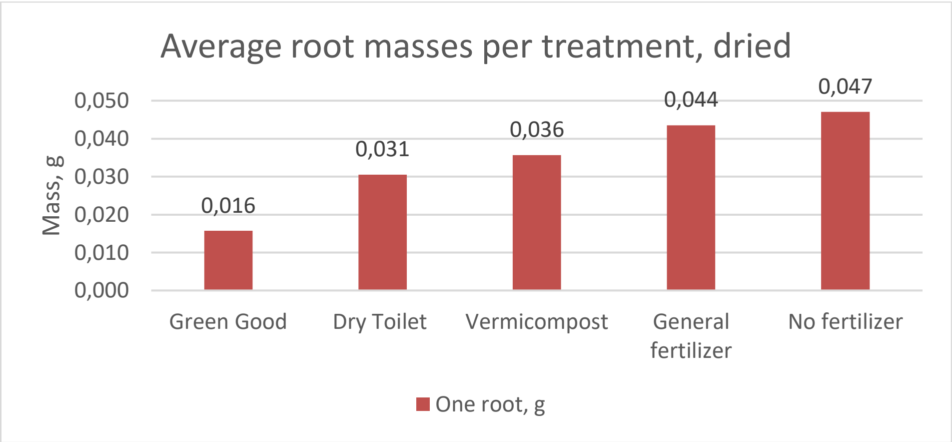

Figure 13. Average root masses for one plant, dried

3.3 Total Nitrogen using vario TOC after the growth experiment

Total Nitrogen using vario TOC select measured the nitrogen in mg/g. In order to compare how much nitrogen was left in the boxes versus how much they had in the beginning, the weight-volume ratio was measured. The obtained values from the vario TOC select were over calibration range for samples Vermi 1, Vermi 2 and General 1 in the first measurement but not in the second. The obtained values had some variation but it was seen that all samples still had nitrogen left in them. As vario TOC measures both nitrates and ammonium, it is difficult to say how much of the initial nitrogen was consumed by the silver beets. The second measurement gave more consistent results than the first. The obtained values can be seen in Table 18. TNb average is the average from the first and the second measurement. Figure 14. represents the obtained values as a graph. It can be seen that the first measurement TNb (1) resulted in high peaks for Vermicompost 1 and 2 and for General fertilizer 1. As the nitrogen testing before and after the experiment were done using different methods, the results cannot be fully compared.

Table 18. Total nitrogen levels from each treatment using varioTOC

Sample	TNb(1),%	TNb(2),%	TNb average, %	g/kg
GG1	0,15	0,12	0,14	1,37
GG2	0,13	0,08	0,10	1,04
Dry1	0,17	0,15	0,16	1,61
Dry2	0,15	0,13	0,14	1,44
Vermi1	0,26	0,11	0,19	1,87
Vermi2	0,57	0,15	0,36	3,57
General1	0,42	0,10	0,26	2,63
General2	0,18	0,15	0,16	1,63
No fertilizer1	0,15	0,10	0,12	1,22
No fertilizer2	0,12	0,15	0,14	1,35

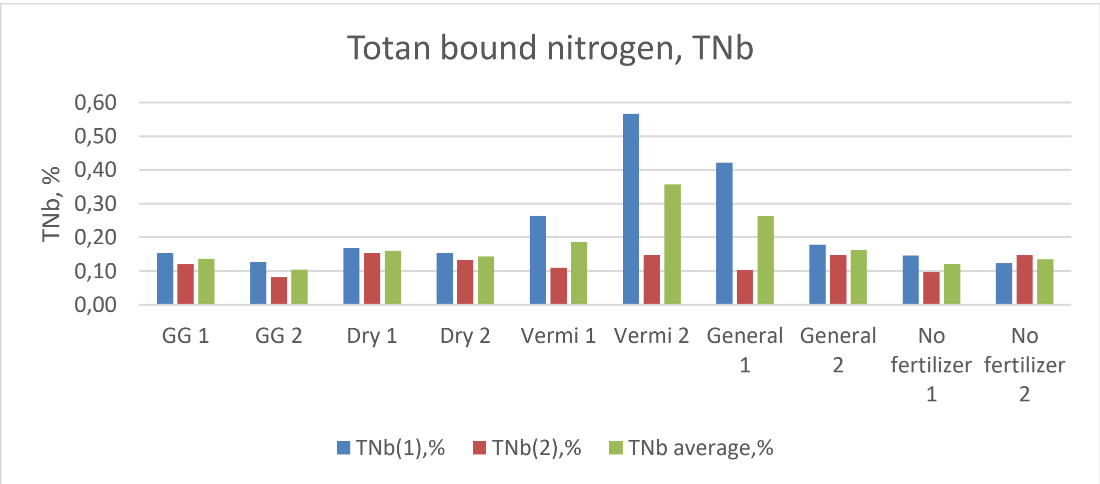

Figure 14. Total bound nitrogen results from varioTOC.

4 DISCUSSION

4.1 Growth experiment

From the whole experiment, it was clear that the plants growing closer to the window had a smaller leaf size than the ones further from the window. This was most likely due to the wide bar on the green house window which resulted in less light. The plants grew overall very nicely and the monitored temperatures stayed quite steady with no significant drops. The plants got a bit dry in the middle of the experiment during one weekend but no visible damage was caused.

From Table 9, it can be seen, that Dry Toilet 1 had the tallest leaves at 33,4 cm whereas the No fertilizer 1 had the shortest at 27,6 cm. From Table 9. it can also be noted that Vermicompost 1 had the same average leaf length as No fertilizer 2 at 28,4 cm. Figure 2. shows that Dry Toilet samples were taller on average than the rest. From Figure 2. some outliers for Dry Toilet can be seen, but they are lower in value. No fertilizer samples had less variation between the samples than General fertilizer. These results can also be seen in Picture 3. Dry Toilet 1 had the highest fresh weight (118,93 g) and both Dry Toilet samples were clearly heavier in total as any other treatment (Table 12.). On average, Dry Toilet treatment had the heaviest leaves per plant, whereas No fertilizer had the lightest (Figure 6.). From Table 15, the dried weights can be seen and Dry Toilet 2 had the heaviest plants. From Table 16. the average dried weights per plant can be seen and Dry toilet 2 had the heaviest leaves. Both fresh and dry weights are quite similar, the biggest difference being that Dry toilet 1 ended up lighter than Dry toilet 2 after drying.

Root lengths and weights differed quite much from the leaf lengths and weights. When finishing the experiment, No fertilizer treatment seemed to have very bushy roots and Vermicompost treatment had very strong roots. From Table 10. it can be seen that No fertilizer 2 had the tallest roots (13,0 cm) and on average, No fertilizer treatment had the tallest roots (11,2 cm). On average, General fertilizer treatment had the shortest roots at 10,1 cm. The average root lengths by treatment are represented in Figure 4. From the figure, it can be seen, that the General fertilizer root lengths have two outliers but they are close to No fertilizer values. All root lengths are quite close together. By mass, No fertilizer 1 had the heaviest average root mass per plant fresh at 0,295 g and dried at 0,048g.

As can be seen in Table 11. General Fertilizer 1 had the most leaves per plant on average at 8,6. From all treatments, Dry Toilet had the biggest number of leaves per plant at 8,3. No fertilizer treatment grew the fewest number of leaves per plant. Figure 5. shows that on average, the Dry Toilet samples had more leaves even though General fertilizer had more leaves in one replica. From the figure it can also be noted that No fertilizer, Green Good and Vermicompost are very close in number of leaves.

As Silver beet is grown as a vegetable, the leaf mass and size can be determined as the most important factor. Dry toilet treatment produced the biggest leaf-masses and the tallest plants. Bigger root size can indicate that the required nutrients are harder to obtain, but also that the plant can last longer. In this study, it can be assumed that longer and heavier roots indicate the difficulty of obtaining nutrients from the soil. From the results, No fertilizer treatment had the heaviest and the tallest roots. This indicates that for No fertilizer samples especially, it was hard to obtain the needed nutrients from the soil.

4.2 Different tests on the composts

4.3 Nitrogen

For total Kjeldahl nitrogen, Green Good samples contained the most. Peat that was used partly in the growing medium, had the second most nitrogen. Vermicompost had the least nitrogen from all the samples. As the composts were used as fertilizers and the required nitrogen amount was the same, by weight Vermicompost had to be added the most since it contained less nitrogen in % than the others. By volume, Dry toilet compost had the greatest amount as it is very light and it had the lowest bulk density.

For varioTOC total nitrogen TNb, Vermicompost samples had the highest amount of nitrogen with General fertilizer 1. Other samples were around the same but the lowest nitrogen amount was measured with Green Good 2. The results with varioTOC were quite inconsistent but some nitrogen was clearly still left in the soil. This was expected since the growing medium had some nitrogen in it as well. As the amount put in the varioTOC samples is around 100 mg, it seemed impossible to obtain samples that are homogenous enough to represent the whole treatment.

4.4 Other tests

The dry matter content w_{dm} was the highest in Dry Toilet samples, which means they had the least amount of water. Vermicompost had quite high w_{dm}, which means it contains quite much water. The dry matter content of the compost is usually dependent on the raw materials. Lower dry matter content makes the sample easier to handle since it is not as dusty as for example Green Good samples were.

Loss on ignition testing indicates that Green Good samples had the greatest organic matter content and Vermicompost had the lowest. Higher amount of organic matter in soil can cause decrease in soil bulk density and therefore be beneficial to crop growth (Celik, I. Ortas, I. Kilic. S. 2004). Having high organic matter means that when used as a fertilizer, more organic materials get back to nature. Organic matter usually decreases during composting (Haynes, R.J. Naidu, R. 1998).

Bulk density also indicates that Vermicompost might not be that good due to heavy weight and less nutrients. Vermicompost has the highest bulk density which means that it weighs the most. Dry Toilet has the lowest bulk density which means it is the lightest. With Vermicompost, there are less required nutrients in a heavier amount of substance where as Dry Toilet has more. High bulk density might indicate lower porosity which is not that beneficial for plant growth (Celik, I. Ortas, I. Kilic, S. 2004). As Dry Toilet has the lowest bulk density, when mixed with the growing medium, it decreases the entire bulk density, making the growing medium less dense and providing bigger pores for air and roots.

The compost materials were sent to an outside laboratory for other tests. The laboratory was KVVY and the results can be found in Appendix 1. The results indicate that the materials are within organic compost regulations according to decree 24/2011 by the Ministry of Acriculture and Forestry. The allowed amounts mentioned in the degree of can be found in Appendix 2. All measured amounts were lower than the limit values. The materials had no microbiological activity present.

5 CONCLUSION

It was clear that the Silver beet seedlings were not treated equally due to the sun direction and the bar on the greenhouse window. The bar occasionally casted a shadow on the seedlings which resulted in the smaller size of the seedlings closer to the window. The growing area per plant was also quite small which resulted in finalizing the experiment a bit earlier than planned. The proximity of the plants in the balcony boxes may have affected the roots as the growing space was smaller than it should. The recommendation for sowing distance is 50-80 cm depending on the cultivation and where they are grown (Wade, S. Silver beet growing. 2009.).

From the growing experiment, it can be noted that Dry Toilet samples had the best results. Dry Toilet had the heaviest leaf-mass, tallest leaves and the biggest number of leaves. Dry Toilet did not have as tall and heavy roots as No fertilizer samples, which indicates that Dry Toilet samples put more energy into growing its leaves, because it was easier for Dry Toilet samples to obtain the required nutrients from the soil. General fertilizer grew the second heaviest leaves and Vermicompost the third. No fertilizer samples had visibly the smallest leaves and the measurements confirm that.

When fertilizing, it was clear that Dry Toilet compost was very un-uniform and spreading it proved to be a bit of a challenge. The light weight of the Dry Toilet compost also made it quite hard to handle. Green Good -compost was quite sticky and very light. The odour of the Green Good -compost was unpleasant and it had poor solubility with water. Vermicompost and General fertilizer were both very nice to handle, but the growing experiment results suggest that they were not as good fertilizers as Dry Toilet -compost. The results indicate that high amount of nitrogen is not the only requirement for the material when used as a fertilizer. Green Good -compost contained the highest amount of nitrogen and highest organic matter count from all the compost materials and it still did not grow the biggest leaves. Dry Toilet -compost contained the second most nitrogen and organic matter and it grew the best. General fertilizer was the easiest to use and not much was required, but there was clear variation between the plants from the treatments.

It can be noted that using compost as a fertilizer is beneficial, and from the used samples, Dry Toilet -compost was the best. Using compost as a fertilizer recycles nutrients back to nature and they are easy to use. Dry Toilet -compost can be obtained from home or summer cottages for small-scale farming. Using other compost materials, such as vermicompost, also had a positive effect on the plant growth compared to No fertilizer samples.

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APPENDICES

Appendix 1. Analyses conducted at KVVY laboratory

Analysis	Unit	Green Good 1	Green Good 2	Dry Toilet 1	Dry Toilet 2	Vermicompost 1	Vermicompost 2
Arsenic	mg/kg DM	1,1	1,1	2,2	2	1,1	0,8
Cadmium	mg/kg DM	0,14	0,14	0,12	0,1	0,08	0,07
Cobalt	mg/kg DM	0,96	0,92	0,91	0,96	0,89	0,8
Lead	mg/kg DM	5,1	5,1	3,3	3,1	1,9	1,6
Selenium	mg/kg DM	0,54	0,48	0,35	0,29	0,19	0,16
Salmonella	/25g	Not Found	Not Found	Not Found	Not Found	Not Found	Not Found
Zinc	mg/kg DM	91	90	13	15	31	30
Calcium	g/kg DM	36	36	14	16	9,4	9
Copper	mg/kg DM	26	26	16	16	13	12
Iron	g/kg DM	1,7	1,6	5	5	3,8	3,2
Potassium	g/kg DM	2,8	2,5	1,1	1,3	4,2	3,2
Sodium	g/kg DM	5,5	5,4	0,24	0,33	0,52	0,44
Phosphorus	mg/kg DM	17 000	18 000	880	800	1600	1400
E.coli	pmy/g	<10	<10	<10	<10	<10	<10
Dry matter content	%	93,5	91,4	94,2	93,4	47,9	42,5
Total nitrogen	g/kg DM	42	42	13	12	16	10
Magnesium	g/kg DM	2,6	2,6	2,8	3,6	2,2	1,9

Appendix 2. Allowed substance amounts in organic fertilizers (Ministry of agriculture and forestry decree on Fertilizer Products 24/2011)

Sample	**Unit**	**Amount allowed**
Cadmium	mg/kg DM	1,5
Arsenic	mg/kg DM	25
Selenium	mg/kg DM	15
Salmonella	/25g	Not Found
*E. coli	pmy/g	<100

*(professional growth mediums, where the edible part of plant is in contact with the growth medium)