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Final thesis

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# THE FERTILIZATION VALUE OF HUMAN EXCRETA FOR CABBAGE AND POTATO GROWTH

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# ABSTRACT

Seeking for new ways to upgrade soil fertility and improve sanitary system will promote recycling of human waste. The aim of this study was to demonstrate the fertilization value of human excreta. A field experiment was conducted to evaluate the fertilizer value of human excreta with cabbages and potatoes, compared to mineral fertilizer. The study involved two trial plots with an area 22.4m x 4m for potato and 26.4m x 6m for cabbage each with five treatments: control, mineral fertilizer, human urine, human composted faeces and human urine + composted faeces in ratio 1:1. Influences of human excreta on soil nutrients and crop yields were studied. Total and soluble nitrogen, phosphorus and potassium and TOC were analysed from the soil before and after the application of fertilizers. Harvest determination was carried out by weighing the yield of test crops and calculating the average size per treatment. Application of human excreta increased cabbage yield. Clear increase in yield was seen from human urine treatment followed by composted faeces treatment. However, the yield of potato in the human excreta treated plots was small compared to mineral fertilizer. This is probably due to the characteristics of potato tuber towards nutrients uptake, especially N. The human excreta fertilizers affected more to the growth of stems instead of tubers. Excessive nitrogen in coincidence with tuber growth might have led to a reduced yield as there was sufficient nitrogen availability in the soil. Hence, the added fertilizers did not have an effect toward tuber yield. Human excreta increased the status of soil nutrients to an average level particularly with soluble phosphorus and potassium.

#### FOREWORD

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Tampere, May 2008

Jacqueline Mwakangale

# LIST OF ABBREVIATIONS

AAS	Atomic absorption spectrophotometer
HCl	Hydrochloric acid
HNO <sub>3</sub>	Nitric acid
$H_2SO_4$	Sulphuric acid
ISO	International Organization for Standardization
Κ	Potassium
KCl	Potassium chloride
Ν	Nitrogen
Р	Phosphorus
SnCl <sub>2</sub>	Tin Chloride
TOC	Total organic carbon
UHP	Ultra high purity

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# **1 INTRODUCTION**

In most parts of the world "drop and store" and "flush and forget" are two alternatives applied to tackle sanitation problems. "Flush and forget" has frequently been used after the change to modern sanitation. This form of wastewater management and sanitation system has based its perception on human excreta as revolting. Yet the design of technology is more on the basis that excreta are waste and only suitable for disposal. However, the linear flow in conventional sanitation is heavy financial and environmental burden especially to developing countries. Even to developed, the system is still not promising and the chances of become sustainable is low. Not only the high cost in operation and maintenance, but also the impact to the environment. Conventional sanitation over-exploit limited renewable water resource and cause pollution to soil and ground water. /19/

The quest to find options to improve soil fertility for sustainable crop production has resulted in recycling of waste material including human excreta. The driving forces behind the increase is due to an increased water scarcity, pollution of water resources, population growth in relation to an increased demand for food and a growing recognition of the resource value of human excreta. It is estimated that within next 50 years, more than 40% of the world population will live in countries facing water stress and the growing population is expected to occur in urban and periurban areas particularly in developing countries. /21, 28/

#### **1.1 SUSTAINABLE SANITATION**

Sustainable sanitation is an alternative approach in practice to circumvent the drawbacks of conventional sanitation. The paradigm in sustainable sanitation is based much on closure of nutrient flow cycles which considers human excreta as resource rather than a waste and need to be made available for re-use. /19, 28/

The concept is novel to people and majority of them even the legislation still disapprove, mainly due to the previous impact of pit latrines as it was not managed well. Difference in perception, opinions and attitudes of people hinders the progress while in a way, if we look closely to the whole idea and agenda the approach is a holistic and ethical toward ecological sustainable sanitation.

Human excreta can help to improve food production especially for subsistence farmers who do not have means of affording artificial fertilizers. The use of treated and source-separated faeces and urine has been suggested as suitable for urban agriculture. Wastewater is used already to a large extent in these applications. Treated excreta would potentially pose fewer risks in these types of applications. /28/

#### **1.2 COMPOSITION OF HUMAN EXCRETA**

Human excreta are accessible source of important plant nutrients such as phosphorus, nitrogen and potassium. According to study done in Sweden, human urine from urine-diverting toilet contains about 72% N, 48% P and 35% K and human faeces contains 8% N, 27% P and 17% K. /26/

Agricultural value of human excreta has been studied intensively in developed and developing countries with vegetables, cereals and ornaments. Human urine has showed vast increase in crop yields and greater attention been received among researchers. The nutrients in the urine are in ionic form and readily available to plants. Simply, human urine is sterile unless cross contamination happens with faeces. The pathogens can be eliminated from the urine when stored for long a period. In the tropics the survival of microorganisms is shorter because of high temperature. /21/

Conversely, human faeces contain pathogens, which are contagious to human health. However, these pathogens can be destroyed if the excrement is properly composted. Pathogens do not tend to survive under high temperature and absence of moisture, making it possible for fertilization. /14/

In comparison to urine, the total amount of nutrients excreted is lower in faeces because are incorporated into organic forms and bacteria. In addition, human faeces contains high fraction of carbon for organic matter. The content of organic matter in the faeces increases water holding and ion buffering capacities of soils, which of importance for improving soil structure and stimulate microbial activities. /14/

# 2. GROWING EXPERIMENT

In this thesis the nutrient content (total and soluble nitrogen, phosphorus potassium) in the soil, fertilizers and crop yields were studied to comprehend the fertilization values, its possible use and environmental risks of using separated human urine and composted human faeces in crop production.

The research study was carried out in cooperation with Tampereen ammattikorkeakoulu, University of Applied Sciences (TAMK) and University of Kuopio (UKU). The selected sample plants for the experimental study were Potato (Solanum tuberosum var. Nicola) and Cabbage (Brassica oleracea var. Castello F1). Both of the selected sample plants were late variety. Potato was chosen because it is a common food crop produced worldwide and usually cultivated in home gardens whereas Cabbage was selected due to its sensitivity toward environmental pollution and very demanding in nutrients quantity.

#### 2.1 EXPERIMENTAL SET-UP

The experimental study took place in Hatanpää region near Hatanpää regional Hospital about 3km from the city centre. The size area of the study site was 30m x 13m (L x W). Earlier, the area was inhabited by trees and shrubs and had never been used for agricultural activities. The existence of trees and shrubs fostered the growth of weeds; approximately two-third of the site area was occupied by weeds. Features of soil type were loamy mixed with peat in some parts of the site. Previously, the soil was mixed with peat to improve the growing medium and to reduce the impact of waterways.

The dimensional area set for growing potatoes was 22.4m by 4m. The area was compartmentalized into five plots based on five levels of treatments; urine treatment, mixed treatment (urine + composted faeces in 1:1), composted human faeces treatment, control treatment (no fertilization) and mineral fertilizer treatment which was used as a reference i.e. treatments had an equal area of 4m by 3.2m. To each of the treatment, the soil was divided into four parallel subplots (replicates). Each replicate had a dimensional area of 4m by 0.8m. A corridor of 1.6m was kept between each treatment to prevent contamination.

For cabbages, the area set for cultivation was 26.4m by 6m. The area was also compartmentalized into five plots based on five levels of treatments and each treatment was subdivided into four replicates of equal dimensions. The area of the treatments was 6m by 4m and of the replicates was 6m by 1m. A corridor of 1.6m was maintained between treatments to avoid contamination.

The two segments were separated by 2m corridor (Fig 1). The experiment had five treatments per test crop (cabbage and potato) which were replicated four times to ensure statistical validity. Numbers 1-4 were assigned to replicates of each treatment using marking sticks for easy presentation.

Human urine and composted faeces were taken from dry toilet in Västanfjärd, located in the province of Western Finland. The urine was from the cafeteria and the composted human faeces were from the private households. The excrement has been composted for at least two years before use and it was mixed well with saw-dust and litter to absorb the smell, making it dry and balancing phosphorus and potassium content.

Harrowing was done two times before setting the plots. This was done in order to lessen the amount of weeds and to level the soil so as to avoid the formation of depressions that will allow water to stagnate incase of rainfall and irrigation.

Weeding was done almost everyday before and after seeding to allow the nutrients from the fertilizers and soil to be taken by plants only.

Fencing of the site was done after leveling of the soil to prevent vandalism (i.e. uprooting of plants because the site was situated very close to people's working area). Around the edges of the fence, soil was raised into banks to avert hares from going through the site and eat cabbages.

The test crops were harvested on 13<sup>th</sup> August 2007 for potato and 3<sup>rd</sup> September 2007 for cabbage. Potatoes were harvested first because of the potato blight (*Phytophthora infestans*). Initially, monitored crops were gathered followed by the ones which were sent to UKU for microbe and taste analyses.



**Fig 1:** Layout of the experiment field used for growing potato and cabbage with five treatments in each case.

(\*\*\*Legend: RU= Human urine treatment, RM= Mixed treatment (composted faeces + human urine 1:1), RF=Composted human faeces treatment, RB= Control treatment and RA= Mineral fertilizer treatment i.e. the same meaning as for sample tags in potato growing section. NOTE: Symbol S was used to describe potato and R was for cabbage).

#### 2.2 SAMPLING

Sampling of the soil was done according to the Finnish standard SFS-EN 12579. The samples were taken in the beginning and at the end of the experiment. In the beginning of the experiment, incremental samples were taken from five selected sampling points (Fig 2). From each sampling point, the soil was taken from approximately 10-15cm depth from the surface. 3L of the soil samples were taken from each of the sampling point into polythene bags. Samples were air dried at room temperature for further analysis.



**Fig 2:** Sampling points where incremental samples were taken in the beginning of the experiment

Immediately after harvesting soil samples were obtained from a composite of five cores from within each treatment plot (Fig 3). About 3L of the soil samples from each treatment were taken, air-dried at room temperature and ground to 2mm prior to analysis.

Sampling of composted human faeces was done using the same standard as for soil. Approximately 1.5L composted faeces were taken put into polythene bag and tagged accordingly. For human urine, about 1.7L was collected from the storage container and transferred into 5L plastic gallon. Urine was stored in the fridge at a temperature of 5°C whereas the composted human faeces were put into black boxes air dried marked accordingly and placed in an ambient temperature to dry for later analyses.

Sample portions of urine and composted faeces were taken first before storage to determine total nitrogen prior to application for crop growing.

<b>CABBAGE GROWING SECTION</b>					
RU	RM	RF	RB	RA	
X X	X X	X X	X X	X X	
x	x	х	Х	X	
x x	X X	X X	X X	хх	
	MAIN CORRIDOR				
X X	X X	X X	X X	X X	
X	x	x	Х	x	
x x	X X	X X	X X	X X	
SU	SM	SB	SF	SA	
POTATO GROWING SECTION					

**Fig 3:** Sampling points of the soil samples from each treatment at the field at the end of the experiment

#### **2.3 FERTILIZERS**

The amount of fertilizers applied was determined according to the Finnish legislation on limit values of fertilizers in agriculture. The nitrogen content was used as a determining factor in calculations. For growing potatoes, the value used was 80kgN/ha and for cabbages 175kgN/ha.

Total nitrogen content in the human urine and composted human faeces was determined according to the Kjeldahl method. The amounts of total nitrogen in the composted human faeces and human urine are presented in Table 1.

Awakangale

The type of commercial fertilizer which was used as reference was Puutarhan Kevät. The amounts of nutrients are presented in Table 2.

**Table 1:** Total nitrogen content in the human urine and composted faeces in percentage

 by weight

Nutrient content	Concentration	
	(%)	
Composted faeces fertilizer		
Total Nitrogen (N)	1.006	
Human urine		
Total Nitrogen (N)	0.548	

**Table 2:** Nutrient concentration of commercial fertilizer in percentage by weight

Puutarhan Kevät/fertilizer	
	Concentration (%)
Nutrient content	
Total Nitrogen (N)	8
Ammonium Nitrogen (NH <sub>4</sub> N)	5.5
Nitrate Nitrogen (NO <sub>3</sub> N)	2.5
Phosphorus (P)	4
Phosphorus water soluble	3.4
Potassium (K)	14
Magnesium (Mg)	2
Sulphur (S)	8
Boron (B)	0.07
Copper (Cu)	0.05
Iron (Fe)	0.05
Manganese (Mn)	0.35
Molybdenum (Mo)	0.01
Zinc (Zn)	0.05

#### 2.3.1 CALCULATIONS ON THE AMOUNT OF FERTILIZERS

#### **Potatoes**

#### a). Amount of human urine for growing potato

Potato needs 80kgN/ha for growing

 $80 \text{kgN/ha} \approx 8 \text{g/m}^2$ 

Conc. of N in the urine = 5.5 g/l

Per  $m^2 = 8g/m^2 \div 5.5g/l = 1.5l/m^2$ 

 $\rightarrow$  1 m<sup>2</sup>, 1.5litres of urine is needed

Area of the treatment =  $12.8m^2$ 

Area of 1 replicate =  $3.2m^2$ ; therefore  $1.5l/m^2 \times 3.2m^2 = 4.8$  litres of urine per replicate

For the urine treatment 19.2litres of urine was applied.

# b). Amount of composted faeces for potato

Conc. of N in the composted faeces = 10g/kg

Per  $m^2 = 8g/m^2 \div 10g/kg = 0.8kg/m^2$ 

 $\rightarrow 1 \text{ m}^2$ , 0.8kg of composted faeces is needed

Area of the treatment =  $12.8m^2$ 

Area of 1 replicate =  $3.2m^2$ ; therefore  $0.8kg/m^2 \times 3.2m^2 = 2.56kg$  of compost per replicate

For the composted faeces treatment 10.24kg of compost was applied.

# c). Amount of composted faeces + urine in ratio 1:1

Potato need half of N from urine and compost, therefore 40kgN/ha each

 $40 kg N/ha \approx 4g/m^2$ 

Conc. of N in the urine = 5.5 g/l

Per  $m^2 = 4g/m^2 \div 5.5g/l = 0.72 l/m^2$ 

 $\rightarrow$  1 m<sup>2</sup>, 0.72 liters of urine is needed

Area of the treatment =  $12.8m^2$ 

Area of 1 replicate =  $3.2m^2$ ; therefore  $0.72 \text{ l/m}^2 \times 3.2m^2 = 2.32$  liters of urine per replicate

For the treatment 9.31 liters of urine was applied.

Conc. of N in the composted faeces = 10g/kg

Per  $m^2 = 4g/m^2 \div 10g/kg = 0.4kg/m^2$ 

 $\rightarrow 1 \text{ m}^2$ , 0.4kg of composted faeces is needed

Area of the treatment =  $12.8m^2$ 

Area of 1 replicate =  $3.2m^2$ ; therefore  $0.4kg/m^2 \times 3.2m^2 = 1.28kg$  of compost per replicate

For the treatment 5.12kg of compost was applied.

#### d). Amount of commercial fertilizer for potato

Conc. of N in the commercial fertilizer = 80g/kg

Per  $m^2 = 8g/m^2 \div 80g/kg = 0.1kg/m^2$ 

 $\rightarrow 1 \text{ m}^2$ , 0.1kg of composted faeces is needed

Area of the treatment =  $12.8m^2$ 

Area of 1 replicate =  $3.2m^2$ ; therefore  $0.1kg/m^2 \times 3.2m^2 = 3.2kg$  of commercial fertilizer per replicate

For the commercial fertilizer treatment 1.28kg of commercial fertilizer was applied

#### **Cabbages**

#### a). Amount of human urine for growing cabbage

Cabbage needs 175kgN/ha for growing

 $175 \text{kgN/ha} \approx 17.5 \text{g/m}^2$ 

Conc. of N in the urine = 5.5g/l

Per  $m^2 = 17.5 g/m^2 \div 5.5 g/l = 3.18 l/m^2$ 

 $\rightarrow$  1 m<sup>2</sup>, 3.18 litres of urine is needed

Area of the treatment =  $24m^2$ 

Area of 1 replicate =  $6m^2$ ; therefore  $3.18 l/m^2 \times 6m^2 = 19.08$  litres of urine per replicate For the urine treatment 76.32 litres of urine was applied.

#### b). Amount of composted faeces for cabbage

Conc. of N in the composted faeces = 10g/kg

Per  $m^2 = 17.5 g/m^2 \div 10 g/kg = 1.75 kg/m^2$ 

 $\rightarrow 1 \text{ m}^2$ , 1.75kg of composted faeces is needed

Area of the treatment =  $24m^2$ 

Area of 1 replicate =  $6m^2$ ; therefore  $1.75kg/m^2 \times 6m^2 = 10.5kg$  of compost per replicate For the composted faeces treatment 42kg of compost was applied.

#### c). Amount of composted faeces + urine in ratio 1:1

Cabbage need half of N from urine and compost, therefore 87.5kgN/ha each

87.5kgN/ha  $\approx 8.75$ g/m<sup>2</sup>

Conc. of N in the urine = 5.5g/l

Per  $m^2 = 8.75g/m^2 \div 5.5g/l = 1.59 l/m^2$ 

 $\rightarrow$  1 m<sup>2</sup>, 1.59 liters of urine is needed

Area of the treatment =  $24m^2$ 

Area of 1 replicate =  $6m^2$ ; therefore 1.59  $l/m^2 \times 6m^2 = 9.54$  liters of urine per replicate

For the treatment 9.54 liters of urine was applied.

\*\*Conc. of N in the composted faeces = 10g/kg

Per  $m^2 = 8.75 g/m^2 \div 10 g/kg = 0.875 kg/m^2$ 

 $\rightarrow 1 \text{ m}^2$ , 0.875kg of composted faeces is needed

Area of the treatment =  $24m^2$ 

Area of 1 replicate =  $6m^2$ ; therefore  $0.875kg/m^2 \times 6m^2 = 5.25kg$  of compost per replicate

For the treatment 21kg of compost was applied.

#### d). Amount of commercial fertilizer for potato

Conc. of N in the composted faeces = 80g/kg

Per  $m^2 = 17.5 g/m^2 \div 80 g/kg = 0.22 kg/m^2$ 

 $\rightarrow$  1 m<sup>2</sup>, 0.22kg of composted faeces is needed

Area of the treatment =  $24m^2$ 

Area of 1 replicate =  $6m^2$ ; therefore  $0.22kg/m^2 \times 6m^2 = 1.31kg$  of commercial fertilizer per replicate

For the commercial fertilizer treatment 5.25kg of commercial fertilizer was applied

The summarized amounts of applied fertilizers for cabbage and potato growing are presented in Table 3.

POTATO (Solanum tuberosum var. Nicola)					
		Amount	Amount		
	Type of	per	per		
Treatments	fertilizer	treatment	replicate	kg/ha	L/ha
Urine	Human				
	urine	18.62L	4.65L	-	15,000
Mixed	Urine +				
	composted	9.3L;	2.32L;		
	faeces	5.12kg	1.28kg	4,000	7,200
Compost	Composted				
	faeces	10.24kg	2.56kg	8,000	-
Control	No				
	fertilizer	-	-	-	-
Mineral	Mineral				
	fertilizer	1.28kg	0.32kg	1,000	-
CABBAGE (	Brassica olera	icea var. Caste	llo F1)		
		Amount	Amount		
	Type of	per	per		
Treatments	fertilizer	treatment	replicate	kg/ha	L/ha
Urine	Human				
	urine	76.36L	19.09L	-	31,800
Mixed	Urine +				
	composted	38.2L; 21kg	9.55L;	8,750	15,900
	faeces		5.25kg		
Compost	Composted				
	faeces	42kg	10.5kg	17,500	-
Control	No				
	fertilizer	-	-	-	-
Mineral	Mineral				
	fertilizer	5.25kg	1.31kg	2,200	-

**Table 3**: Amounts of fertilizers applied to potato and cabbage

Urine was diluted first with water in ratio 1:1 before being applied to vegetables in order to prevent the plants from burning. For potatoes, urine was added 3 times every 2 weeks after seeding whereas composted faeces and commercial fertilizer were applied per one time during planting.

For cabbages, fertilizers were applied 3times per 2 weeks since the amounts were too big and it would have been difficult for the plants to utilize the nutrients from fertilizers.

### 2.4 CULTIVATION PERIOD

Planting of potato seeds and cabbage seedlings was done early June; 1<sup>st</sup> and 2<sup>nd</sup> June 2007 for potato and 11<sup>th</sup> and 12<sup>th</sup> June 2007 for cabbage. Potato seeds were planted first to prevent them from growing since potatoes are tubers and can be affected easily depending on the environmental conditions. Cabbage seedlings were transplanted later on after potatoes.

Potatoes were seeded to four replicates in each of the treatment (Fig 4). Fertilizers were added first to each of the replicates followed by potato seeds.10 seeds per replicate were planted into banks covered well with the soil to prevent sunlight exposure. To each of the plants 40cm distance was kept and 20cm was left from the fence edge during planting.



Fig 4: The arrangement of potato plants in each of the treatments

23 (54)

Cabbage seedlings were planted to four replicates in each of the treatments. The calculated amounts of fertilizers were added to each point where seedlings were going to be planted. To each replicate 10seedlings were placed into the ground pressed against the soil in order for the roots to be attached well during growing. The distance between seedlings to seedling was 60cm and 30cm was left from the fence edge (Fig 5).



Fig 5: Placement of cabbage seedlings in each of the treatment

#### **2.5 MAINTEINANCE**

The site was taken care almost everyday. Much of the work done at the site was weeding since the main aim was to allow only potatoes and cabbages to utilize the nutrients from the soil and the fertilizers.

Monitoring of plants was done once a week. For potatoes, it was done twice after sprouting due to the weather conditions (heavy rains). Lengths of stems were measured using a meter ruler to check the rate of growth. Colour of the leaves was also estimated. The existence of pests and eggs on plants leaves were observed everyday however no pests were found during that period.

For cabbages, stem thickness, the diameter of the formed cabbage and diameter of whole plant (including outer leaves) were measured once a week. Vernier caliper was used to measure stem thickness and a meter rule for the size of the formed cabbage and the diameter of the whole plant. The colour of the plants was also assessed. Pests were checked every day after planting. Monitoring of cabbage and potato was done to three of the selected plants in each of the replicates to represent the rest.

However, in mid-June which was the dry period cabbage flies (*Delia spp*) appeared to the cabbage seedlings. Some of the seedlings were attacked severely especially those in control treatment with no fertilizer. Pesticide 4.5ml Maverick (at a concentration 1.5ml/L) was applied once for cabbage flies (*Delia spp*) control.

During that period, pests and eggs on the cabbages leaves were checked thoroughly to monitor the number of leaves damaged by pests.

Irrigation of plants was done in June as there was not so much rainfall. Cabbages were irrigated at least twice a week because they need plenty of water during their growing period. Potatoes were irrigated once a week depending on the soil moisture; not so much water was added to potatoes. This was done to prevent the growth of fungi to the potatoes underground.

# **3. SOIL AND FERTILIZERS ANALYSES**

#### 3.1 pH

The determination of soil pH was done according to the Finnish Standards SFS-EN 13037. Soil pH was determined in the beginning and at the end of the experiment. Distilled water of temperature 22°C and conductivity less than 0.2mS/cm was used for the extraction of solid samples.

Extraction was done in ratio of 1:5 (v/v) using 30ml of samples and 150ml of water in the beginning. The mixture solution was put into shaking machine for 1hour at a room temperature and later on pH of the samples was recorded from the settled suspension Table 4.

	Equivalent weight of	pH from sampling
Sample	<b>30ml (g)</b>	point
S1	22.21	7
S2	20.72	6.66
S3	23.9	6.65
S4	20.48	6.45
S5	19.08	6.92
Average		6.74

At the end of the experiment the pH of the soil was determined from soil samples of potato and cabbage crops. 60mL volume of soil was measured for the analysis; in which 12mL of soil per treatment were taken and mixed to get a combined sample. The values on pH of the soil at the end for both cabbage and potato growing section were 6.5 and 6.33 respectively.

For fertilizers, pH was determined using the same standard as for soil. 30ml volume of composted human faeces and human urine were taken for measurement. Human urine was measured directly since it is in liquid. The values on pH of the two fertilizers were 4.61 for composted faeces and 8.45 for human urine.

#### **3.2 DRY MATTER AND MOISTURE CONTENT**

The determination of dry matter and moisture content of the soil was done according to the Finnish Standards SFS-EN 13040. Determination was done from five incremental samples. The temperature used for drying was 103°C. The dry matter and moisture content values are shown in Table 5.

	Dry matter content	Moisture content
Sample	%	%
S1	80.78	19.22
S2	75.12	24.88
S3	81.44	18.56
S4	80.83	19.17
S5	79.61	20.39
Average	79.56	20.44

**Table 5:** Dry matter and moisture content of the soil

For the composted human faeces, the dry matter and the moisture content was found in the same way as for the soil. About 23g of the composted faeces was used for drying. Dry matter of the composted faeces was found to be 23.18% and moisture content 76.22%.

#### 3.3 ORGANIC MATTER CONTENT

The determination of organic matter in the soil was done according to the Finnish Standards SFS-EN 13039. Determination was done from five incremental samples. Dried soil samples which were used for dry matter determination were used to determine organic matter. The soil samples were placed into muffle furnace heated at temperature 450°C for 1hour. Values on organic matter are presented in Table 6.

Sample	Organic matter content %
S1	7.6
<u> </u>	12.45
S3	6.27
S4	7.49
85	9.39
Average	8.64

**Table 6**: Organic matter content in the soil

The same method was used in determining organic matter in the composted human faeces. The amount of organic matter in the composted faeces was 83.87%.

#### 3.4 DETERMINATION OF TEXTURE OF THE SOIL

The texture of the soil was determined by feel method taught in Soil and Geomorphology course by Eeva-Liisa Viskari. About 25g of the soil sample was used for this method. The amount of soil sample was placed into the palm of a hand; a little amount of water was added to the sample and kneaded to break the lumps. The soil remained in a ball shape after being squeezed. The ball of soil was then placed between thumb and forefinger rubbed in an upward motion to form a ribbon of uniform thickness and width. However, the soil made a weak ribbon less than 2.5cm long before breaking.

A pinch of soil sample was put again into the palm of a hand and wetted. Rubbing was done with forefinger and the soil did not feel very gritty nor smooth, which gave the answer of neither grittiness nor smoothness predominates. This way, it was clarified that the texture of the soil was loam. /27/

#### 3.5 BULK DENSITY

Bulk density was determined according to the instructions from Radojevic & Bashkin (1999). The determination was done from dried soil samples, fresh soil samples and fresh composted human faeces.

Measuring cylinder of 1L was used for the determination of bulk density. The measuring cylinder was weighed and then filled with dried soil samples to the top without being compacted. Full cylinder with soil sample was weighed and values were recorded. The procedure was done two times to see any variations in the results. Average values were used to calculate the bulk density.

Un-compacted bulk density of fresh soil and composted human faeces was done in the same way as for soil. The results of bulk density are shown in Table 7.

Soil	
Condition of the soil	Bulk density (g/L)
dry soil	968
fresh soil	895
Fertilizer	
Composted faeces	378

**Table 7:** Bulk density of the soil and composted human faeces

# 4. NUTRIENT ANALYSES OF SOIL AND FERTILIZERS

#### 4.1 TOTAL NITROGEN

Total organic nitrogen in the soil and fertilizers was analysed according to Kjeldahl using Büchi training material. From the soil, total nitrogen was determined in the beginning and at the end of the experiment. Soil and composted human faeces samples were weighed to 1.000-1.030g with analytical balance Precisa XT 220A, TEOPAL. For human urine 1ml was taken for the analysis

In the beginning of the experiment, the analysis was done from five replicates of soil samples, three replicates of composted human faeces and six from human urine where as at the end of the experiment, total nitrogen was analysed from soil samples of five treatments of potato and cabbage crops. From each treatment, three replicates of samples were made for the analysis. Blanks were also prepared. Kjeldahl tablets,  $K_2SO_4$  were used as catalyst two tablets per sample. 20ml of concentrated  $H_2SO_4$  *pro analysis* was added to the samples for the hydrolysis of organic bound nitrogen. 0.005M of  $H_2SO_4$  was used for titration of samples in the beginning of the experiment and 0.25M of  $H_2SO_4$  was used titrate samples at the end.

#### 4.2 SOLUBLE NITROGEN

Soluble nitrogen was analysed referring to Kjeldahl method. The analysis was done from soil in the beginning and at the end of the experiment and from the composted human faeces. Soluble nitrogen was not analysed from the human urine because it was assumed to be 100% soluble due to its liquid phase.

Dried soil samples of mass 10g were weighed and put into Erlenmeyer flasks of 300mL. Distilled water UHP of 100mL was added for the extraction of soluble nitrogen out of the solid sample i.e. extraction was done in ratio 1:10 v/v. The samples were put to shaking machine at a speed 180rpm for 8hours in a room temperature. After that, the samples were allowed to settle for a while and then filtration was done with Büchner funnels and Schleicher & Schuell 589<sup>3</sup> filter papers of diameter 70mm. From each sample 20mL of the extracted filtrate solution were taken for the analysis.

Filtrate sample solutions (20mL) were put into digestion tubes where 1 tablet of  $K_2SO_4$  was added as a catalyst followed by 5mL of concentrated  $H_2 SO_4$  pro analysis. Büchi Scrubber B-414 was put into operation and then samples were preheated first to 250°C for 30mins then 370°C for 50mins (Fig 6). Samples were left to be digested for 1 hour at 370°C.



Fig 6: Büchi K-437 Wet Digestion Apparatus and Büchi Scrubber B-414 in operation

After the digestion samples were allowed to cool down to room temperature then 5mL of distilled water UHP was added. Erlenmeyer flasks contained 20ml of 2% boric acid and 2 drops of Sher indicator were prepared to collect distillate sample from the distillation unit (Fig 7).

Digestion tubes were placed into the sample tube holder in Buchi distillation unit K-314 one by one and the Erlenmeyer flasks were placed to the receiver plate to collect the distillate. 20ml of 32% NaOH was used for the distillation and the samples were distilled for 4 minutes. Samples were then titrated with Metrohm 806 Exchange Unit until equivalent point was reached where the colour of the samples turned to greybrown. 0.05M of  $H_2SO_4$  was used for titration.



Fig 7: Büchi distillation unit K-314

# 4.3 TOTAL PHOSPHORUS

The total phosphorus was determined with two procedures. First, wet digestion of the samples was done according to the Finnish Standards SFS-EN 13650 and the analysis was done using spectrophotometer and molybdenum blue procedure. The principle of molybdenum blue procedure is that, orthophosphate anions form a blue-coloured ammonium phosphor molybdate complex and the intensity of the colour is compared with phosphorus concentration of the solution as long as the pH and molybdate ions concentration remained unchanged. Acidic acetate solution was used for the extraction of phosphorus. The latter procedure was done according to the Finnish National Board of Education for Spectroscopic analysis of soluble phosphorus from soil.

Total phosphorus was analysed from composted human faeces and human urine fertilizers. From the soil phosphorus was done in the beginning and at the end of the experiment. 3.000-3.008g of soil and composted faeces samples was measured for the analysis. For urine, 25mL was used. 1ml of water was added and then 21ml of concentrated HCl *pro analysis* followed by 7ml of concentrated HNO<sub>3</sub> *pro analysis*. The digestion was done using Büchi K-437 Wet Digestion Apparatus for Kjeldahl nitrogen determination.

After the digestion, the contents from the reaction vessels were filtered with filter paper and then transferred into 100ml volumetric flasks filled to the mark with distilled water UHP. The solutions were left to stand for insoluble particles to settle and then total phosphorus was analyzed with acidic acetate extraction solution using molybdate blue procedure.

The acidic acetate extraction solution is an ammonium acetate solution that contains of 0.5M acetic acid and 0.5M ammonium acetate in pH 4.65. Soil sample solutions from the digestion were diluted in a ratio of 1:20 and from fertilizers 1:50 with the acidic ammonium acetate extraction solution into 100ml volumetric flasks. Two replicates were made from each sample solutions. 10ml of each sample solution was pipetted and transferred into 200ml Erlenmeyer flasks. To each 10ml of deionised water, 10ml of 1M  $H_2SO_4$  and 20ml of 0.8% molybdate was added correspondingly. The solutions were mixed gently; 5ml of diluted SnCl<sub>2</sub> was added and the blue colour developed.

The samples were analysed with UV-Spectrophotometer. Calibration solutions were made for spectrophotometer analysis from Phosphorus stock solution that contains 100mg/L of phosphorus. Intermediate dilution of 10mg/L (100ml volume) was made. From 10mg/L phosphorus solution the calibration solutions of 0.5mg/L, 1.0mg/L, 1.5mg/L and 2.0mg/L were made to 100mL volumetric flasks.

The concentration of phosphorus was analysed in an order starting with blank sample which contained only acidic acetate solution, calibration solutions from the smallest to the largest concentration and the samples.

#### 4.4 SOLUBLE PHOSPHORUS

Soluble phosphorus was analysed according to the Finnish National Board of Education for Spectroscopic analysis of soluble phosphorus from soil instructions. The analysis was done from soil in the beginning and at the end of the experiment and from the composted human faeces. Soluble phosphorus in the human urine was assumed to be 100% soluble due to its liquid phase therefore no analysis was done.

Soluble phosphorus was extracted by shaking the samples with acidic acetate solution and then analysed using spectrophotometer and molybdenum blue procedure. The acidic acetate solution contained 0.5M acetic acid and 0.5M ammonium acetate in pH 4.65.

Of the soil samples taken in the beginning of the experiment, the analysis was done from five samples each with replicate. At the end of the experiment the analysis was done from soil samples of five treatments of potato and cabbage crops. Soil samples were measured to 25mL using beakers. Each beaker was knocked three times against the table to remove the air after filling. The samples were transferred into 500mL bottles where acidic acetate solution was added and the bottles were secured with caps. The samples were allowed to be shaken for 1hour with a shaking machine.

After shaking, the samples were allowed to settle for a while before being filtered. The sample solutions were filtered using vacuum filtration with Büchner funnels and Schleicher & Schuell filter papers. Filter papers were moistened first with acidic acetate solution and then samples were poured through filter.

Filtrates were put into 250mL volumetric flasks and acidic acetate solution was added to the mark. From each sample, 10ml was pipetted and transferred into 200ml Erlenmeyer flasks. 10ml of deionised water, 10ml of 1M  $H_2SO_4$  and 20ml of 0.8% molybdate were added respectively. The solutions were mixed gently; 5ml of diluted SnCl<sub>2</sub> was added and the blue colour developed.

The samples were analysed with UV-Spectrophotometer. Calibration solutions were made for spectrophotometer analysis from Phosphorus stock solution that contains 100mg/L of phosphorus.

The stock solution was diluted to 10mg/L (100ml volume) and from 10mg/L phosphorus solution the calibration solutions of 0.5mg/L, 1.0mg/L, 1.5mg/L and 2.0mg/L were made to 100mL volumetric flasks.

The concentration of soluble phosphorus was analysed in an order starting with blank sample which contained only acidic acetate solution, calibration solutions from the smallest to the largest concentration and the samples.

#### 4.5 TOTAL POTASSIUM

The total potassium was analysed with two procedures. First, wet digestion of the samples was done according to the European Standards EN-13650 and the analysis was done using flame atomic absorption spectrophotometer according to International Standards ISO 11047. Total potassium was determined from the soil and fertilizers; from the soil it was done in the beginning and at the end of the experiment.

The digestion procedures of the samples were the same as in the determination of total phosphorus. The extracted samples from the digestion were diluted and then analysed with flame atomic absorption spectrophotometer (AAS). First, the samples were diluted in ratio 1:200 and second 1:5.

Calibration solutions were made for AAS analysis from KCl stock solution that contains 1000mg/L K<sup>+</sup>. Intermediate dilutions of 100mg/L (500ml volume) and 10mg/L (100ml volume) were made. From 10mg/L K<sup>+</sup> solution the calibration solutions of 0.5mg/L, 1.0mg/L, 1.5mg/L and 2.0mg/L were made to 100mL volumetric flasks.

The concentration of potassium was analysed starting with blank sample which was distilled water UHP, calibration solutions from the smallest to the largest concentration and the samples.

#### 4.6 SOLUBLE POTASSIUM

The soluble potassium in the soil was determined with two procedures. First, extraction of the samples was done according to the Finnish Standards SFS-EN 13652 and the analysis was done using flame atomic absorption spectrophotometer according to International Standards ISO 11047. The analysis was done from soil in the beginning and at the end of the experiment and from composted human faeces.

Samples were measured to a volume of 60mL by beakers and then transferred into 500mL Erlenmeyer flasks. Distilled water UHP; 300mL by volume was added for the extraction. Erlenmeyer flasks were covered with parafilm and the samples were shaken for 1hour with a shaking machine.

After that, the samples were filtered using vacuum filtration with Büchner funnels and Schleicher & Schuell filter papers. The filtration was of samples was done two times due to many suspended particles. White ribbon filter paper was used first followed by blue ribbon (ashless) of 70mm diameter during filtration. After that, the samples were centrifuged and transferred into 100mL volumetric flasks for AAS analysis.

Calibration solutions were made for AAS analysis from KCl stock solution that contains 1000mg/L K<sup>+</sup>. Intermediate dilutions of 100mg/L (500ml volume) and 10mg/L (100ml volume) were made. From 10mg/L K<sup>+</sup> solution the calibration solutions of 0.5mg/L, 1.0mg/L, 1.5mg/L and 2.0mg/L were made to 100mL volumetric flasks.

The concentration of potassium was analysed starting with blank sample which was distilled water UHP, calibration solutions from the smallest to the largest concentration and the samples.

# **5. ANALYSIS METHODS FOR CABBAGE AND POTATO**

#### 5.1 SAMPLING

Sampling and pre-treatment was done by following the principles of Radojevic & Bashkin (1999). Potatoes were sampled first because of the potato blight which appeared after the heavy rains. During that time, potatoes were already developed and were big in size ready to be harvested.

Sampling of potatoes was done from monitored plants first. To each of the replicates three potato plants were chosen to represent the rest. Potatoes were taken from the ground brushed on the surfaces to remove the soil by a smooth brush and packed loosely in paper bags. These monitored potatoes were separated from the rest since were used for heavy metals analysis.

The rest of the potatoes were packed into paper bags marked according to the treatments for weight analysis and counting the number of potatoes per treatments produced.

Cabbages were harvested and sampled two weeks later. Monitored cabbages were sampled first followed by the rest of the cabbages. 60 of monitored cabbages from five treatments were separated from the rest for heavy metals analysis. The rest of the cabbages packed into marked polythene bags for weight analysis. During sampling of the cabbages polythene gloves were used to avoid any source of interference.

#### **5.2 DETERMINATION OF MOISTURE**

The determination of moisture content for potato and cabbage was done according to the Finnish Standards SFS-EN 13040 for soil improvers and growing media. Determination was done from five treatments.

For potato, monitored potatoes from replicates of one treatment were mixed to get the combined sample from every treatment. Potatoes were thinly sliced transversely and weighed to mass of 100g. The potato samples were put to dry in an oven for 16 hours at temperature 55°C. The moisture content and dry matter from potato are presented in Table 8.

	Dry matter content	Moisture content
Sample treatment	<b>%</b>	%
Human Urine	18.57	81.43
Composted faeces+urine		
(1:1)	17.64	82.36
Composted human faeces	17.43	82.57
Control with no fertilizer	18.5	81.5
Commercial fertilizer	17.84	82.16

**Table 8:** Moisture content from the potatoes per treatment

Moisture content from the cabbages was done in the same way as for potatoes. Foliage leaves of the cabbages were peeled and weighed to a mass of 100g and then put to dry for 16 hours at 55°C. The moisture content and dry matter from cabbage are presented in Table 9.

	Dry matter content	Moisture content
Sample treatment	%	%
Human Urine	8.97	91.03
Composted faeces+urine		
(1:1)	8.93	91.07
Composted human faeces	8.63	91.37
Control with no fertilizer	8.97	91.03
Commercial fertilizer	9.39	90.61

**Table 9:** Moisture content from the cabbages per treatment

# 6. RESULTS

### 6.1 GROWTH MONITORING

Potato and cabbage growths were assessed in terms of plants heights for both and stem thickness for cabbage. A summary of the growth monitoring measurements in (Fig 8), showed that potatoes fertilized with human urine had the tallest plants followed by control treatment with no fertilizer and human urine + composted faeces treatment. Potato plants in composted faeces treatment and mineral fertilizer had the least growth.



Fig 8: Potato plants growth analysis based on height from five treatments

For cabbages, the growth was better off in human urine treated plots followed by human urine + composted faeces treatment and with composted faeces only. The plant size and stem thickness augmented with weeks. Growth monitoring graphs on plant size and stem thickness are presented in Fig 9 and Fig 10 respectively.



Fig 9: Cabbage growth analysis based on height from five treatments



Fig 10: Cabbage growth analysis based on stem thickness from five treatments

#### 6.2 POTATO SIZE AND YIELD

Yields of potatoes were determined in terms of the average size per treatment in order to compare which of the treatment had the best crop size and yields. Large amount of yields were surprisingly found from control treatment with no fertilizer. Potatoes grown were big and had variety of shapes; oblong and round (Fig 11).



**Fig 11:** Average mass of potato yields (g) from five treatments ( $\pm$  SD)

Potatoes from mineral fertilization treatment were the second largest in terms of potato size followed by human urine + composted faeces treated plots. Many of the potatoes obtained had cracks on the surface which was suspected to be as a result of water, nutrients and carbohydrates accumulation (Fig 12). Composted faeces treatment had small sizes of potato however human urine treatment had the smallest of all.

In terms of yield per treatment, a significant increase was in control treatment followed by compost treated plots and mineral fertilization treatment. Urine treatment ranked the fourth and urine + compost treatment was the last having the lowest yield of potatoes.



Fig 12: Potatoes fertilized with composted faeces

The small yields of potatoes in human urine only and composted faeces treatment were most likely due to slow release of nutrients when plants demand were high. At the same time the amount of soil nutrients particularly nitrogen was high due to the present of peat in the soil. Excessive nitrogen in coincidence with tuber growth might have led to a reduced yield. Therefore, the added fertilizers did not have an effect toward tuber yield.

In addition, the appearance of potato blight (*Phytophthora infestans*) in early August after heavy rains in July might have influenced the results. It was easy for the disease to spread through plants leaves because many of the branches and leaves were confined thus it was difficult for the passage of air through the plants.

Too much moisture had encouraged the spread of potato blight. The disease managed also to affect the underground potatoes. Potatoes fertilized with composted faeces were attacked more with the disease and the number was big compared to other treatments Table 10.

Treatment	Number of potatoes with Potato blight
Human urine	4
Composted faeces+urine (1:1)	5
Composted faeces	11
No fertilization	10
Mineral fertilizer	1

**Table 10:** Number of potatoes affected with Potato blight in each of the treatments

#### 6.3 CABBAGE SIZE AND YIELD

Increased cabbage yield was significant with human urine treated plots and composted human faeces treatment only (Fig 13). Cabbages were very huge in terms of size and fully formed in shape. Cabbages fertilized with human urine + composted faeces were the second largest followed by mineral fertilization treatment. Control treatment gave the least amount yields.



Fig 13: Average mass of cabbage yields (kg) from five treatments (± SD)

The growth of cabbages in the control treatment with no fertilizer was very weak and the sizes of the formed cabbages were small. Many of the foliage leaves were attacked by cabbage flies (*Delia spp*) therefore it was easy to assume that the rate of photosynthesis was low. Only one of the seedlings died in the control treatment during the cultivation time.

In the mineral fertilization treatment, one of the replicates had the weakest growth of cabbages. About two-thirds of the cabbages developed were small and foliage leaves had violet colour (Fig 14). It was suspected that the appearance of the colour was due to deprive of oxygen. The soil was uneven around that area and the occurrence of depressions held water during heavy rain in July. Hence, the pool of water on the cabbages caused the plants to suffocate.



Fig 14: Cabbages with violet colour in mineral fertilizer treatment

#### 6.4 MEASUREMENTS

Precipitation was monitored daily. The amount of rainfall was measured using a rain meter cylinder which was kept at the site. Values on the rainfall were recorded for three months during growing period. July was the only month with the heaviest rainfall record. Precipitation was above the seasonal mean throughout the country. June and August had lower values below the seasonal mean. The results of rainfall obtained during growing period where then compared to monthly hydrological report in 2007 (Table 11). /6/

Month	Rainfall at the site (mm/m <sup>2</sup> )	Precipitation range 2007 (mm/m <sup>2</sup> )
June	79	30-80
July	116.5	80-180
August	27	40-120

**Table 11:** Amount of rainfall recorded during growing period compared with the precipitation values throughout Finland in 2007

#### 6.5 TOTAL AND SOLUBLE NITROGEN IN THE SOIL

The amount of total nitrogen increased in the soil after harvesting especially in cabbage soil samples. Total nitrogen of the five treatments in cabbage soil samples exceeded the initial amount compared with the soil samples from potato. The largest difference was seen from human urine treatment followed by control and mineral fertilizer treated plots. For potato, the amounts were low at the end except in control and mineral fertilizer treated mineralizer treatments. The lower in values shows that total nitrogen was able to be mineralized and absorbed by potatoes. The high values of total nitrogen in cabbage soil samples could possibly be from the added amount fertilizers as were big compared to potato. The results of total nitrogen are shown Fig 15.



**Fig 15:** Total nitrogen in cabbage and potato soils of the five treatments compared with the mean values in the beginning and at the end of the experiment.

The amounts of soluble nitrogen in both potato and cabbage soil samples were low at the end if to compare with the amount in the beginning of the experiment. In the cabbage soils soluble nitrogen were lower than in the potato (Fig 16).



**Fig 16:** Soluble nitrogen in cabbage and potato soils of the five treatments compared with the mean values in the beginning and at the end of the experiment.

#### 6.6 TOTAL AND SOLUBLE PHOSPHORUS IN THE SOIL

The amount of total phosphorus in the beginning was high possibly due to the presence of iron compounds in the soil. In general the concentration of phosphorus in soil is 100-3,000 P mg/kg and from this study the concentration of soil phosphorus was 608mg/kg in between the specified range. Compared to other macronutrients, soil phosphorus exists in low amount making it a critical nutrient limiting plant growth. /24/

In comparing the results in the beginning and at the end the amount of total phosphorus in the soil has decreased by 36%. The net loss from the soil is probably from the harvested crops. The largest differences between in the beginning and at the end were in human urine treatments for both of the test crops. The results of total phosphorus are shown in Fig 17.



**Fig 17:** Total phosphorus in cabbage and potato soils of the five treatments compared with the mean values in the beginning and at the end of the experiment.

Soluble phosphorus increased to a certain amount at the end in both potato and cabbage soil samples. The amount was high in cabbage soil sample of composted feaces treatment and for potato, the amounts were lower except for control treatment (Fig 18).



**Fig 18:** Soluble phosphorus in cabbage and potato soils of the five treatments compared with mean values in the beginning and at the end of the experiment.

#### 6.7 TOTAL AND SOLUBLE POTASSIUM IN THE SOIL

The amounts of potassium fixed in the soil were high in the beginning this could be due to the nature of the soil colloids to contain clay. Clay soil is known to its ability to fix potassium readily and in large quantities. /3/

Total potassium was found in high amount in cabbage samples than in potato. The values were high with human urine + composted faeces treatment followed by urine treatment. On the average comparing the amount in the beginning and at the end of the experiment, the amounts have decreased by 14% which shows that had been absorbed by the plants during growing time. The results are shown in Fig 19.



**Fig 19**: Total potassium in cabbage and potato soils of the five treatments compared with the mean values in the beginning and at the end of the experiment.

This was the same for soluble potassium as the values were high in cabbage soil samples compared to those of potatoes except for mineral fertilizer treatment and control treatment. The biggest variance was with human urine treatment for cabbage and mineral fertilizer treatment for potato (Fig 20).



**Fig 20:** Soluble potassium in cabbage and potato soils of the five treatments compared with the mean values in the beginning and at the end of the experiment.

#### 6.8 NUTRIENTS IN THE HUMAN URINE AND COMPOSTED FAECES

The composition of nutrients between the two human fertilizers is presented in Table 12. The amounts of nutrients were found in large amount from human composted faeces than in human urine. Total nitrogen was twice, phosphorus was three thousands times and potassium was four hundred times in the human composted faeces compared to human urine. Human urine was taken from a cafeteria and it is possible for the concentration of nutrients to be low because of the physical metabolism of the human body. In the morning, the urine is more concentrated while during day time is more diluted because of the drinking. The amount of TOC in the composted faeces was high including the C: N ratio.

	Human urine	Human composted faeces
Total N %	0,55	1,01
Soluble N %		1,43
Total P (mg/kg)	1,3	3619
Soluble P (mg/kg)		3170
Total K (mg/kg)	85,55	36024
Soluble K (mg/kg)		6601
TOC %		36,6
C: N		36,2

 Table 12: Concentration of nutrients in the human urine and composted faeces

#### 6.9 TOTAL ORGANIC CARBON IN THE SOIL

Neither of the human fertilizers increased the TOC of the soil. The increased values shown in the human urine and mineral fertilizers treatments are possibly from the existence of peat (Fig 21). Earlier the soil was mixed with peat to improve the organic carbon content of the soil. In general if to compare the average values of TOC before and after harvesting of the plants, there was small decrease at the end which means organic carbon have been used by plants.



Fig 21: Total organic carbon in cabbage and potato soils.

# 7. DISCUSSION

In this study, the influence of human excreta on cabbage and potato growth, size yield including soil nutrients NPK were studied and compared to mineral fertilizers. The rate applications of fertilizers were governed by the amount of nitrogen that is defined in Finnish agricultural legislation. The amount of nitrogen needed by potato is 80kgN/ha and cabbage 175kgN/ha.

Application of human excreta as a fertilizer has showed a significant increase in terms of plant growth. Generally, plants fertilized with human urine had the best growth compared to mineral fertilization treatment. Human urine + composted faeces and composted faeces treatments followed after human urine treatment.

Nutrients in the urine are in ionic forms and readily available to plants. Owing to easy availability has led to an improved growth for both cabbage and potato. Conversely this is different for composted faeces as many of the nutrients are bound to organic matter and slowly released. The ratio of C: N was high which could have a considerable effect on the movement of mineral nitrogen in the soil. Usually, C: N ratio of the compost determines the balance between mineralization and immobilization. /4/

Of the crop size yields best results were on cabbage fertilized with human excreta. A significant increase was in human urine treatment followed by composted faeces and urine + composted faeces treatments. Yields from mineral fertilizer were low. The increased size yield of cabbages in human excreta treated plots is related to nutrients NPK availability and uptake relative to mineral fertilizer. In addition fertilizers were applied in parts (three times) because the amounts were huge. This has made the nutrients to be released and taken easily by cabbages.

However, for potato it was different as the size yields were small in human excreta treated plots relative to mineral fertilizer. This could be due to the excessive nitrogen in the soil and fertilizers. Potatoes respond to an increase in available N by maximizing tuber growth and maintaining the growth throughout the growing season.

Yet, too much available N can have negative effects on tuber yield and quality. Excess N at or before tuberization can reduce yield and specific gravity of indeterminate varieties. /1, 20/

In this case, the amount of determined nitrogen in the soil was high enough before the start of the experiment because of the presence of peat. Hence the added fertilizers did not have an effect toward tuber yield as a result of limiting factors.

The effect of fertilizers to the soil pH was not studied in deep from each of the treatments therefore it is difficult to know which of the fertilizers had the largest impact. In general, the soil pH at the end of the experiment decreased to a certain level if to compare with the results in the beginning. The decrease in soil pH could probably be attributed by accumulation of organic matter or oxidation of nitrogen during nitrification. /3/

Use of compost and urine increased the soil nutrient content. Soil phosphorus was high in the cabbage soils than in potato particularly in the composted faeces treatment. The availability of phosphorus in the composted faeces fertilizer was high therefore it is possible the amount of phosphorus was added to the soil. At the same time the calculated amounts of fertilizers for cabbages were greater than for potato because cabbage is more demanding for nutrients especially N. However, total phosphorus were much lower in the end than in the beginning for both cabbage and potato soils.

In general available potassium was increased in cabbage soils with applied human urine. The rise in the levels of potassium might be due to the clay content in the loam soil which may have absorbed K during the growing period. There were no increases of soil potassium in potato soils with human excreta fertilizer except in the mineral fertilization treatment where the increase could be due to easy solubility and utilization by potato. For nitrogen, the amounts were lower in the end than in the beginning for both cabbage and potato soils which means that nitrogen has been used by plants. Soluble nitrogen was much lower in the cabbage soils than in the potato because cabbage needs large amount of nitrogen for growing. In the human excreta treated plots, the levels of nitrogen were lower than in the control and mineral fertilization treatments indicating that nitrogen has been intensively used.

#### 8. CONCLUSION

The outcome of this study have confirmed results reported by other researchers that human excreta is an effective as mineral fertilizers as a source of nutrients; nitrogen, phosphorus and potassium for crops. There was a strong correlation in human excreta treatments between soil nutrients, plant growth and crop size yields suggesting that the application of human excreta to agricultural fields could be of beneficial in the near future. Overall, application of human excreta increased levels of nutrients of soil with human urine more effective for nitrogen, potassium and composted faeces the available soil phosphorus.

Looking closely to the idea of sustainable sanitation if we switch into it, it will help to find better solution for solving sanitation problem. Recycling of nutrients from the human excreta might be a big step toward ensuring food production for feeding the growing population. Composted faeces are very important in improving the structure and texture of the soil, speeds up the microbial activities and for this reason it will help to recover soil fertility that has been lost through intensive practice and use of commercial fertilizer.

Human excreta is a free fertilizer, it is easy to access unlike the commercial fertilizer. In a way, it will help out many of the poor families who do not have means of affording fertilizer for growing food. If the human waste is recirculated to the agricultural fields, between 75% and 85% of the nitrogen, phosphorus and potassium will be used as a resource instead of being a potential pollutant to the environment consequently will minimize risk of contamination level. /26/

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