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Biosolids and Biochar for the Biofortification of Mineral Nutrients (MNs) in Plants

Masterarbeit

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Diese Arbeit möchte ich meiner verstorbenen Großmutter Mizzi widmen, die weder von Bologna noch vom Bachelor- und Mastersystem eine Ahnung hatte und daher enttäuschter weise zu mir sagte:
"Masta wirst und gor ka Diplomingenieur? Do hättst gleich Mechaniker a bleiben können, do wärst schon längst Masta!"

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Unterschrift

Kurzzusammenfassung:

Zweiundzwanzig Mineralstoffe sind für die menschliche und tierische Gesundheit essentiell. Über 50 % der Menschheit weist Defizite in einem oder mehreren Mineralstoffen auf. Mineralstoffdefizite in Neuseelands Böden beeinträchtigen erheblich deren Land- und Forstwirtschaft, wobei 25-30 % von Neuseelands Farmen betroffen sind. Viele Viehweiden weisen unzureichenden Mengen von Co, Cu, I, Se und Zn auf. Das Ziel von Biofortification ist die Konzentrationserhöhung von Spurenelementen in Feldfrüchten auf natürlichem Wege. In einem Gefäßversuch wurden 13 verschieden Pflanzen (Rote Rübe, Brokkoli, Karotte, Lauch, Salat, Radischen, Spinat, Mais, Tomate, Zucchini, Raigras und Manuka) in Canterbury (sandiger Löß, pH = 5,7)- und Balmoral (Lehm, pH = 4,2)-Erde unter Zusatz von Klärschlamm (4 % an Gewicht) und/oder Biokohle (2 % an Gewicht) angebaut. Biokohle alleine als Bodenzusatz beeinflusste weder die Biomasse noch die Metallkonzentration in den Pflanzen. Klärschlamm erhöhte sowohl die Biomasse als auch die Metallkonzentration in den Pflanzen wobei Klärschlamm kombiniert mit Biokohle zu den stärksten Erhöhungen führte. Die Ergebnisse zeigen, dass Klärschlamm/Biokohle-Bodenzusätze als wirkungsvolle und billige Alternative zu handelsüblichen Düngern für agrikulturelle Anwendungen eigesetzt werden können. Die Verwendung von Klärschlamm führte zu einer 7-fachen Erhöhung der Zn Konzentration (auf 1200 mg/kg) in den Blättern der Roten Rübe. In den meisten Pflanzen führte Klärschlamm kombiniert mit Biokohle zu signifikanter Erhöhung der Zn und Cu-Konzentration. Bei der wiederholten Verwendung von Klärschlamm als Bodenzusatz ist darauf zu achten, dass es zu keiner Anreicherung von Mineralstoffen in toxischen Mengen oder zur Einbringung von Schwermetallen wie Cd kommt.

Schlagworte:

Biokohle, Biofortification, Klärschlamm, Mineralstoffe

Abstract:

Twenty-two Trace Element Micronutrients (TEMs) are essential for animal and human wellbeing. More than 50 % of humanity suffers from a deficiency of one or more TEMs. Soil deficiencies of TEMs have negative effects on agriculture and forestry in New Zealand, with 25-30 % of New Zealand's farms affected. Many pastures are deficient in Co, Cu, I, Se and Zn. Biofortification aims to increase the concentrations TEMs in crop plants using natural means. I conducted a pot experiment where 13 different crops (beetroot, broccoli, carrot, leek, lettuce, radish, spinach, sweet corn, tomato, courgette, ryegrass and manuka) were planted in Canterbury (sandy loam, pH = 5.7) and Balmoral (silt, pH = 4.2) soils, treated with biosolids (4 % by weight) and/or biochar (2 % by weight). Biochar addition, without biosolids, affected neither the biomass nor the TEM concentration of the plants. Biosolids increased both the biomass and the TEM concentration of the plants. Biosolids combined with biochar produced even greater increases. The results show that biosolids/biochar amendments have the potential for an effective and cheap alternative to commercial fertilizer for agricultural applications. Biosolids addition resulted in sevenfold increase of Zn concentration (up to 1200 mg/kg) in beetroot leaves. Biosolids combined with biochar led to significant increase in Zn and Cu concentrations in most plants. Caution is required when adding biosolids to soil as repeated applications may cause the accumulation of TEMs to toxic levels, as well as introduce toxic heavy metals such as Cd.

Keywords:

Biochar, Biofortification, Biosolids, Mineral Nutrients

List of abbreviations

ATP	Adenosine-5′-triphosphate
BCH	Biochar
BS	Biosolids
CCD	Charge-coupled device
CDTA	Cyclohexanediaminetetraacetic acid
DOM	Dissolved organic matter
DL	Detection limit
DNA	Deoxyribonucleic acid
DTPA	Diethylene triamine pentaacetic acid
EDTA	Ethylenediaminetetraacetic acid
e.g.	exempli gratia (for example)
g	Gram
ha	hectare
HM	Heavy metal
ICP-OES	Inductively coupled plasma optical emission spectrometry
kg	Kilogram
mg	Milligram
mL	Millilitre
MN	Mineral nutrient
NTA	Nitrilo-triacetic acid
RNA	Ribonucleic acid
TEM	Trace element micronutrient
TE	Trace element
TS	Topsoil
WHO	World Health Organization
yr	Year

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1. Introduction

1.1 The importance of mineral nutrients (MNs) in a healthy nutrition

The quality of human life depends on the chemical composition of food and of the surroundings. The importance of mineral elements in nutrition and health cannot be underestimated. During the last 3 decades research has documented the appearance and characteristics of mineral nutrient deficiencies. Humans require 22 mineral elements (see table 1), which are provided by adequate nutrition (White and Broadley, 2005). Several diseases are caused by mineral deficiencies. Worldwide, some 36.5 % (285 million) school-age children suffer from iodine deficiency (WHO, 2004). According to Ho (2004), 10% of the U.S. population consumes less than half the recommended dietary allowance for Zn and are at increased risk for Zn deficiency. Micronutrient malnutrition (e.g., Fe, Zn, I, Se, etc.) affects over 3 billion people, mostly women and children in resource-poor families. The consequences to human health, well-being and national development are dire, including increased mortality and morbidity rates, decreased worker productivity, poverty (Welch and Graham, 2005). Mineral nutrients are involved in many cellular functions, including pH buffering, maintaining cell turgidity, and the activation or inhibition of enzymes during metabolism. The Classification of mineral nutrients depends on their concentrations (Kreutzig, 2002; McDowell, 1992).

Table 1. Essential mineral nutrients required by humans, modified according to White and Bradly, 2005 and Belitz et al., 2008 (NS: none specified; RDA: The US recommended daily allowances)

Element	RDA	Function
N	NS	Component of amino acids, synthesis of enzymes, hormones
S	NS	Component of amino acids
K [mg]	1600-3500	Osmotic regulation, activation of enzymes
Cl [mg]	750-3400	Cation-anion balance, osmotic regulation
Ca [mg]	1000-1200	Development of skeleton, tissue and muscle systems
P [mg]	700	Energy metabolism, component of DNA and RNA molecules
Na [mg]	500-2400	Osmotic regulation, activation of enzymes
Mg [mg]	310-420	Activation and component of enzymes, metabolism
Fe [mg]	8.0-18.0	Structural component in heme proteins, in respiratory chain, part of oxidizing and reducing enzymes
Zn [mg]	8.0-11.0	Structural component, metabolism, growth, development and reproduction, gene expression, immune system
Mn [mg]	1.8-2.3	Controlling metabolisms of carbohydrates, proteins and lipids (including cholesterol) and nitrogen metabolism, involved in gene expression processes, stabilizes the DNA structure
Cu [mg]	0.9	Part of several proteins and metalloenzymes, regulation of gene expression
I [µg]	150	Synthesis of thyroid hormones which are involved in most biological processes
Se [µg]	55	Antioxidant, component of amino acid selenocysteine
Mo [µg]	45	Involved in oxidation-reduction processes (oxidoreductase), regulates the metabolism of purines and fats
Cr [µg]	25-35	Energy metabolism, affects enzymes that regulate cholesterol synthesis
F [mg]	3-4	Bone- and teeth formation, reproduction
B [mg]	NS	Bone formation, role in cell membrane function, mineral and hormone metabolism and enzyme reactions
Ni [µg]	NS	For some enzymes (e. g. urease), plays a role in the metabolism of methionine, vitamin B_{12} and folate
V [mg]	NS	Regulatory effects, inhibitor of Na-K and Ca-Mg balances
Si [mg]	NS	Required for bone, cartilage and connective tissue formation and is also needed for right development of skin and hair
As	NS	Growth, relation to methionine metabolism

1.1.1 Macronutrients (e.g. Na, K, Ca, Mg, P, S,...)

These electrolytes occur at concentrations > 50 mg/kg body weight and are required in the diet at amounts in the range of g per day. Many human and animal diseases are related to deficiencies of macronutrients. Phosphorus for example is needed for bone formation as well as energy metabolism and it is component of DNA and RNA. According to Masters and White (1996), deficiencies of P in sheep lead to reduced growth and reproductive rates as well as softening of bones, lameness and depressed appetite. Deficiencies of Ca, Mg or Na in sheep bring up less of weight and reduced milk production which are important issues for dairy farming.

1.1.2 Micronutrients (Co, Cu, Fe, I, Se, Zn,...)

The main focus of this work is aimed at micronutrients. The term "trace elements" (TEs) is related to their abundance and includes elements of various chemical properties (Kabata-Pendias and Mukherjee, 2007). TEs Occur at low Concentrations in the organisms. Most of them are metal-ions. They occur at concentrations ≤ 50 mg/kg body weight (excepting iron: ca. 60 mg/kg) and are needed in a range of µg – mg per day. A balanced nutrition of micronutrients is essential to assure human health according to Yang, 2005. TEs occur at small concentrations in organisms, less than 0.01% however, they have an extensive effect as essential micronutrients. TEs considered essential for nutrition by the WHO are Fe, Zn, Cu, Cr, I, Co, Mo and Se. The elements Si, Mn, Ni, B and V are considered to be probably essential (Prasad, 2008). The criterion for essentiality is that absence or deficiency of an element brings abnormalities that can be connected to specific biochemical changes reversed by supplying the element. TEs are needed for several catalytic processes in the cell and a deficit can cause considerable disruptions of the metabolism (Kreutzig, 2002). Copper and Zn are two essential elements that are often deficient in New Zealand's livestock because of nutrient-poor pastures. Copper is of utmost importance for life (Hänsch and Mendel, 2009). Copper is essential because it is part of several proteins and metalloenzymes and plays a role in regulation of gene expression. It is needed for growth, defence, bone strength, blood cells production, metabolism, Fe transport and mitochondrial respiration. Copper deficiency leads to several diseases including: anaemia, slow growth, decrease in white blood cells, hair and weight loss, disorders of central nervous system, osteoporosis, cardiovascular problems and several other metabolic dysfunctions. Zinc is also an essential micronutrient and it is a structural component of over 300 enzymes, important for metabolism of all macromolecules in the metabolism of nucleic acids, and in the metabolism of other minerals. Zinc is needed for growth, development and reproduction. Zn plays a central role for gene expression as a constituent of transcription factors and is also needed for a working immune system. Severe Zn deficiency leads to frequent infections, diarrhoea, alopecia, delayed sexual development and mental disturbances. Zinc deficiency also induces bone impairments and increased severity of facial eczema. Different organisms have different nutritional requirements, so some elements can be essential for one organism and toxic to another. Every TE is toxic at high concentrations. There are big differences in the toxicity of the TEs, which depends on the chemical speciation. Figure1 shows the effect of essential TE concentration on the growth and functioning of organisms. Diseases and death will be the result of both low and high TE concentration. At the low scale of the TE-curve deficiency syndrome would appear. When the amount rises the syndrome becomes hidden or would not be recognisable any more. The centre of Figure 1 stands for a healthy balance of a particular TE. TE concentrations that are too high cause disease, intoxication and in rare cases death. Therefore, it is important that the supply of trace elements by food is sufficient in all growing and development stage during the whole life (Stanway, 1991). Figure 2 shows the effect of non-essential TE concentration on function of organisms. TE concentrations that are too high lead also to intoxications.

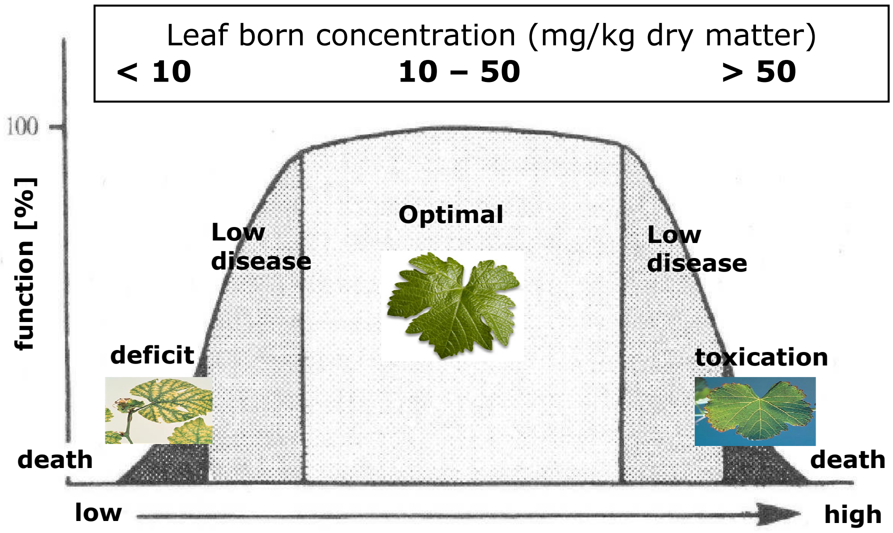

Figure 1. The effect of too low or too much amount of essential TEs. (modified according to Stanway, 1991)

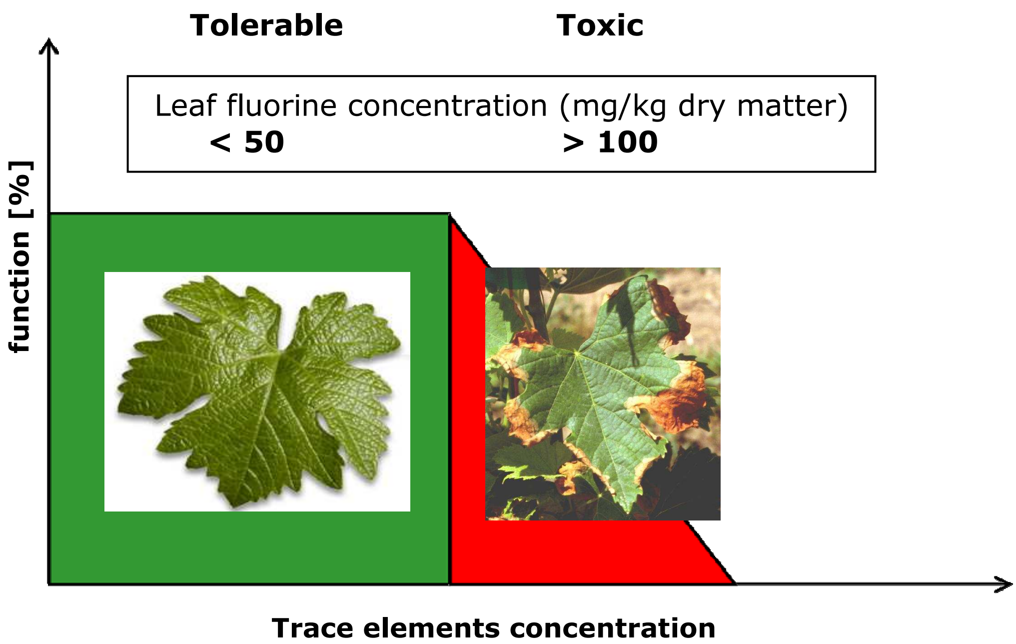

Figure 2. Tolerable and toxic concentrations of non- essential TEs (modified according to Robinson, 2006).

1.2 The fate of TEMs from soil up to the entrance into the food chain

1.2.1 The distribution of TEs in the environment

Earth`s crust may be considered as a natural reservoir for all chemical elements of the biosphere (Markert and Friese, 2000). Soil consists of a complex and heterogeneous mixture of minerals (TEs originate from natural and man-made sources.), living and dead organic material, water and air. These components afford to each soil specific physicochemical and biological properties. Therefore, their concentrations can differ profoundly. TE concentration in soil is a function of the parent material plus consequent atmospheric or water-borne deposition (Prasad et al., 2006). Figure 3 shows the biogeochemical cycling of TEs in terrestrial ecosystems.

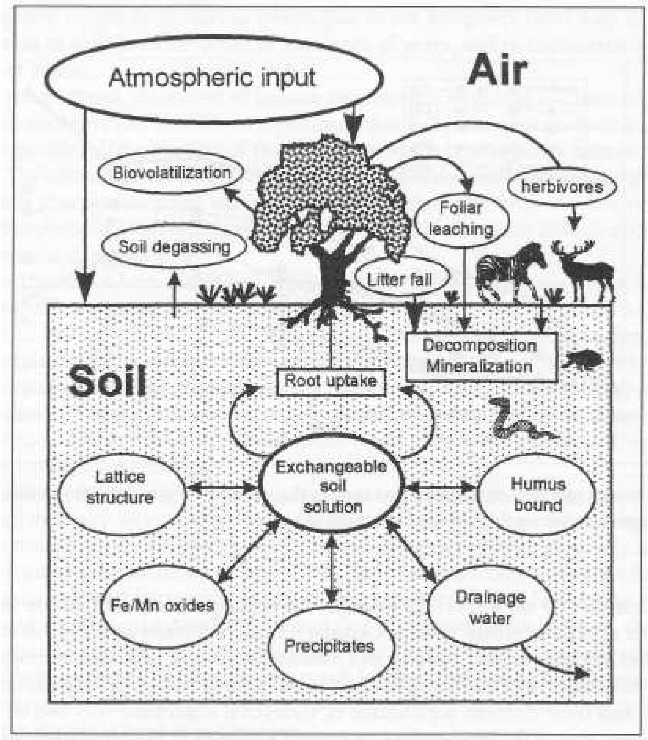

Figure 3. The biogeochemical cycling of TEs in terrestrial ecosystems (Bargagli, 1998)

A soil is considered deficient when additional nutrients improve plant growth. The efficiency of a soil cannot be predicted by measuring the overall content of TEs. This is because only the soluble and mobile fraction of TEs has the potential to leach or to be taken up by plants and reach the food chain (Prasad et al., 2006). The amounts of soluble and insoluble forms of TEs in soil varies extensively, being depend on nature of compounds containing TEs, soil type, composition of the soil forming rocks, weathering conditions, retention capacity, plant factors, qualitative composition of the microflora and several more parameters (Aller et al., 1989). The most important parameters for processes in soil such as dissolution, sorption, binding, volatilization, migration and diffusion of TEs are soil pH and redox potential (Kabata-Pendias and Pendias, 1992). TE deficiency detrimentally affects livestock, particularly in areas where TEs are deficient in soils.

1.2.2 Trace element uptake in plants

According to Singh and Ward (2004), plants are able to extract, bind, immobilize and degrade substances from soil, sediments and water. Therefore essential elements for growth as well as contaminates in soil can be absorbed and subsequently accumulated by different plants. Nineteen elements (see table 2) are known to be essential for plant growth and these many are absorbed into plants in different forms. The plants usually obtained the different elements through their surrounding gases, water and the environment soil (Reid and Hayes, 2003). After mobilization in the rhizospere, the elements must be taken up by the root cells. Solubilised metal ions can enter the roots via extracellular or intracellular pathways whereas several transport proteins and intracellular high-affinity binding sites induce the absorption of trace elements across the membrane. The nutrient uptake into the plant cells, demands accumulation of nutrient molecules to higher concentrations than in the surroundings, and therefore remarkable energy is necessary in form of ATP (Reid and Hayes, 2003). Metal ions can be stored or exported to the shoot. The metal transport probably takes place in the xylem but redistribution in the shoot via phloem is possible (Prasad et al., 2006).

Table 2. Mineral elements for plant growth (Maathuis, 2009; Hänsch and Mendel, 2009; Pilon-Smith et al., 2009; Marschner, 2002)

Essential Macronutrients	Essential Micronutrients	Beneficial Mineral Elements
• Nitrogen	• Iron	• Sodium
• Sulphur	• Manganese	• Silicon
• Phosphorus	• Copper	• Cobalt
• Magnesium	• Zinc	• Selenium
• Calcium	• Nickel	• Aluminium
• Potassium	• Molybdenum	
	• Boron	
	• Chlorine	

1.2.3 TEs from the plants into the food chain

The transfer of TEs from soil to humans can occur via multiple pathways (see figure 4). The TEs can be taken up from soil to various plants, where they were stored and accumulated. Once in the plants, the TEs can get enter humans directly by consuming plants via livestock that have consumed the plants. Most of TEs that are essential to humans are also essential to plants but there are some important differences. Selenium, I, Co, Si and F are not essential to plants but essential to animals and humans. Plants have no specialised mechanisms to take up these elements (Kabata-Pendias and Mukherjee, 2007). When higher plants are deficient in essential TEs, many important metabolic functions are disrupted and the result is poor growth and yield of crops (Srivastava and Gupta, 1996). Unfortunately, the concentrations of most elements that may be harmful to humans and animals are not toxic to plants. This has created an increased transfer of some elements into the food chain (Kabata-Pendias and Mukherjee, 2007). Therefore, supplying of essential elements from plants to animals and humans is as possible as intoxication. However, a soil-plant barrier may protect the food chain from toxicity of elements by limiting maximum levels of that element in edible plant parts to levels safe for animals and human (Chaney et al., 2000). The three major processes in forming soil-plant barriers are:

- Precipitation or adsorption of metals by soil particles, or in the fibrous root system hinders uptake of most elements.

- Phytotoxicity of some elements (Zn, Cu, Ni, and Mn) occurs at concentration of these elements in the edible plant part below levels harmful to animals and human (the plant dies before it can accumulate the element to concentrations that are toxic to animals and human).

- Interactions between elements which hinder uptake, translocation or bioavailability of soil metals.

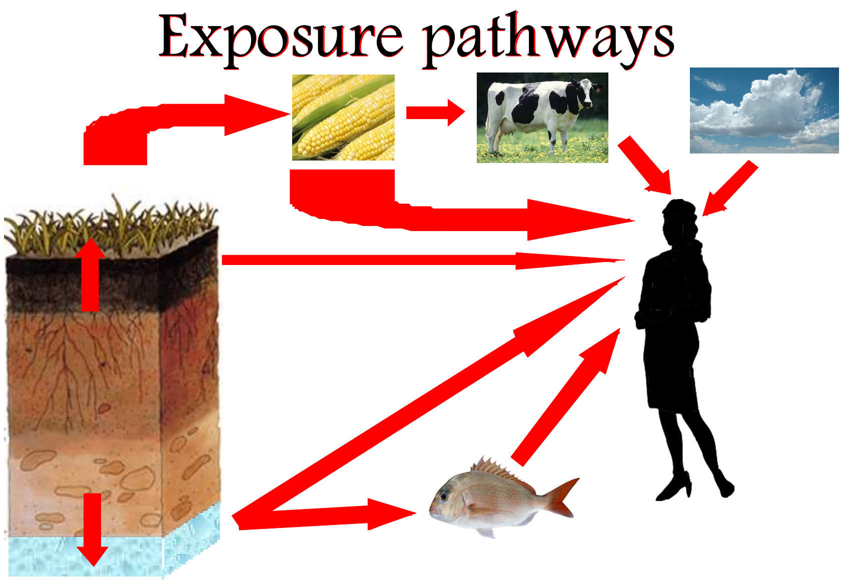

Figure 4. Exposure pathways of TEs to humans (Robinson, 2006)

The total TE concentration in food plants is not the only factor in respect of covering the required human demands. Another essential factor for the nutritional impact is the bioavailability (availability for biological and biochemical processes in the organism) of the TEs (Welch and Graham, 2005). Several food components form soluble or insoluble complexes with TEs. This may lead to a positive or negative influence of bioavailability by varying the TE absorption in the small intestine. Compounds that may have a positive effect with regard to bioavailability are citric acid, ascorbic acid, lactose and EDTA. Compounds with a potential negative effect on bioavailability of TEs are phytic acid, dietary fibre and polyphenolic compounds.

1.3 Trace element deficiency in New Zealand

Sheep farming is a mayor sector of New Zealand's industry. New Zealand is responsible for one third of the World's dairy trade and agriculture is the 2nd biggest earner of FOREX after tourism. Besides livestock breeding, fruit- and vegetables growing are also important areas in New Zealand's agriculture. Soils with low TE concentrations exists worldwide including New Zealand, therefore these areas are also notable for having low TE status in feed and food crops, humans and animals. More than the half of the area of New Zealand is used for pastoral grazing by sheep and cattle (Gibbs, 1980). Nutritional quality of pastures is the key factor in managing grazing animals (Brown, 2005). Soil deficiencies of TEs have had a considerable influence on agriculture and forestry in New Zealand according to Will, (1990). 25-30 % of New Zealand's farms are deficient in one or more trace elements. Table 3 shows the extent of trace element deficiency in New Zealand and gives the effects of these deficiencies on plants and animals. Co, I and Se deficiencies are widespread in New Zealand soils. Sufficient Co in pasture is essential for ruminant health in New Zealand pastoral agriculture and many New Zealand soils are known to be potentially Co-deficient (Li et al., 2001). According to Will (1990), Cu and Zn deficiencies in areas of the North Island of New Zealand have affected tree growth. Many studies in New Zealand proved also a high frequency of Se responsive disease in sheep (Hawkesford and Zhao, 2007). Many other trace element deficiencies result only in general yellowing and/or stunting of plants. It is often impossible to determine by eye which trace element or macro nutrient is deficient.

Table 3. Trace elements those are commonly deficient in New Zealand.

Element	Distribution of deficiency	Deficiency Symptoms
Cobalt	Central plateau, Hawkes Bay, Nelson, Westland, Canterbury, Southland	"bush sickness", poor growth rates of sheep and cattle
Copper	*Peat and sandy soils throughout NZ	Poor growth, bone fragility, anaemia
Iodine	Otago, Westland, Marlborough, Canterbury, Manawatu, Hawkes Bay, Gisborne	Goitre in young animals
Selenium	Central plateau & virtually all South Island farmland.	Infertility, high mortality of lambs and calves, lowered immunity, reduced growth
Zinc	Over-limed pastures & wheat crops, citrus & stone fruits	Increased cadmium absorption and increased severity of facial eczema.

*Copper deficiency may be induced by high molybdenum concentrations in soil.

1.4 Possible approaches to increase the flux of TEMs from soil to plants and from plants to livestock or humans

Most TEMs that humans take in come from plants. Therefore, enhancing the plant uptake of TEMs in deficient areas would have a large beneficial effect on animal production and human health (Yang et al., 2007). Conventional treatments to combat micronutrient malnutrition – also known as hidden hunger (Mayer et al., 2008) – have aimed on supplementation, food fortification and dietary diversification. The requirement of safe delivery systems, stable political policies, appropriate social infrastructures and continued investment have hindered progress on this issue. A potential solution to mineral malnutrition called "biofortification" is being investigated. Biofortification aims to increase the concentrations and human-bioavailability of mineral nutrients in edible crop plants. Figure 5 shows the passage of Trace Element Micronutrients from soil to humans and the four key steps in biofortification.

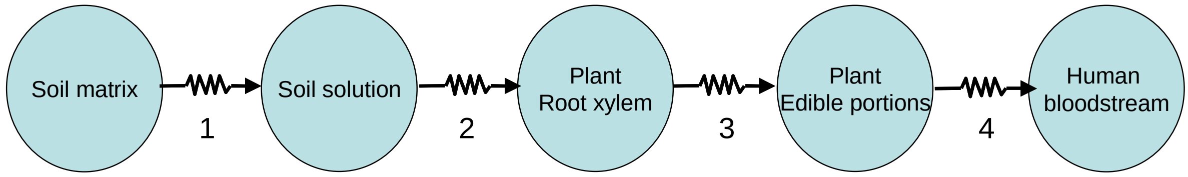

Figure 5. The passage of Trace Element Micronutrients from soil to humans and the four key steps in biofortification

Step 1: TEMs that are bound to the soil matrix are biologically inactive, i.e. insoluble and unavailable to plants (Robinson et al., 2009). Biofortification must therefore ensure that plant uptake is not limited by the concentration present in soil solution. This requires a sufficiently high total concentration in the soil, and a chemical environment that favours TEM solubility (Zhao and McGrath, 2009).

Step 2: TEMs must move from soil solution into the plant root xylem. For this to happen the TEM must traverse biological barriers, a process affected by the chemical form of the TEM (Nowack et al., 2006), microorganisms in the root-zone (Whiting et al., 2001), as well as plant physiological variables (Marschner, 1995).

Step 3: The translocation of TEMs from the roots to the edible portions. This step is not usually limiting in leafy crops, but may be limiting in seed or fruit crops (Ernst et al., 1992).

Step 4: The transfer of TEMs from the edible portions of the plant into the human bloodstream. This step is affected by the chemical form of the TEM as well as other compounds in the consumed produce (Zhou and Erdman, 1995). Step 4 is also affected by methods of food preparation and other components of the diet, which are beyond the scope of this project.

Increased bioavailability can be achieved in different ways of agronomic intervention or genetic selection through plant breeding (White and Broadley, 2005). By means of these modern possibilities, the TE concentration in staple food crops may be increased in order to require human needs (Welch and Graham, 2005). There are various implements for increasing TE contents in plants, which have many disadvantages. Fertilisation is a common effort for overcoming TE deficiencies in New Zealand soils but only correction of TE content in soil via fertilization is not always successful because of agronomic (reduced availability due to topsoil drying and subsoil constraints) and economic factors (high costs) (Hacisalihoglu and Kochian, 2003). In any case, the total TE content in soil is often sufficient, only the plant-available fraction is deficient. Therefore TE fertilisation has little effects. Adding too much of a trace element reduces productivity and may render the soil infertile. Over fertilisation can also lead to an enhanced risk for ground water pollution because of leaching. Much research indicates other methods to increase accumulation of metals in plants such as the application of synthetic chelates (EDTA, CDTA, DTPA and NTA) or plant produced chelators (phytosiderophores) as soil additives. However, these methods are rather used for remediation purposes in heavy metal contaminated soils, where it may leads to an accumulation of toxic metal levels in plants. Some scientists reported that rhizosphere bacteria enhance plant uptake of TEs and others described a reduction or no effect regarding uptake (Rajkumar, 2009). Sheng and Xia (2006) demonstrated that Cd-solubilizing and growth-promoting bacteria could promote Cd uptake in rape and in addition the translocation of Cd from roots to shoots. Various strains of *Bacillus* and *Pseudomonas* increased the total concentration of Cd accumulated by *Brassica juncea* seedlings (Prasad et al., 2006). Rajkumar, (2009), reported that the addition of *Pseudomonas jessenii* to *Ricinus communis* enhanced the Zn concentrations in shoot tissues with concurrent stimulation of plant growth. Unfortunately, the application of endophytic bacteria is currently limited because they can only colonize particular plants. Various direct methods besides fertilisation (indirect method) are used by New Zealand's farmers for supplying TEs to grazing sheep. For that reason, different licks, blocks, intraruminal pellets and drenches are used. Drenches are generally cheaper than other supplements but they are usually short acting, especially for elements such as Zn and Mn. The animals do not have the capacity to store these elements in physiologically significant quantities (Masters and White, 1996). A further disadvantage of drenching is that it can pollute the soil and ground water where sheep are grazing because of high metal concentration in their excretion. Because of the numerous disadvantages of the previous applications the effect biofortification using biosolids and biochar could be an alternative, which aims to maximise the nutritional value of food and fodder by natural means.

1.4.1 Biosolids

Biosolids also called sewage sludge are the solid portions that remains after treatment (to the stage that they are able to be safely to land after application) of household and industrial wastewater by waste water treatment plants. Biosolids usually contain high amounts of nutrients, organic matter and TEMs (Cu, Zn) and therefore it has the potential for an effective and cheap alternative to commercial fertilizer for agricultural applications. But the application of biosolids to land has not been without controversy (concerns over 1) nitrate leaching, 2) HM accumulation, 3) pathogens, 4) organic contaminates, 5) cultural factors) and therefore some countries prohibit the application of biosolids to land. Nevertheless, the general trend has been towards increased use of biosolids on land, because of following reasons according to the Biosolids Guidelines, 2003:

- Discharge of sludge to the sea has been banned in most countries
- Costs of landfilling sludge are high / Shortage of space for new landfills
- Disposal of biosolids in landfills results in the production of greenhouse gasses
- Combustion can cause atmospheric pollution, and accrued ash requires disposal
- Agronomic and economic benefits from applying biosolids to land
- Adding biosolids to land adds heavy metals but so too does conventional fertilisers such as superphosphate.

Using biosolids as a soil addition can have positive economic benefits but it needs to be monitored to avoid excessive nitrate accumulation or excessive levels of HMs (Cd, Ni, Pb) or other potentially harmful substances such as organic micropollutants (Lagae et al., 2009; Parat et al., 2007). The risk of infection through pathogens must be also eliminated or reduced to an acceptable level before applying biosolids to land. Over the last decade a lot of research has been done on the addition of heavy metals to agricultural soils through sewage sludge applications for a possible entry into the food chain (Kidd et al., 2007). Nevertheless, Kidd et al., (2007), reported that the overwhelming majority of research indicates that agricultural treatments with biosolids have crop production benefits with low environmental risks. However, the addition of biosolids to soil may not always result in increased plant uptake of trace elements. Plant uptake is dependent upon the concentration of the trace element in soil solution as well as its speciation. Trace elements in biosolids are strongly bound to the organic matrix and therefore less available for plant uptake than more mobile metal salt additive found in commercial fertilizers (Prasad et al., 2006). The addition of biosolids to soil may even immobilise soil-borne trace elements, rendering them unavailable for plant uptake. However, New Zealand's 320 public wastewater treatment plants generate approximately 235000 tonnes of sewage sludge annually (Global atlas of excreta, wastewater, sludge, and biosolids management, 2008) which is a huge amount for different beneficial applications.

Figure 6. Collection of the biosolids from Kaikoura

1.4.2 Biochar

Biochar is charcoal created by the reduction of biomass to carbon in a low oxygen atmosphere through a process called pyrolysis (see figure 7). By means of this technique atmospheric CO_2 can be converted into a robust and safe form. Besides this environmental benefit biochar can be used as soil amendments for improving soil properties and crop yield (Sohi et al., 2010). Biochar in soils is considered as means for constantly sequestering carbon (Hossain et al., 2010). Biochar is also used a soil conditioner and fertilizer by increasing cation exchange capacity (CEC), pH, and water retention (Uchimiya et al., 2010).

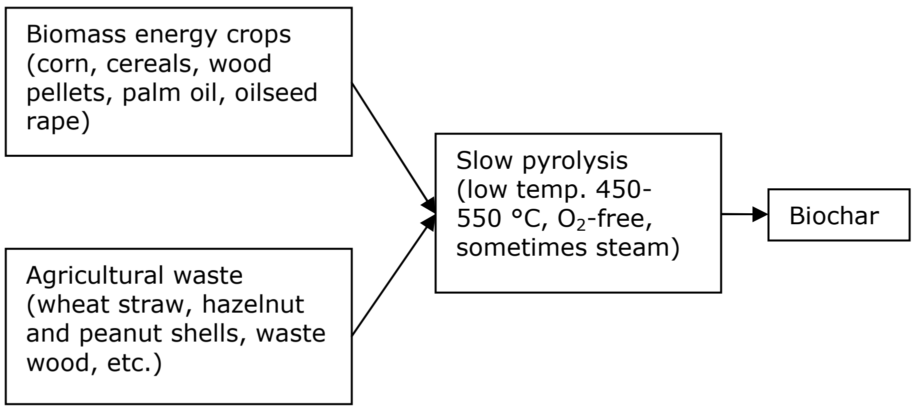

Figure 7. The production and use of biochar according to Sohi et al. (2010).

1.4.3 Hypothesis

1) The addition of biosolids will increase plant uptake of elements, such as Zn, which occur at high concentrations in the biosolids because of an improvement in soil structure.

2) The high organic matter content of the biosolids will decrease plant uptake of elements that occur on low to moderate concentrations in the soil and that this decrease may occur in spite of an increase in total concentration.

3) Dissolved organic matter (DOM) released from biosolids will increase the solubility of all trace element cations in the soil. DOM molecules contain functional groups such as COOH and phenolic-OH, capable of complexing metals (Ashworth and Alloway, 20008). This process will decrease the sorption and increase the mobility of metals in soils.

4) The use of biochar will increase the crop yield because biochar can be used as soil amendments for improving soil properties (Hossain et al., 2010). Biochar has sorptive- and high cation exchange-capacity (Sohi et al., 2010), therefore the use of biochar will reduce heavy metal uptake in plants.

1.5 Aim of the study

Soil deficiencies of TEs have had a considerable influence on agriculture and forestry in New Zealand. 25-30 % of New Zealand's farms are deficient in one or more TEs. Therefore, many pastures in New Zealand are deficient in plant and animal micronutrients, especially Co, Se and Zn. The aim of this study is to increase the flux of essential TEs from soils to different plants, where they may provide health benefits to humans or animals. This aim will be reached by determination of the effect of additional biochar and biosolids on TEM fluxes in the soil-plant system and elucidation of the role of DOM on TE fate. The accumulation of non-essential elements, especially Cd and Pb in edible plant parts need to be monitored. A critical point is the correlation between Zn and Cd. These elements are taken up via the same pathway. The question is if the benefit of increased Zn in plants will be offset by increased Cd. Aspects of this programme will be conducted in collaboration with the Soil Protection group at the Swiss Federal Institute of Technology Zürich (ETHZ).

2. Material and methods

2.1 Experimental setup

The experiment was performed in 2 L cylindrical plastic pots-, which were placed on trays to collect the leachate. The pot trial was carried out in a temperature unregulated glasshouse environment (see figure 8). The temperature in the glasshouse fluctuated between 10 and 43 °C depending on the outside temperature and solar irradiation. The treatments were based on Canterbury soil, Balmoral soil, biosolids and biochar were used. The used topsoil was commercial screened topsoil purchased from Parkhouse Garden Supplies, New Zealand. The soil (fine sandy loam) was sourced from land under development in the Christchurch area. Biosolids were sampled from the sewage treatment plant in Kaikoura. Balmoral soil (acid silt soil) was taken from the Balmoral forest GPS (2479155 E, 5823232 N). The slater biochar was made from Kanunka and Black Wattle. Following soil treatments (in % by volume) were prepared for the experiment.

- Control, 100 % topsoil (Canterbury or Balmoral soil)
- 90 % topsoil, 10 % biosolids
- 70 % topsoil, 10 % biosolids, 20 % biochar
- 80 % topsoil, 20 % biochar

Table 4 shows the identification of the planted crops and the date when planting and harvesting were performed.

Table 4: Information to the planted crops

Crop	Identification	Planting	Harvesting
Beetroot	baby beet F1 hybrid seed (*Beta vulgaris* subsp. *Vulgaris*)	Jan 18th	March 19th
Bean	Dwarf barlotti red rooster (*Phaseolus vulgaris*)	March 5th	Not successful
Pea	Dwarf Massey seed (*Pisum sativum*)	Jan 18th	Not successful
Broccoli	seedlings (Brassica oleracea)	Jan 18th	successive
Carrot	ft he supreme seed (*Daucus carota*)	Jan 18th	April 15th
Leek	Seedlings (*Allium ampeloprsum var Porrum*)	Jan 18th	April 20th
Lettuce	Green Oak Leaf seed (*Lactuca sativa*)	Jan 18th	March 4th
Onion	Pukehohe Longkeeper (*Allium cepa var. Cepa*)	March 16th	Not yet
Radish	champion seed (*Raphanus sativus*)	Jan 18th	Feb 19th
Spinach	New Zealand seed (*Spinacia oleracea*)	Jan 25th	March 11th
Sweet corn	gold F1 hybrid seed (*Zea mays var rugosa*)	Jan 18th	April 27th
Tomato	Russian Red seedlings (*Solanum lycopersicum*)	Jan 18th	April 1st
Courgette	Blackjack F1 hybrid seed (*Cucurbita pepo*)	Jan 18th	March 12th
Ryegrass	(Lolium perenne L.) Bronson AR1 endophite	Jan 18th	Feb 15th, March 9th and April 22nd
Manuka	3 months old trees (*Leptospermum scoparium*)	Feb 16th	May 18th

Five replicates of each crop were planted per soil treatment using Canterbury soil. Spinach was not planted at treatment 70 % topsoil, 10 % biosolids, 20 % biochar and only 4 spinach replicates were applied for treatment 90 % topsoil, 10 % biosolids. Grass was also only 3 times planted at treatment 70 % topsoil, 10 % biosolids, and 20 % biochar. On the 23rd of March, the corn was transplanted into 7.5 L cylindrical plastic pots. Three replicates of grass, broccoli and manuka were cropped per soil treatment using Balmoral soil. To eliminate the effects of any environmental heterogeneity in the greenhouse, the pots were randomised in groups. To provide the plants with adequate amount of water, irrigation was carried out manually using a spray, according to actual water consumption. Weeds were continuously removed, seedlings thinned and the healthiest plant from each pot was retained.

Figure 8: Experimental setup in the green house

2.2 Spraying

Because of plant louse infection of the broccoli variants spraying with the insecticide Key Pyrethrum (contains 14 g / litre pyrethrum and 56.5 g / litre piperonyl butoxide in the form of an emulsifiable concentrate), New Zealand at the rate of 5 ml / litre was performed on March 10^{th} and 29^{th} and on May 3^{rd}.

2.3 Fertilisation

Fertilisation with Ruakura solution (see table 5) according to Smith et al. (1983) was performed on some species 2 months after seeding because of the emergence of deficiency symptoms.

Table 5: Ruakura solution without micronutrients

Chemical	Chemical formula	Conc.
Magnesium nitrate hexahydrate	$Mg(NO_3)_2*6H_2O$	4,94 g/L
Potassium nitrate	KNO_3	2,28 g/L
Calcium nitrate 4-hydrate	$Ca(NO_3)_2*4H_2O$	16,78 g/L
Ammonium nitrate	NH_4NO_3	8,48 g/L
Potassium dihydrogen orthophosphate	KH2PO4	2,67g/L
di-Potassiumhydrogenphosphate	K2HPO4	1,64 g/L
Potassium sulphate	K2SO4	6,62 g/L
Sodium chloride	NaCl	0,33 g/L

In a period of 2 weeks, broccoli was fertilised 9 times with 50 mL Ruakura solution, tomatoes 6 times with 50 mL and corn 6 times with 50 and 3 times with 100 mL.

2.4 Next steps with crops

2.4.1 Determination of biomass

After harvesting (see table 2), fresh weight of the crops was measured. After weighing the samples were rinsed with deionised water and separated into roots, shoots and edible parts. Therefore pealing of carrots and beetroot and separation of corn kernels from cob was necessary. Dry weight of the samples was determined after drying at 107 °C for 24 h in a drying oven (omRon E5CS) and cooling down. To provide a homogeneous sample for analysis, beating was performed using a grinder (A 10 yellow-line, IKA®) or mortar.

2.4.2 HNO_3-extraction

The total concentrations in the plants were measured using HNO_3 digestion. 0.50 g (± 0.01 g) of each sample was weight into liner vessels from the microwave (MSD-2000, Microwave Digestion System, CEM Innovators in Microwave Technology, USA). 8 mL Nitric acid (about 69 %; Sp. Gr. about 1.42; BDH ARISTAR®) was added to each sample. The liner vessels were left uncapped in the fume cupboard for at least 15 min to get rid of some gases that can build up before capping. Assembling of the vessels was performed, the turntable including 12 vessels (11 samples and 1 blank) was placed into the microwave and digestion was started. Microwave energy was used to heat the samples in the closed vessel microwave system. Once in the MDS-2000, it is subjected to rapid heating and elevated pressures, causing the sample to digest or dissolve in a short time. The program steps were 10 minutes for assembling the conditions 180 °C / 150 bars, 10 minutes keeping and cooling down. To speed up the cooling procedure, the rotor with the 12 vessels was placed into a water bath. After cooling down the samples were transferred from the vessels to 25 mL volumetric flasks and rinsed 3 times with mili-Q-water DDIW (Barnsted, EASY pure RF, compact ultrapure water system). The volumetric flasks were filled up to the mark with the mili-Q-water. The samples were transferred from the flasks into 30 mL vials for storage until analysis via inductively coupled plasma optical emission spectrometry (ICP-OES) was arranged.

2.4.3 Measuring of mineral concentrations using ICP-OES

The used ICP-OES was a VARIAN 720-ES (USA) with axial plasma viewing, fitted with a SPS-3 auto-sampler, an ultrasonic nebuliser and a CCD (charge-coupled device) detector based on the Vista Chip (wavelength coverage 167-785 nm). The operating gas for the plasma was argon. Three replicate measurements for all samples were performed. For quality assurance, reference materials were used (Lucerne 124, International Plant-Analytical Exchange, Wageningen, ISE 921 Riverday soil). Details of the adjusted operating conditions are summarised in table 6.

Table 6: Adjusted ICP-OES conditions

Parameters	
Plasma flow [L/min]	15.0
Auxiliary flow [L/min]	1.50
Nebulizer flow [L/min]	0.90
Sample uptake delay [s]	20
Pump rate [rpm]	15
Rinse time [s]	20

The used software was ICP Expert II Varian, 2008. For calibration following 4 standards in corresponding dilutions were used:

- ICP multi-element standard solution IV (23 elements in diluted nitric acid; 1000 mg/L; MERCK)
- Potassium ICP standard (10000 mg/L K; Certi PUR®; MERCK)
- Sodium ICP standard (10000 mg/L Na; Certi PUR®; MERCK)
- Calcium ICP standard (10000 mg/L Ca; Certi PUR®; MERCK)

2.4.4 C/N ratio measurement using elemental analysis

200 mg ± 10 mg of each ground grass plant sample was weighed into small vessels for analysis of C / N ratio which was carried out by elemental analyser (elementar vario MAX CN).

2.4.5 Statistics

All data were statistically studied via STATISTICA 7.1 by the use of ANOVA and Duncan tests. Tests of significant differences (5% level) in plant biomass between the 4 different soil treatments were carried out. Tests of significant differences (5% level) between the different soil treatments for all elements and for all plant species were performed. Tests of significant differences (5% level) of Zn, Cu, Cd and Pb across all plant species within each soil treatment were performed.

2.5 Next steps with soils, biosolids and biochar

Representative samples of all soil treatments and of pure biosolids and biochar were taken. After drying at 107 °C for 24 h sieving to < 2 mm was performed.

2.5.1 Acid extraction using aqua regia (Königswasser)

This method was carried out to measure the pseudo-total concentration of the mineral nutrients in soils, biosolids and biochar similar to the HNO_3-extraction in 2.4.2 for plant samples. Aqua regia was made of following 2 chemicals:

- 59 mL HCl (fuming 37 %, MERCK)
- 15 mL HNO_3 (about 69 %; Sp. Gr. about 1.42; BDH ARISTAR)

0.50 g (± 0.01 g) of each sieved and homogenised sample was weight into liner vessels from the microwave and 5 mL aqua regia was added to each sample. The next steps were similar to the HNO_3 extraction in 2.4.2. After cooling, the samples were transferred from the vessels through a filter (Hardened Circles; 110 mm Ø; Cat No 1452110; Whatman®) into 25 mL volumetric flasks and rinsed 3 times with mili-Q-water. The volumetric flasks were filled up to the mark with mili-Q-water. The samples were transferred from the flasks into 30 mL vials for storage until analysis via ICP-OES.

2.5.2 Calcium nitrate ($Ca(NO_3)_2$)-extraction

Besides the pseudo-total concentration of the MNs in soils, biosolids and biochar other exchangeable metals (soluble metals) that indicate the concentration of metals that are likely to leach or be taken up by plants were measured. This method is called $Ca(NO_3)_2$-extraction.

5 g of the homogenised and sieved samples were weight into 50 ml centrifugal tubes. 30 ml of 0.05 M Ca $(NO_3)_2$ were added and mixed well using a vortex mixer. The centrifugal tubes were shaken on the end-over-end shaker for 2 hours and centrifuged at 3200 rpm for 15 minutes. After filtering (52 Hardened Circles; 110 mm Ø; Cat No 1452110; Whatman®) of the samples into 30 ml vials, they were stored in the fridge until the analysis by ICP-OES was performed.

2.5.3 Measuring of mineral concentrations using ICP-OES

The concentration of the elements was measured via ICP-OES similar to 2.4.3.

2.5.4 C/N ratio measurement using elemental analysis

500 mg ± 10 mg of soil samples and 200 mg ± 10 mg of pure biosolids and biochar were weighed in small vessels and analysed in the same way than in 2.4.4.

2.5.5 pH-measurement

The pH-measurement was arranged according to Blankemore et al. (1987). 10.00 g of samples were weighted into 70 mL vials. 25 mL of deionised water was added. The mixture was shaken vigorously and leaved overnight. The samples were shaken again before pH-measurement (Mettler Toledo Seven Easy) was performed.

2.5.6 Statistics

All data were statistically studied via STATISTICA 7.1 by the use of ANOVA and Duncan tests. Tests of significant differences (5% level) between the different soil treatments (acid-extractions as well as $Ca(NO_3)_2$-extractions) for all elements were performed.

Summary of the experimental setup

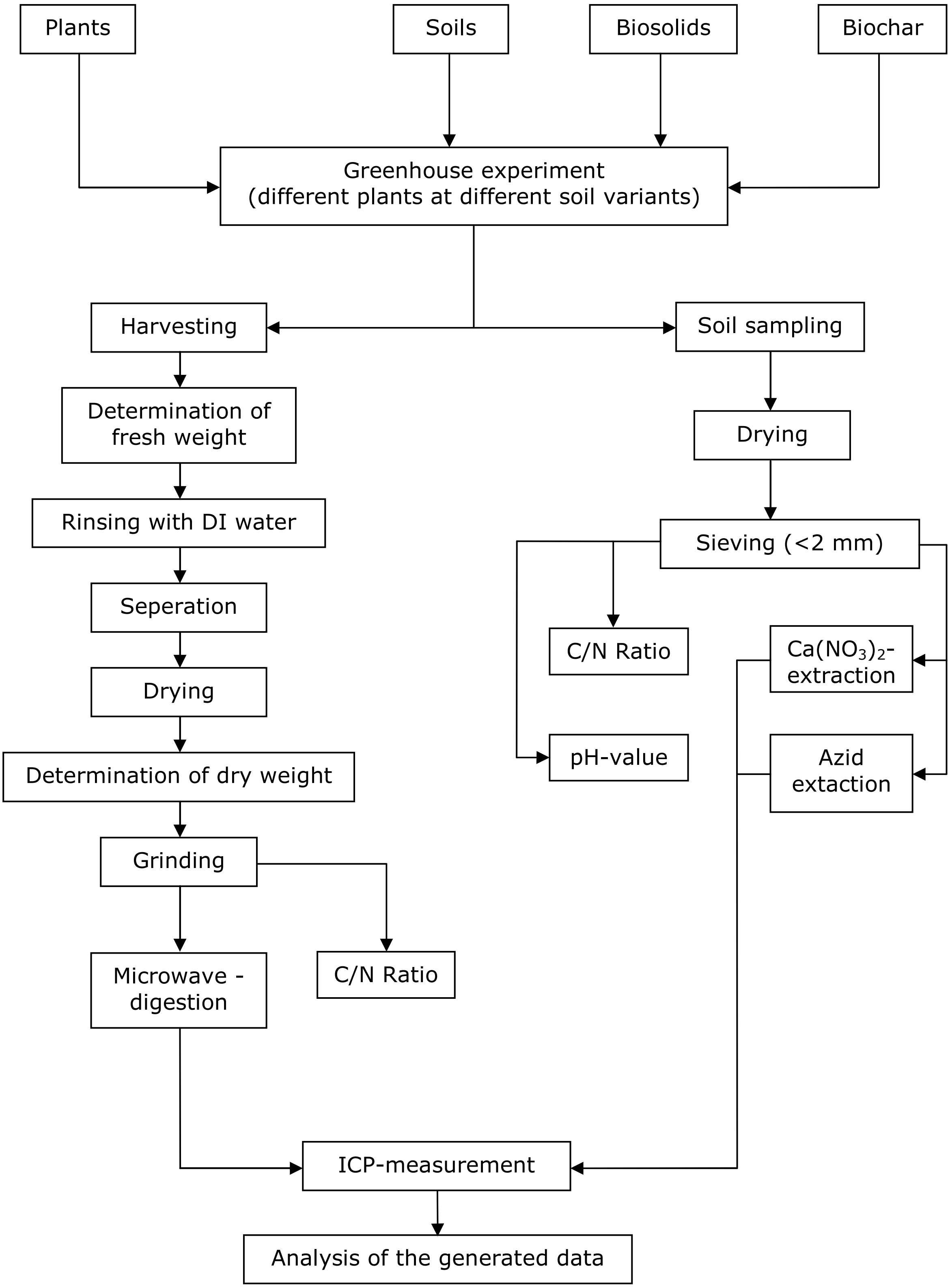

Figure 9: Summary of the experimental set up.

3. Results

3.1 Soils and substrates

Table 7 shows the concentration of Ca, Mg, K, Na, Fe, Cd, Cu, P, S and Zn as well as the nitrogen- and carbon content and pH-value of the used Canterbury soil at 4 different soil variants. The values HNO_3 display the pseudo total metal content in soil and the $Ca(NO_3)_2$ values the concentration of the soluble metals which are bioavailable for plants. Values with the same letter are not significant different at the 5 % level.

Table 7. Characteristics of the Canterbury soil. Values with the same letter are not significant different at the 5 % level. The values in brackets are standard error of the mean. Six replicates were used to obtain each mean.

MNs	Treatment	Aqua regia [mg/kg]		$Ca(NO_3)_2$ [mg/kg]	
Ca	**Control**	5889 (389)	a		
	10 % BS	6082 (334)	a		
	20 % BC	6681 (163)	a		
	10 % Biosolids, 20 % Biochar	6693 (216)	a		
Mg	**Control**	2579 (61.2)	a	14.0 (1.4)	a
	10 % BS	2604 (47.1)	a	15.5 (1.3)	a
	20 % BC	2536 (96.4)	a	18.0 (1.4)	a
	10 % Biosolids, 20 % Biochar	2503 (58.9)	a	17.5 (0.89)	a
K	**Control**	2958 (411)	a	15.4 (1.9)	a
	10 % BS	4010 (290)	ab	16.1 (3.8)	a
	20 % BC	4696 (280)	b	24.9 (4.1)	a
	10 % Biosolids, 20 % Biochar	3852 (759)	ab	21.6 (4.9)	a
Na	**Control**	392 (31.0)	a	42.4 (5.1)	a
	10 % BS	417 (26.7)	ab	49.4 (3.6)	ab
	20 % BC	493 (14.2)	c	57.4 (3.0)	b
	10 % Biosolids, 20 % Biochar	480 (12.5)	bc	58.8 (1.2)	b
Fe	**Control**	13662 (44.1)	a	0.43 (0.11)	a
	10 % BS	13853 (51.8)	ab	0.45 (0.08)	a
	20 % BC	14379 (269)	b	0.82 (0.38)	a
	10 % Biosolids, 20 % Biochar	13987 (258)	ab	0.46 (0.10)	a
Cd	**Control**	0.28 (0.01)	a	0.0016 (0.0002)	a
	10 % BS	0.33 (0.02)	a	0.0031 (0.0004)	b
	20 % BC	0.30 (0.02)	a	0.0017 (0.0001)	a

	10 % Biosolids, 20 % Biochar	0.40 (0.02)	b	0.0042 (0.002)	c
Cu	**Control**	7.3 (0.08)	a	0.021 (0.004)	a
	10 % Biosolids	20.0 (4.6)	b	0.032 (0.004)	a
	20 % Biochar	9.0 (0.44)	a	0.021 (0.002)	a
	10 % Biosolids, 20 % Biochar	29.9 (4.0)	c	0.053 (0.004)	b
P	**Control**	596 (7.4)	a	0.54 (0.09)	a
	10 % Biosolids	693 (29.8)	b	0.74 (0.10)	ab
	20 % Biochar	580 (26.9)	a	0.77 (0.17)	ab
	10 % Biosolids, 20 % Biochar	728 (28.6)	b	1.0 (0.09)	b
S	**Control**	246 (5.9)	a	8.5 (1.7)	a
	10 % Biosolids	360 (29.6)	a	10.4 (1.2)	a
	20 % Biochar	308 (33.2)	a	25.9 (9.5)	ab
	10 % Biosolids, 20 % Biochar	584 (80.4)	b	34.9 (7.8)	b
Zn	**Control**	52.1 (1.4)	a	0.14 (0.02)	a
	10 % Biosolids	68.9 (3.9)	b	0.61 (0.14)	b
	20 % Biochar	54.1 (1.3)	a	0.13 (0.03)	a
	10 % Biosolids, 20 % Biochar	88.6 (3.7)	c	1.1 (0.08)	c
		N [%]		**C [%]**	
	Control	0.216 (0.008)	a	3.3 (0.33)	a
	10 % Biosolids	0.268 (0.016)	a	3.7 (0.13)	a
	20 % Biochar	0.245 (0.003)	a	5.0 (0.26)	b
	10 % Biosolids, 20 % Biochar	0.342 (0.027)	b	5.7 (0.44)	b
		pH			
	Control	5.68 (0.08)	a		
	10 % Biosolids	5.57 (0.07)	a		
	20 % Biochar	5.72 (0.11)	a		
	10 % Biosolids, 20 % Biochar	5.59 (0.05)	a		

The use of Biosolids led to an increased concentration of Zn, Cd, Cu, S and P in soil in which the highest enhancement took place at a combination of biosolids and biochar as soil amendment. Almost a tenfold increase in Zn concentration from 0.14 to 1.1 mg/kg ($Ca(NO_3)_2$-extraction) was observed in this soil variant. Carbon and nitrogen are important factors in soil. Carbon is used as an energy producing factor, nitrogen builds tissue. Only the nitrogen content of the 10 % biosolids and 20 % biochar variant is significantly higher than the control. The different soil treatments had no effect on Mg- and Ca-concentration in soil. Biochar alone increased the pseudo total concentration of K and Fe in Canterbury soil. The use of biochar leads certainly to higher carbon contents in soil. The use of biosolids and biochar had no significant impact on pH-value which was moderately acid at all soil variants.

Table 8 shows the characteristics of the Balmoral soil.

Table 8. Characteristics of the Balmoral soil. Values with the same letter are not significant different at the 5 % level. The values in brackets are standard error of the mean. Six replicates were used to obtain each mean.

MNs	Treatment	Aqua regia [mg/kg]		$Ca(NO_3)_2$ [mg/kg]	
Ca	**Control**	1842 (73.2)	a		
	10 % BS	2030 (80.4)	a		
	20 % BC	1966 (81.0)	a		
	10 % Biosolids, 20 % Biochar	2926 (169)	b		
Mg	**Control**	2496 (17.2)	a	7.6 (0.95)	a
	10 % BS	2438 (21.8)	a	10.1 (1.5)	ab
	20 % BC	2427 (33.4)	a	9.2 (0.95)	a
	10 % Biosolids, 20 % Biochar	2416 (34.5)	a	12.7 (0.62)	b
K	**Control**	3488 (337)	a	14.1 (5.9)	a
	10 % BS	2879 (532)	a	14.7 (2.9)	a
	20 % BC	2948 (276)	a	18.0 (6.2)	a
	10 % Biosolids, 20 % Biochar	3074 (605)	a	19.1 (5.1)	a
Na	**Control**	207 (6.6)	a	36.5 (1.7)	a
	10 % BS	233 (27.5)	a	40.0 (3.8)	ab
	20 % BC	237 (14.6)	a	49.4 (4.9)	b
	10 % Biosolids, 20 % Biochar	246 (6.8)	a	48.9 (2.9)	b
Fe	**Control**	18648 (164)	ab	3.6 (0.87)	a
	10 % BS	19363 (806)	b	4.0 (0.42)	a
	20 % BC	18558 (137)	ab	2.8 (0.14)	a
	10 % Biosolids, 20 % Biochar	17838 (164)	a	6.8 (0.48)	b
Cd	**Control**	0.30 (0.01)	a	0.0016 (0.0005)	a
	10 % Biosolids	0.44 (0.02)	b	0.0095 (0.0012)	b
	20 % Biochar	0.29 (0.01)	a	0.0014 (0.0003)	a
	10 % Biosolids, 20 % Biochar	0.47 (0.02)	b	0.0153 (0.0020)	c
Cu	**Control**	4.4 (0.14)	a	0.0085 (0.0009)	a
	10 % Biosolids	35.7 (4.6)	b	0.0727 (0.0106)	b
	20 % Biochar	5.4 (0.57)	a	0.0095 (0.0007)	a
	10 % Biosolids, 20 % Biochar	37.8 (3.4)	b	0.1230 (0.0108)	c
P	**Control**	612 (82.1)	ab	0.55 (0.08)	a
	10 % Biosolids	717 (21.2)	bc	0.89 (0.11)	b
	20 % Biochar	548 (25.6)	a	0.55 (0.06)	a
	10 % Biosolids, 20 % Biochar	846 (45.9)	c	1.2 (0.10)	c

S	**Control**	234 (28.7)	a	11.0 (3.2)	a
	10 % Biosolids	573 (37.7)	b	21.4 (3.1)	a
	20 % Biochar	268 (31.6)	a	15.4 (4.5)	a
	10 % Biosolids, 20 % Biochar	736 (101)	b	45.2 (13.4)	b
Zn	**Control**	53.2 (0.78)	a	0.066 (0.011)	a
	10 % Biosolids	98.7 (5.8)	b	2.4 (0.26)	b
	20 % Biochar	52.0 (0.51)	a	0.075 (0.024)	a
	10 % Biosolids, 20 % Biochar	119 (8.6)	c	3.8 (0.044)	c
		N [%]		**C [%]**	
	Control	0.161 (0.006)	a	2.4 (0.20)	a
	10 % Biosolids	0.275 (0.011)	b	3.9 (0.20)	b
	20 % Biochar	0.182 (0.005)	a	4.3 (0.30)	b
	10 % Biosolids, 20 % Biochar	0.347 (0.012)	c	7.8 (0.28)	c
		pH			
	Control	4.19 (0.02)	a		
	10 % Biosolids	4.23 (0.04)	a		
	20 % Biochar	4.39 (0.04)	b		
	10 % Biosolids, 20 % Biochar	4.23 (0.02)	a		

The Balmoral soil showed similar trends than the Canterbury soil. That means that the use of biosolids also led to an increased concentration of Zn, Cd, Cu, S, Ca and P in soil in which the highest enhancement took place at a combination of biosolids and biochar as soil amendment. The combination of biosolids and biochar also led to an increased concentration of the bioavailable Fe. The different treatments had no effect on pseudo total concentration of Mg and K in Balmoral soil. The biggest difference between Canterbury soil and Balmoral soil was the pH-value and therefore the degree of tendency. For example the Zn concentration ($Ca(NO_3)_2$-extraction) increased from 0.066 mg/kg (control) to 3.8 mg/kg (10 % biosolids, 20 % biochar) which means an almost sixtyfold enhancement of the metal concentration in soil.

Table 9 shows the characteristics of the used Biosolids and biochar.

Table 9. Characteristics of pure biosolids and biochar. The values in brackets are standard error of the mean. Three replicates were used to obtain each mean.

	Biosolids		**Biochar**
	Aqua regia	**$Ca(NO_3)_2$**	**Aqua regia**
Cd [mg/kg]	2.8 (0.02)	0.108 (0.007)	0.12 (0.01)
Cu [mg/kg]	561 (33.1)	2.8 (0.07)	13.9 (5.1)
P [mg/kg]	4683 (2.1)	34.8 (1.2)	491 (2.2)
Pb [mg/kg]	95.6 (3.1)	0.040 (0.006)	1.4 (0.07)
S [mg/kg]	6972 (42.9)	219 (3.1)	288 (12.1)
Zn [mg/kg]	878 (12.9)	46.1 (1.8)	16.4 (1.3)
N [%]	2.5 (0.07)		
C [%]	27.8 (1.5)		
pH	4.05 (0.02)		

3.2 Biomass

Table 10 displays the dry weight of the used crops. Only one value per four treatments shows an average value because no significant difference in biomass was detected.

Table 10: Dry weight at 4 different soil treatments. Values with the same letter are not significant different at the 5 % level. The values in brackets are standard error of the mean.

Species	**Treatment**	**Total dry weight [g]**	**Dry weight of edible portion [g]**
Leek	100 % TS 10 % BS 10 % BS, 20 % BCH 20 % BCH	7.0 (0.61)	2.86 (0.86)
Lettuce	100 % TS 10 % BS 10 % BS, 20 % BCH 20 % BCH	4.1 (0.45)	Same as total
Spinach	100 % TS 10 % BS 20 % BCH 10 % BS, 20 % BCH	3.6 (0.63)	Same as total
Tomatoes	100 % TS 10 % BS 10 % BS, 20 % BCH 20 % BCH	17.2 (0.83)	9.3 (0.48)
Broccoli (Canterbury soil)	100 % TS 10 % BS 10 % BS, 20 % BCH	24.1 (2.6)	1.7 (0.24)

	20 % BCH		
Manuka (Balmoral soil)	100 % TS	12.3 (1.2)	
	10 % BS		
	10 % BS, 20 % BCH		
	20 % BCH		
Sweet corn	100 % TS	81.6 (3.5)	8.8 (3.1) ab
	10 % BS		17.7 (3.0) b
	10 % BS, 20 % BCH		14.6 (3.4) ab
	20 % BCH		6.2 (2.9) a
Grass (Canterbury soil)	100 % TS	5.1 (0.27) a	
	10 % BS	6.9 (0.41) bc	
	10 % BS, 20 % BCH	8.3 (0.58) c	
	20 % BCH	6.1 (0.65) ab	
Grass (Balmoral soil)	100 % TS	10.0 (0.88) a	
	10 % BS	10.7 (0.73) ab	
	10 % BS, 20 % BCH	15.5 (0.86) b	
	20 % BCH	7.5 (0.21) c	
Manuka (Canterbury soil)	100 % TS	4.9 (0.55) a	
	10 % BS	7.3 (1.3) a	
	10 % BS, 20 % BCH	10.7 (1.6) b	
	20 % BCH	6.0 (0.73) a	
Courgette	100 % TS	14.9 (1.4) ab	2.7 (0.90) a
	10 % BS	11.6 (1.4 a	1.7 (0.54) a
	10 % BS, 20 % BCH	15.8 (0.62) b	5.0 (0.40) b
	20 % BCH	13.2 (0.57) ab	2.5 (0.49) a
Radish	100 % TS	2.8 (0.25) a	2.2 (0.18)
	10 % BS	3.9 (0.60) ab	
	10 % BS, 20 % BCH	4.3 (0.49) b	
	20 % BCH	3.9 (0.45) ab	
Carrot	100 % TS	3.1 (0.59) a	2.0 (0.37) a
	10 % BS	6.6 (1.7) ab	3.7 (0.84) ab
	10 % BS, 20 % BCH	7.6 (1.6) b	4.0 (0.75) b
	20 % BCH	5.4 (0.68) ab	3.4 (0.28) ab
Beetroot	100 % TS	4.9 (1.5) a	2.7 (0.76) a
	10 % BS	10.4 (0.61) b	6.4 (0.55) b
	10 % BS, 20 % BCH	9.4 (0.36) b	6.0 (0.19) b
	20 % BCH	9.4 (1.1) b	6.1 (0.79) b
Broccoli (Balmoral soil)	100 % TS	16.7 (1.6) a	2.6 (0.16)
	10 % BS	30.0 (0.44) b	
	10 % BS, 20 % BCH	27.7 (2.3) b	
	20 % BCH	29.6 (1.8) b	

10 % biosolids and 20 % biochar as soil amendment increased the dry weight of grass significant. Biochar alone even led to reduced biomass of grass, grown on Balmoral soil. Full particulars to the developing of grass in point 3.2.1. The best soil variant for manuka (Canterbury soil) was also the use of biosolids and biochar together. Compared to the control, all soil treatments led to an increased dry weight of radish (total) whereas the only significant enhancement was detected at soil treatment 10 % biosolids and 20 % biochar. The same tendency was observed for carrots. All soil treatments affected the biomass of beetroot and broccoli (Balmoral soil) significant. Biochar alone had a negative impact on the biomass of sweet corn cob. Figure 10 shows the Manuka planted in Canterbury soil before harvesting was performed.

Figure 10: Manuka planted in 4 different Canterbury soil treatments (5 replicates; a: control; b: 10 % biosolids; c: 10 % biosolids and 20 % biochar, d: 20 % biochar).

The significant highest total dry weight resulted at soil treatment 10 % biosolids and 20 % biochar. The use of biosolids or biochar alone as soil amendment had no effect on biomass.

3.2.1 Pasture

Figure 11 shows the development of grass planted in Canterbury and Balmoral soil during 3 harvests.

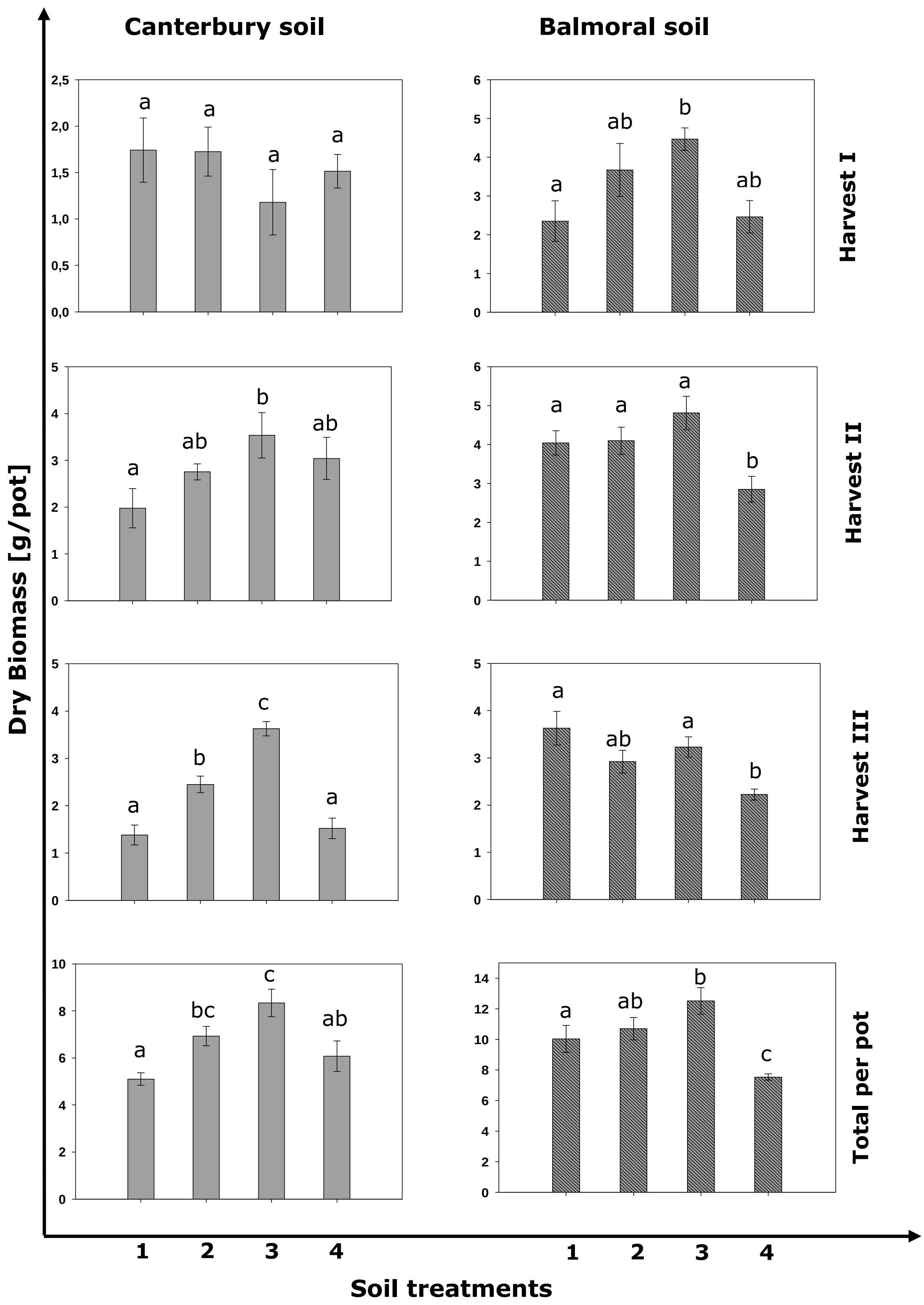

Figure 11: Dry biomass of ryegrass at 4 different soil treatments (1: control; 2: 10 % biosolids; 3: 10 % biosolids and 20 % biochar; 4: 20 % biochar). Values with the same letter are not significant different at the 5 % level.

The biomass of grass planted on Canterbury soil showed no significant difference within the different soil treatments after harvest I. In contrast the biomass of grass planted in Balmoral soil was significant higher at the 10 % biosolids and 20 % biochar variant compared to the control. After harvest II the variant 10 % biosolids and 20 % biochar promoted the growth significant in Canterbury soil and the variant 20 % biochar decreased the biomass in Balmoral soil. 20 % biochar had no impact on biomass at the treatments with Canterbury soil at harvest III. However, the biochar alone had a negative effect on biomass using Balmoral soil. Biosolids promoted the biomass production in the treatments with Canterbury soil. The best growth in Canterbury soil was reached using biosolids and biochar together. However the biomass of the control variant (Balmoral soil) after harvest III was higher than the other treatments. The general tendency was that biosolids promotes the plant growth. The highest production of biomass was reached using 10 % biosolids and 20 % biochar. The yield was higher using Balmoral soil for the treatments.

3.3 Biofortification of TEMs (Cu, Zn) and HMs (Cd)

The following tables (11-21) represent the progress of the key-trace element micronutrients (Cu, Zn) and the heavy metal Cd, within one crop where significant variations between the 4 soil treatments were noticeable. Copper and Zn are two major elements which are often deficient in New Zealand's soils and therefore main focus in this chapter. The progress of Cd during different soil treatments is also important because of the possibility of Cd contamination using biosolids as soil amendment. An enhancement of Pb concentration due to the use of biosolids was not detectable. Lettuce and spinach did not grow proper and therefore no statistical analysis was possible. So these two crops are not displayed in the following tables. The biofortification of metals in grass is shown in point 3.4. No enhancement of Cd-, Cu- or Zn absorption in corn and broccoli (Canterbury soil) at any soil treatment was detectable. Values with the same letter are not significant different at the 5 % level.

The Cu-concentration in radish bulbs (see table 11) was only significantly higher in soil variant 10 % biosolids. All soil treatments led to a significant enhancement of Zn-concentration but 10 % biosolids had the biggest impact on Zn-accumulation.

Table 11. Concentrations [mg/kg] of mineral nutrients in radish bulbs at 4 different soil treatments. Values with the same letter are not significant different at the 5 % level. The values in brackets are standard error of the mean.

MNs	100 % Topsoil		10 % Biosolids		20 % Biochar		10 % Biosolids 20 % Biochar	
Cu	2.6 (0.29)	a	3.9 (0.24)	b	2.9 (0.23)	a	3.1 (0.12)	a
Zn	32.9 (1.4)	a	111 (6.5)	b	54.4 (11.1)	c	84.4 (4.9)	d

The metal accumulation in the radish leaves (see table 12) followed the same trend as the bulbs, but with higher (~1.5 times) total concentration. The Cd- and Cu concentrations were only significantly higher in soil variant 10 % biosolids. Biochar alone had no impact on metal accumulation.

Table 12. Concentrations [mg/kg] of mineral nutrients in radish leaves at 4 different soil treatments. Values with the same letter are not significant different at the 5 % level. The values in brackets are standard error of the mean.

MNs	100 % Topsoil		10 % Biosolids		20 % Biochar		10 % Biosolids 20 % Biochar	
Cd	0.38 (0.04)	a	0.50 (0.03)	b	0.41 (0.03)	ab	0.45 (0.02)	ab
Cu	3.9 (0.20)	a	5.6 (0.86)	b	4.1 (0.30)	ab	5.2 (0.27)	ab
Zn	53.7 (7.2)	a	191 (20.4)	b	55.9 (11.4)	a	139 (12.0)	c

The soil variant 10 % biosolids was the only way to increase the Cu-concentration in courgettes (see table 13) significant. For a raise of Zn in courgettes the use of biosolids and in combination with biochar was successful.

Table 13. Concentrations [mg/kg] of mineral nutrients in courgettes at 4 different soil treatments. Values with the same letter are not significant different at the 5 % level. The values in brackets are standard error of the mean.

MNs	100 % Topsoil		10 % Biosolids		20 % Biochar		10 % Biosolids 20 % Biochar	
Cu	7.5 (0.61)	a	9.4 (0.64)	b	8.0 (0.22)	ab	8.8 (0.30)	ab
Zn	55.2 (3.1)	a	83.2 (1.7)	b	54.2 (1.7)	a	83.9 (1.7)	b

Biosolids advanced the Cd- and Zn-concentration in pealed beet bulbs (see table 14). However, 20 % biochar as soil addition significantly decreased the Cu concentration.

Table 14. Concentrations [mg/kg] of mineral nutrients in Beets (pealed bulbs) at 4 different soil treatments. Values with the same letter are not significant different at the 5 % level. The values in brackets are standard error of the mean.

MNs	100 % Topsoil		10 % Biosolids		20 % Biochar		10 % Biosolids 20 % Biochar	
Cd	0.18 (0.02)	a	0.36 (0.05)	b	0.12 (0.01)	a	0.33 (0.03)	b
Cu	7.0 (0.44)	a	8.0 (0.78)	a	5.4 (0.32)	b	7.4 (0.29)	a
Zn	68.5 (5.5)	a	215 (21.2)	b	35.1 (4.1)	a	178 (10.9)	b

Biosolids alone and in combination with biochar as soil conditioner enhanced the metal concentration in beet leaves (see table 15) essential. Biochar alone had no effect on metal absorption. The Zn accumulation in the leaves was extremely high (almost sevenfold higher) using biosolids as soil amendment.

Table 15. Concentrations [mg/kg] of mineral nutrients in Beets (Leaves) at 4 different soil treatments. Values with the same letter are not significant different at the 5 % level. The values in brackets are standard error of the mean.

MNs	100 % Topsoil		10 % Biosolids		20 % Biochar		10 % Biosolids 20 % Biochar	
Cd	0.78 (0.12)	a	3.4 (0.40)	b	1.0 (0.11)	a	2.8 (0.06)	b
Cu	5.0 (0.74)	a	10.8 (1.8)	b	5.5 (0.38)	a	13.8 (0.71)	b
Zn	179 (25.2)	a	1178 (89.5)	b	201 (8.48)	a	1200 (74.0)	b

Biosolids also influenced the Cu- and Zn-absorption of tomatoes (see table 16). Biochar alone had no effect on metal absorption and the highest accumulation took place using biosolids and biochar together.

Table 16. Concentrations [mg/kg] of mineral nutrients in tomatoes at 4 different soil treatments. Values with the same letter are not significant different at the 5 % level. The values in brackets are standard error of the mean.

MNs	100 % Topsoil		10 % Biosolids		20 % Biochar		10 % Biosolids 20 % Biochar	
Cu	5.5 (0.13)	a	7.3 (0.27)	b	6.0 (0.32)	a	8.1 (0.14)	c
Zn	16.5 (0.53)	a	22.9 (1.1)	b	16.0 (1.3)	a	26.4 (2.0)	b

10 % biosolids as soil conditioner enhanced the Cd- and Zn-concentration of the carrots (see table 17) significant. Biochar alone and in combination with biosolids had no significant impact on cadmium and Zn accumulation.

Table 17. Concentrations [mg/kg] of mineral nutrients in carrots at 4 different soil treatments. Values with the same letter are not significant different at the 5 % level. The values in brackets are standard error of the mean.

MNs	100 % Topsoil		10 % Biosolids		20 % Biochar		10 % Biosolids 20 % Biochar	
Cd	0.26 (0.05)	a	0.64 (0.13)	b	0.20 (0.03)	a	0.39 (0.06)	a
Zn	29.7 (3.1)	ab	68.0 (12.7)	c	25.3 (0.98)	a	50.1 (5.1)	bc

The Cu- and Zn- concentration in leek (see table 18) were only enhanced at soil variant 10 % biosolids and 20 % biochar. Biosolids or biochar alone as soil amendment had no influence on metal absorption.

Table 18. Concentrations [mg/kg] of mineral nutrients in leek (bulbs) at 4 different soil treatments. Values with the same letter are not significant different at the 5 % level. The values in brackets are standard error of the mean.

MNs	100 % Topsoil		10 % Biosolids		20 % Biochar		10 % Biosolids 20 % Biochar	
Cu	3.7 (0.28)	a	2.9 (0.34)	a	2.9 (0.51)	a	5.7 (0.68)	b
Zn	15.5 (1.1)	a	20.4 (5.0)	a	19.7 (1.5)	a	29.8 (3.2)	b

Only 2 of 3 broccoli replicates at the control variant (100 % Balmoral soil) grew successfully. Therefore the data of this variant were not reliable enough for statistic analysis and were left out. Using biosolids as soil additive led to a significant higher concentration of cadmium, copper and Zn compared to the use of only biochar (see table 19). Because no values of the control variant are available no prediction if biochar had an impact on metal accumulation is possible.

Table 19. Concentrations [mg/kg] of mineral nutrients in Broccoli, Balmoral soil at 3 different soil treatments. Values with the same letter are not significant different at the 5 % level. The values in brackets are standard error of the mean.

MNs	10 % Biosolids		20 % Biochar		10 % Biosolids 20 % Biochar	
Cd	0.15 (0.02)	a	0.06 (0.007)	b	0.16 (0.02)	a
Cu	14.6 (0.44)	a	4.6 (0.23)	b	13.6 (0.85)	a
Zn	178 (20.7)	a	61.5 (6.4)	b	143 (15.7)	a

Table 20 represents the Cu- and Zn-concentration of Manuka, planted in Canterbury soil. Biosolids alone as well as together with biochar led to a significant enhancement of the metal concentration in the plant. The lowest metal concentration was detected in plants grew at soil treatment 20 % Biochar.

Table 20. Concentrations [mg/kg] of mineral nutrients in Manuka, Canterbury soil at 4 different soil treatments. Values with the same letter are not significant different at the 5 % level. The values in brackets are standard error of the mean.

MNs	100 % Topsoil		10 % Biosolids		20 % Biochar		10 % Biosolids 20 % Biochar	
Cu	6.9 (0.32)	a	11.7 (1.3)	b	6.3 (0.37)	a	12.0 (1.4)	b
Zn	47.2 (2.5)	a	78.7 (6.7)	b	35.3 (2.2)	a	64.8 (6.7)	b

The use of biosolids increased the Cd-, Cu- and Zn-concentration in Manuka, Balmoral soil (see table 21). Biochar alone had no influence on metal accumulation. The highest metal absorption of Manuka took place at variant 10 % biosolids. It is noticeable that the accumulated Zn was much higher than in Manuka planted in Canterbury soil (see table 19).

Table 21. Concentrations [mg/kg] of mineral nutrients in Manuka, Balmoral soil 4 different soil treatments. Values with the same letter are not significant different at the 5 % level. The values in brackets are standard error of the mean.

MNs	100 % Topsoil		10 % Biosolids		20 % Biochar		10 % Biosolids 20 % Biochar	
Cd	0.14 (0.03)	a	0.45 (0.13)	b	0.08 (0.01)	a	0.29 (0.02)	ab
Cu	6.5 (0.40)	a	12.5 (0.70)	b	7.0 (0.47)	a	12.3 (1.6)	b
Zn	35.5 (4.1)	a	220 (27.9)	b	26.3 (2.3)	a	206 (20.3)	b

3.4 The progress of MNs in pasture within 3 harvests

The following figures (12-21) display elements in pasture, which underwent a change in concentration during 3 harvests within 2 months. Figure 12 shows the developing of Zn-concentration during 2 months. The use of biosolids alone and in combination with biochar as additive to Canterbury or Balmoral soil significantly increased the Zn-concentration. The increase was much greater using Balmoral soil for the variants. Using Canterbury soil, the Zn-concentration decreased within the 3 harvests. The Zn-concentration stayed nearly equal using Balmoral soil. Biochar alone had no effect on Zn-absorption in pasture.

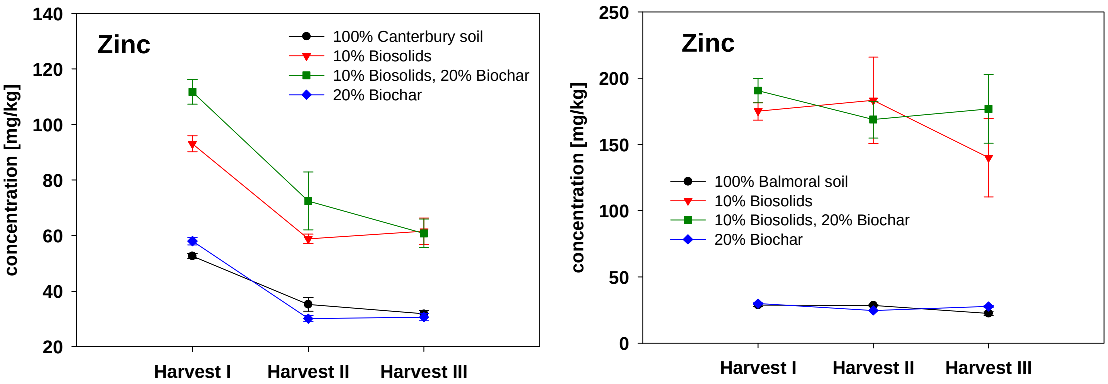

Figure 12: The progress of Zn-concentration in grass during 2 months. The left figure shows the variants used Canterbury soil the right one used Balmoral soil.

Figure 13 shows the developing of Cd-concentration in pasture during 2 months. At harvest I (Canterbury soil) only biosolids and biochar together increased the Cd-concentration significant. The other two soil treatments had no influence on Zn-accumulation. The Cd-concentration in Canterbury soil reduced within the three harvests. After harvest III the Cd-concentrations of the different soil treatments (Canterbury soil) were nearly the same. Applying Balmoral soil, Biosolids alone and in combination with biochar increased the Cd-concentration significant. After harvest III the Cd-concentrations were higher than at the beginning. Biochar alone had no big effect on Cd-absorption neither using Canterbury soil nor using Balmoral soil.

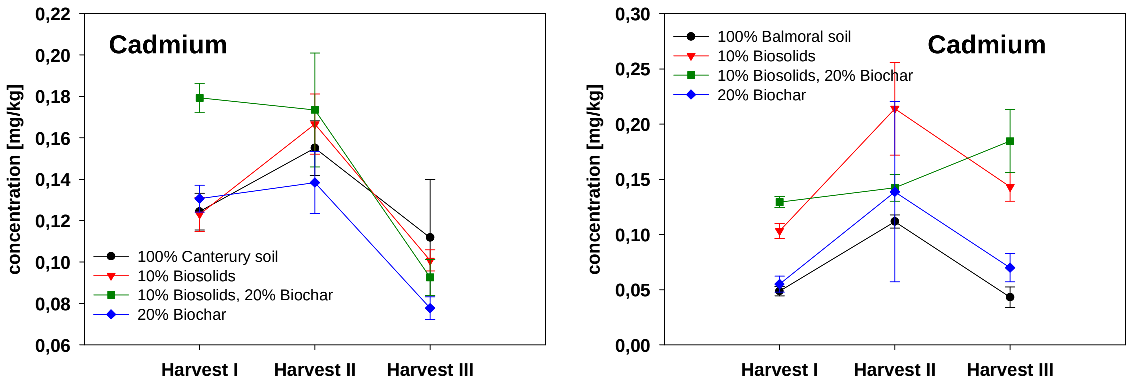

Figure 13: The progress of Cd-concentration in grass during 2 months. The left figure shows the variants used Canterbury soil the right one used Balmoral soil.

Figure 14 shows the developing of Cu-concentration in pasture during 2 months. Biosolids significantly increased the Cu-concentration. The Cu-concentration reduced within the 3 harvests in all soil treatments using Canterbury soil and also in the biosolids treatments using Balmoral soil. Only the control and the 20 % biochar variant (both using Balmoral soil) did not reduce the Cu-concentration during the 3 measurements.

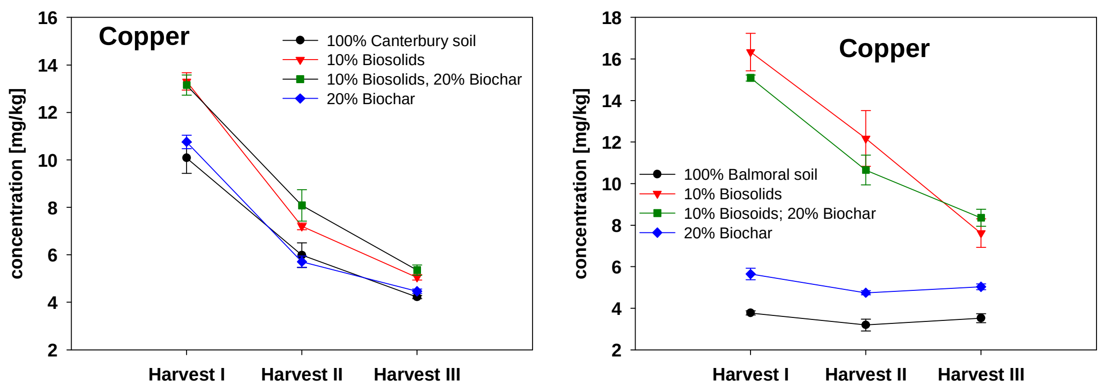

Figure 14: The progress of Cu-concentration in grass during 2 months. The left figure shows the variants used Canterbury soil the right one used Balmoral soil.

Figure 15 shows the developing of the K-concentration in pasture during 2 months. The different soil treatments had no big effect on K-absorption. The K-concentration decreased in all cases in the course of the time.

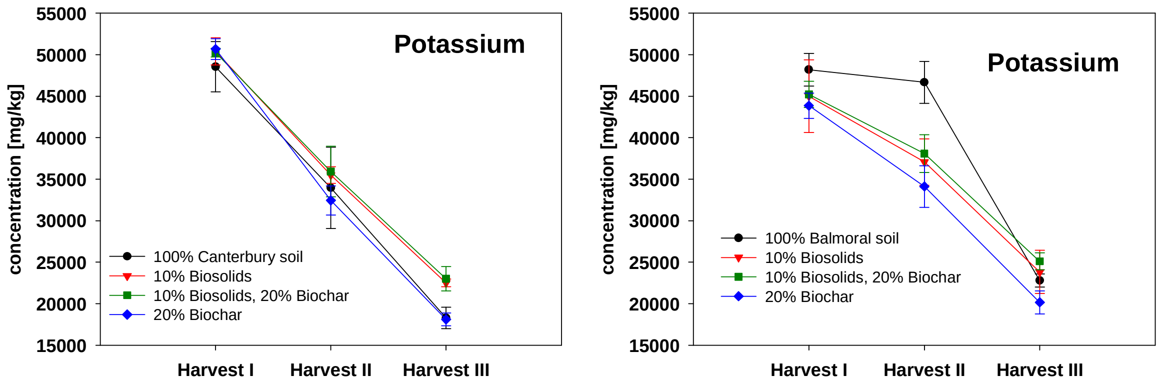

Figure 15: The progress of K-concentration in grass during 2 months. The left figure shows the variants used Canterbury soil the right one used Balmoral soil.

Figure 16 shows the developing of the nitrogen-content in pasture during 2 months. Using Canterbury soil, all soil treatments increased the nitrogen-content significant compared to the control at harvest I. Using Balmoral soil, the soil treatments had no big influence on nitrogen-content in pasture. The nitrogen-content decreased in all cases in the course of the time and finally all contents were nearly the same.

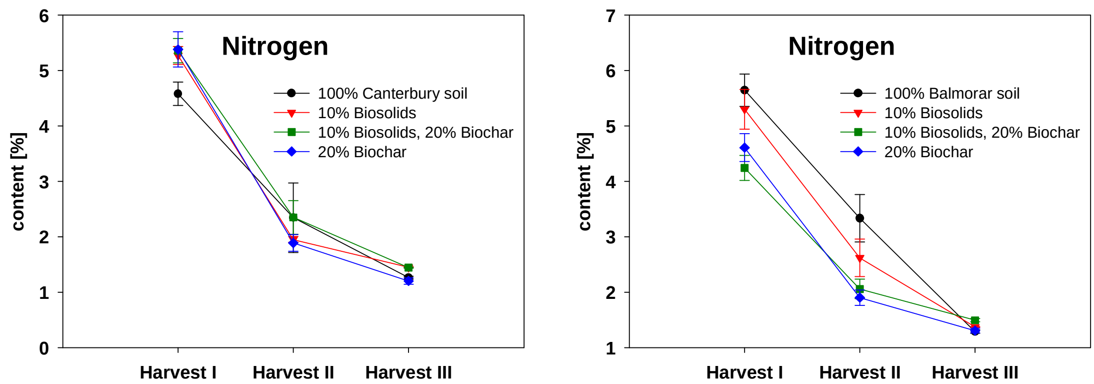

Figure 16: The progress of nitrogen-content in grass during 2 months. The left figure shows the variants used Canterbury soil the right one used Balmoral soil.

Figure 17 shows the developing of the P-concentration in pasture during 2 months. Using Canterbury soil, biosolids increased the P-concentration significant but the difference to the control variant decreased in the course of time. Biochar alone had no big effect on P-absorption using Canterbury soil. The P-concentration at soil treatments control, 10 % biosolids and 20 % biochar using Balmoral soil reduced steady. Only biosolids and biochar in combination as additive to Balmoral soil led to a rise of the P-concentration-curve in the course of time. However, finally the P-concentrations of all soil treatments using Balmoral soil were significant higher than in control.

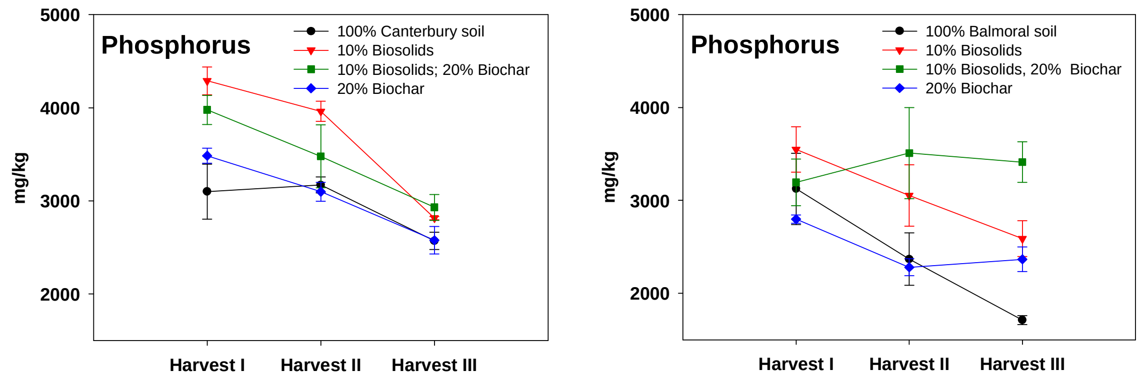

Figure 17: The progress of P-concentration in grass during 2 months. The left figure shows the variants used Canterbury soil the right one used Balmoral soil.

Figure 18 shows the developing of the S-concentration in pasture during 2 months. Using Canterbury soil the soil treatments had no significant influence on S-absorption. The S-concentrations in all Canterbury variants increased from the beginning to harvest III to a significant higher value. All soil treatments using Balmoral soil increased the S-absorption furthermore the trend increased over time.

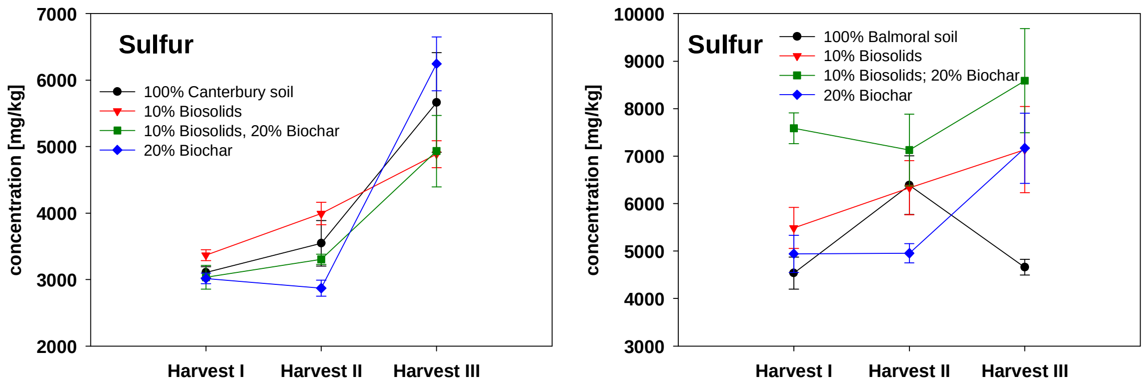

Figure 18: The progress of S-concentration in grass during 2 months. The left figure shows the variants used Canterbury soil the right one used Balmoral soil.

Figure 19 shows the developing of the Ca-concentration in pasture during 2 months. The Ca-concentrations increased in all cases within the 3 measurements. After harvest III the Ca-concentration in biosolids treatments using Canterbury soil was significant lower than in control and variant 20 % biochar. Using Balmoral soil all soil treatments increased the Ca-concentration compared with the control in a similar way.

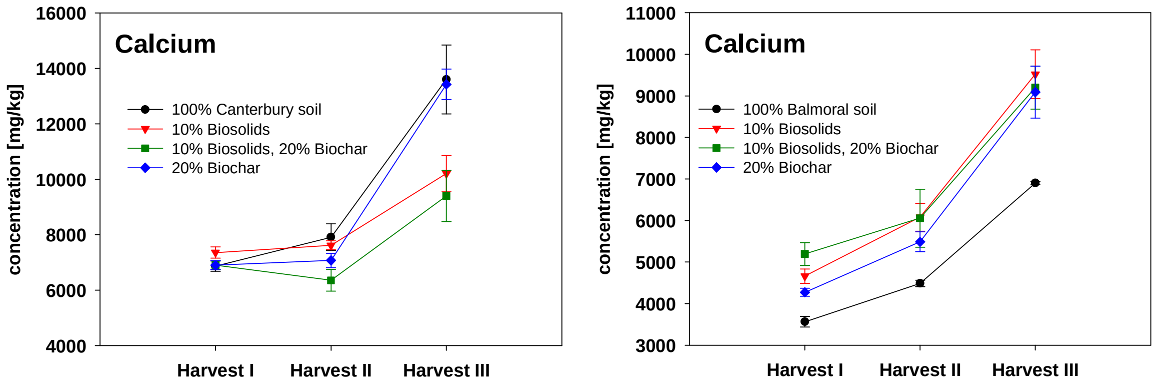

Figure 19: The progress of Ca-concentration in grass during 2 months. The left figure shows the variants used Canterbury soil the right one used Balmoral soil.

Figure 20 shows the developing of the Mn-concentration in pasture during 2 months. After harvest III the Mn-concentrations in all variants were significant higher compared to the beginning. 10 % biosolids and 20 % biochar together additional to Canterbury soil led to a reduction of the Mn-concentration. Using Balmoral soil 20 % biochar as soil conditioner led to the highest enhancement of Mn. Using either Canterbury soil or Balmoral soil led to a huge difference in Mn-concentration.

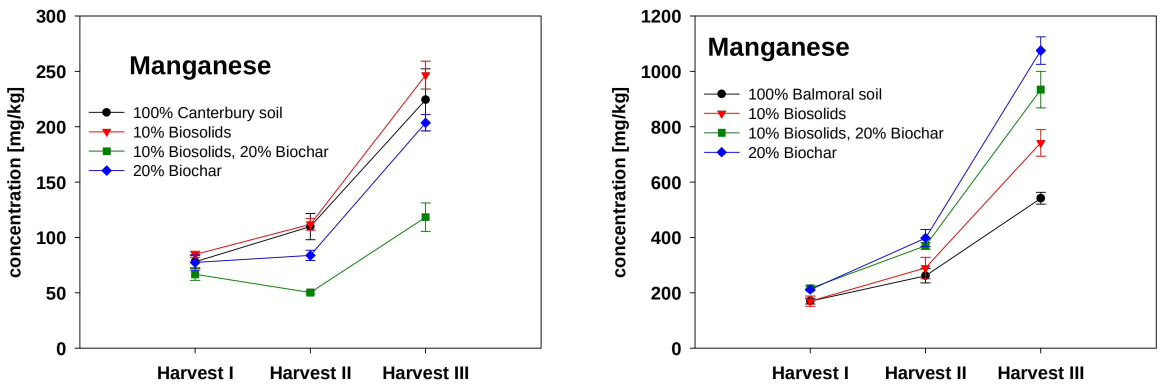

Figure 20: The progress of Mn-concentration in grass during 2 months. The left figure shows the variants used Canterbury soil the right one used Balmoral soil.

Figure 21 shows the developing of the Na-concentration in pasture during 2 months. Using 10 % biosolids additional to Canterbury soil the treatment decreased the concentration. As longer the grass grew in Canterbury soil as higher was the Na-concentration. Within all Balmoral-treatments the Na-concentration did not change significantly from harvest I to III. After harvest III (Canterbury soil as well as Balmoral soil) the variants with 20 % biochar showed the highest Na-values.

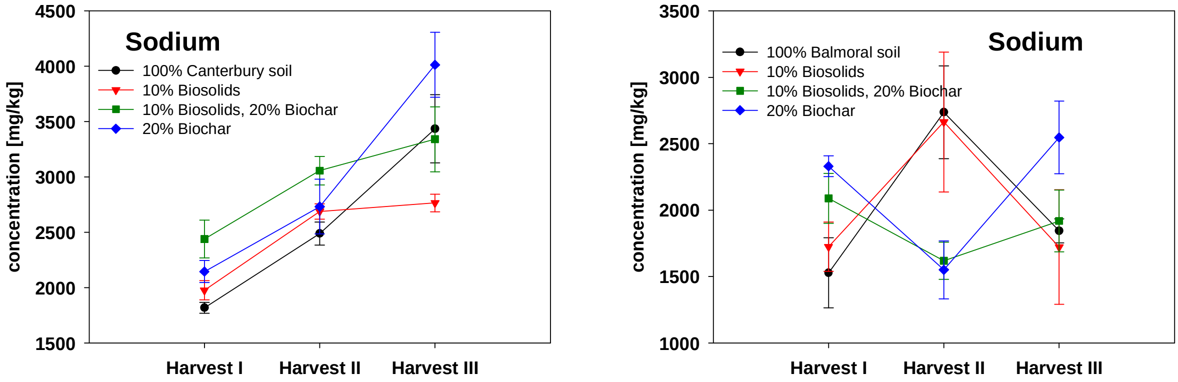

Figure 21: The progress of Na-concentration in grass during 2 months. The left figure shows the variants used Canterbury soil the right one used Balmoral soil.

3.5 Health concerns

Cadmium is toxic for animals and humans even at low concentrations and therefore considered an environmental contaminant. Figure 22 shows the correlation between Zn and Cd of all planted crops.

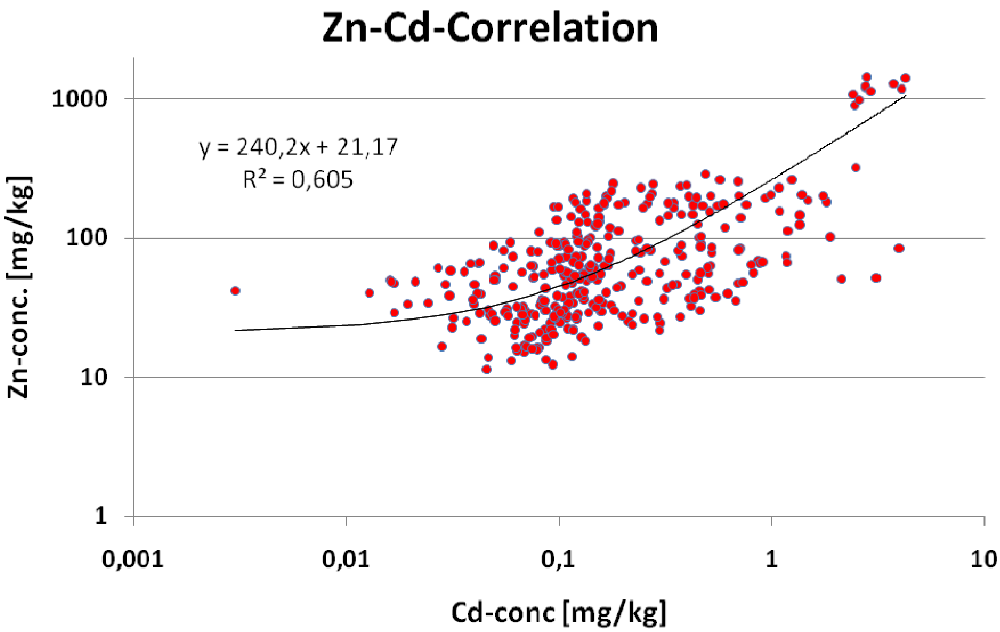

Figure 22: Zinc-cadmium-correlation

Cadmium is strongly associated with Zn in its geochemistry and therefore quite similar in chemical behaviour. Cadmium and Zn belongs to mobile, relative easily displaceable and available metals. The higher the Cd concentration in the plants the higher their Zn concentration. The measured correlation between Zn and Cd was 0.778.

4. Discussion and conclusion

The use of Biosolids led to an increased concentration of some metals in soil in which the highest enhancement took place at a combination of biosolids and biochar as soil amendment. Balmoral soil was acid (pH-value ~ 4) compared to Canterbury soil and therefore the degree of tendency was much higher which led to an almost sixtyfold increase of the bioavailable Zn concentration in soil. A reason for this phenomenon could be because of the lower pH value, more cation exchange sites are occupied by H^+, which leads to reducing the soil ability to adsorb cations. This means that cationic elements, such as Ni^{2+}, Zn^{2+} and Cd^{2+} become more mobile on the soil profile, increasing the risk of leaching or plant uptake. However, the maximum metal concentration in soil for agricultural purpose according to the Canadian Guidelines (Zn: 200 mg/kg; Cd: 1.4 mg/kg) were not reached with the application of biosolids.

The different soil treatments had no impact on the biomass of leek, lettuce, spinach, tomatoes, broccoli (Canterbury soil), manuka (Balmoral soil), radish bulbs and sweet corn (total). However, Chan et al. (2008) reported about pot trial results, where the application of biochar significantly improved the yield of radish. Steinbeiss et al. (2009) also reported about improvement of soil fertility resulting in increased crop yields on agricultural lands when using biochar as soil amendment. The nutrient content in the control soil was apparently sufficient for adequate plant growth and no improvement of soil texture due to the soil treatments necessary. No increased absorption of essential plant nutrients (Cu and Zn) or heavy metals (e.g. Cd) in corn and broccoli (Canterbury soil) was detectable at the use of biosolids and/or biochar. Lettuce and spinach did not grow proper in general. Maybe the applied seeds were useless. The size of the plant pots was too small for some plants, especially for corn. Therefore the plant growth would definitely differ in the nature. After the third harvest III of ryegrass planted in Balmoral soil, the control variant showed the highest dry biomass. A possible explanation could be an occurred toxication of metals because of the low pH-value.

Biochar alone had no effect on biofortification of metals in plants. But according to Hossain et al. (2010), the application of biochar to the soil should improve the availability of phosphorus, total nitrogen and major cations. This effect was only present using biochar in combination with biosolids or biosolids alone. Singh and Agrawal (2007) found also increased concentrations of Pb, Cr, Cd, Cu, Zn and Ni in Beta vulgaris when grown in a greenhouse environment with sewage sludge amended soil. The Zn concentration in the leaves of beetroot (10 % biosolids and 20 % biochar) showed the highest measured value (1200 mg/kg dry weight). The accumulation was more in the leaves than in bulbs. The measured Zn concentration was more than ten times higher than the concentration of healthy leaves, which is 15-100 mg/kg (Robson, 1993). The tolerable upper Zn intake level for adults is 40 mg/day (WHO, 2010). This level would be reached by eating 33 g dry weight of the biofortified beet leaves. The dry matter of the beetroot leaves was 10 % and therefore 330 g fresh leaves could be eaten before reaching the tolerable upper Zn intake level for adults. Because of the high Zn accumulation it may be concluded that beetroot is not a suitable vegetable to be grown under biosolids amendment.

Although Cd is considered to be a non-essential element, it is effectively absorbed by root and leaf systems via the same pathway than Zn because of chemical similarity (Kabata-Pendias and Pendias, 1992). The uptake and translocation of Zn by plants is higher than that of Cd, which means that Cd accumulates more in roots whereas Zn can be translocated to the shoots where it may be required for several metabolic functions (Chakravarty and Srivastava, 1997). Cadmium is already at lower concentrations toxic than Zn and therefore a heavy metal which needs to be monitored at the use of biosolids as soil amendment. The question is if the benefit of increased essential Zn offset by increased contaminant Cd. The highest Cd concentration was detected in the beetroot leaves (3.4 mg/kg dry weight) when using 10 % biosolids as soil amendment. The US tolerable daily intake of Cd is 50 µg for adults. This level would be reached by eating 147 g fresh beet leaves.

As the results show, biosolids has the potential for an effective and cheap alternative to commercial fertilizer for agricultural applications. Biochar has absorptive properties and could reduce leakage of those elements which had been mobilized because of complexation by the organic components deriving from biosolids. Maybe the observed positive effect on plant biomass gain was caused by the synergistic interactions of the two amendments. In other words, biosolids made the elements bioavailable, biochar kept them in place until uptake by the roots.

The question is how long an application of biosolids would be possible until the maximum concentration of Cd (1 mg/kg) allowed in agricultural soils in New Zealand would be reached, compared to the application of super phosphate fertiliser.

Following data were taken for the calculations:

- Soil density of silt loam: 1.3 (McLaren and Cameron, 1996)
- Soil mixing depth: 0,10 m
- Soil weight 1300 t (0.1 * 1 ha * 1,3)
- Background Cd: 0.1 mg/kg
- Background Zn: 53 mg/kg
- Background Cu: 15 mg/kg
- Background Pb: 20 mg/kg

(Percival et al., 1995)

- Application rate Fertiliser: 50 kg P/ha; 250 mg Cd/kg P; 9.1 % P in Fertiliser
- Maximum Rate of 200 kg N/ha/year if biosolids were used

Super Phosphate Fertiliser could be applied for 94 years until the threshold concentration of cadmium would be reached. If biosolids would be applied at a maximum nitrogen rate of 200 kg/ha/yr, the allowed cadmium threshold would be reached after 52 years. The cadmium threshold would be already reached after 39 years if biosolids would be applied in an amount to give the same P as with the fertiliser. Table 22 shows how long an application of biosolids would be possible until the maximum allowed concentrations of Cu, Pb and Zn would be reached.

Table 22: Years of application until threshold values are reached

Metal	Soil limits [mg/kg] (Global Atlas of E.,W.,S.,B.M., 2008)	Biosolids, to give same P as with Fertiliser	Biosolids, at a maximum N rate
		YEARS	
Cu	100	19	24
Pb	300	357	476
Zn	300	34	45

The threshold of Cu would be already reached after 19 years which is unfortunately a very short period of time. Another concern at application of biosolids is the possibility of contamination with pathogens. For protecting the environment and human health, thresholds concerning this matter are given. The analysis of possible contamination with pathogens because of the use of biosolids was no issue of this work but would be informative for further steps in this project.

Parallel to this work, more projects to the topic "biofortification of trace elements" are running at Lincoln University. One project deals with the possibility of heavy metal leaching in ground water when using biosolids as soil amendment. The aim of another project is to detect how long the increased Zn concentration in sheep blood serum consists when feeding with biofortified pastures compared to drenched sheep. The ryegrass, planted for this thesis is still growing in the pots and further samples will be taken and analysed for monitoring the further progress of the elements. All results together should give exploration if the benefits of using biosolids overbalance the resulting drawbacks.

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Appendix

Table 23. Summary of all measured data (mg/kg) via ICP-OES

Plant	Soil	Soil variant	Rep	Al	As	B	Ca	Cd	Co	Cr
Grass, I	Cant	100% TS	1	101,15	0,44	22,57	6570	0,14	0,12	0,34
Grass, I	Cant	100% TS	2	206,02	0,24	56,52	7315	0,15	0,13	0,39
Grass, I	Cant	100% TS	3	90,87	0,25	40,90	7322	0,10	0,13	0,34
Grass, I	Cant	100% TS	4	56,44	0,32	21,06	6555	0,11	0,12	0,25
Grass, I	Cant	100% TS	5	50,81	0,27	24,05	6551	0,11	0,12	0,28
Grass, I	Cant	10% BS	1	81,27	0,74	27,57	7515	0,14	0,09	0,32
Grass, I	Cant	10% BS	2	105,37	0,42	27,83	6972	0,13	0,15	0,46
Grass, I	Cant	10% BS	3	42,71	0,68	22,50	7894	0,14	0,13	0,33
Grass, I	Cant	10% BS	4	58,63	<DL	22,77	6808	0,10	0,12	0,23
Grass, I	Cant	10% BS	5	81,03	0,64	22,52	7590	0,11	0,10	0,32
Grass, I	Cant	10% BS, 20% BCH	2	41,01	0,55	21,79	7203	0,18	0,08	0,21
Grass, I	Cant	10% BS, 20% BCH	4	23,94	0,57	24,29	6693	0,17	0,10	0,21
Grass, I	Cant	10% BS, 20% BCH	5	36,63	0,58	20,46	6814	0,19	0,11	0,29
Grass, I	Cant	20% BCH	1	36,28	0,45	24,82	6697	0,11	0,11	0,18
Grass, I	Cant	20% BCH	2	56,63	0,50	41,34	7286	0,14	0,13	0,26
Grass, I	Cant	20% BCH	3	33,52	0,38	18,90	6563	0,13	0,08	0,24
Grass, I	Cant	20% BCH	4	25,43	0,52	31,47	7300	0,13	0,12	0,18
Grass, I	Cant	20% BCH	5	43,00	0,52	44,19	6643	0,15	0,12	0,22
Grass, I	Balm	100% TS	1	49,48	<DL	14,77	3817	0,04	0,56	0,22
Grass, I	Balm	100% TS	2	54,50	0,27	12,48	3477	0,05	0,37	0,20
Grass, I	Balm	100% TS	3	79,47	0,13	22,21	3397	0,06	0,78	0,29
Grass, I	Balm	10% BS	1	49,14	<DL	12,12	5004	0,09	0,45	0,23
Grass, I	Balm	10% BS	2	47,43	0,20	11,95	4437	0,12	0,45	0,23
Grass, I	Balm	10% BS	3	37,18	0,29	10,40	4541	0,10	0,46	0,21
Grass, I	Balm	10% BS, 20% BCH	1	42,56	<DL	13,34	4889	0,13	0,47	0,20
Grass, I	Balm	10% BS, 20% BCH	2	38,81	0,45	14,09	4954	0,12	0,44	0,23
Grass, I	Balm	10% BS, 20% BCH	3	36,21	0,78	25,82	5738	0,13	0,47	0,20
Grass, I	Balm	20% BCH	1	33,16	0,33	13,43	4140	0,05	0,53	0,18
Grass, I	Balm	20% BCH	2	45,88	<DL	12,98	4463	0,05	0,51	0,23
Grass, I	Balm	20% BCH	3	34,25	0,25	21,77	4216	0,07	0,58	0,18
Radish	Cant	100% TS	1	18,55	0,35	24,02	4052	0,11	0,11	0,45
Radish	Cant	100% TS	2	26,58	0,33	31,22	3369	0,07	0,07	0,32
Radish	Cant	100% TS	3	28,21	<DL	28,05	4251	0,11	0,16	0,25
Radish	Cant	100% TS	4	99,77	0,45	27,63	5601	0,11	0,10	0,58
Radish	Cant	100% TS	5	25,36	0,46	26,40	3512	0,10	0,09	0,62
Radish	Cant	10% BS	1	36,11	0,34	26,47	4021	0,12	0,17	0,74
Radish	Cant	10% BS	2	29,97	0,44	23,61	3679	0,12	0,10	2,34
Radish	Cant	10% BS	3	16,93	0,28	26,97	3861	0,12	0,04	0,47
Radish	Cant	10% BS	4	29,27	0,23	26,55	3974	0,15	0,09	0,49
Radish	Cant	10% BS	5	48,43	0,49	26,48	5020	0,16	0,07	2,54
Radish	Cant	10% BS, 20% BCH	1	42,40	<DL	24,00	2890	0,13	0,08	0,58
Radish	Cant	10% BS, 20% BCH	2	29,53	0,27	24,35	3569	0,09	0,04	0,44
Radish	Cant	10% BS, 20% BCH	3	27,72	0,16	24,50	4745	0,23	0,06	0,21
Radish	Cant	10% BS, 20% BCH	4	19,04	0,35	24,00	4022	0,11	<DL	0,25
Radish	Cant	10% BS, 20% BCH	5	47,94	0,28	23,94	3587	0,12	0,09	0,29
Radish	Cant	20% BCH	1	41,08	<DL	24,56	4479	0,12	0,09	0,37
Radish	Cant	20% BCH	2	37,53	<DL	25,11	4513	0,13	0,12	1,30

Plant	Soil	Soil variant	Rep	Al	As	B	Ca	Cd	Co	Cr
Radish	Cant	20% BCH	3	33,88	<DL	22,02	3641	0,11	0,06	0,17
Radish	Cant	20% BCH	4	54,56	0,49	25,84	3571	0,08	<DL	0,79
Radish	Cant	20% BCH	5	39,14	0,29	26,49	3745	0,09	0,09	0,30
Radish	Cant	20% BCH	3	31,41	<DL	24,17	3738	0,13	0,12	0,20
Lettuce	Cant	100% TS	4	280,46	0,64	30,10	11400	0,51	0,08	0,47
Lettuce	Cant	100% TS	5	128,33	0,45	30,94	10752	0,69	0,08	0,31
Lettuce	Cant	10% BS	2	70,95	0,46	25,94	8976	0,46	0,05	0,41
Lettuce	Cant	10% BS	3	333,14	0,70	27,89	11045	1,37	0,26	0,97
Lettuce	Cant	10% BS	5	241,55	0,35	21,75	7729	0,42	0,14	0,42
Lettuce	Cant	10% BS, 20% BCH	1	159,14	0,66	30,28	10585	1,37	0,07	1,00
Lettuce	Cant	10% BS, 20% BCH	3	276,07	0,69	26,95	11587	1,81	0,11	0,66
Lettuce	Cant	10% BS, 20% BCH	4	119,82	0,83	25,35	10124	1,48	0,10	0,49
Lettuce	Cant	10% BS, 20% BCH	5	153,04	0,50	26,57	11401	1,20	0,05	0,49
Lettuce	Cant	20% BCH	2	216,41	0,57	29,36	11952	0,87	0,16	0,65
Lettuce	Cant	20% BCH	4	100,77	0,45	29,40	8657	0,68	0,07	0,36
Radish Leaves	Cant	100% TS	1	407,19	0,87	34,00	41705	0,36	0,25	0,89
Radish Leaves	Cant	100% TS	2	189,96	1,08	48,33	47152	0,27	0,11	0,78
Radish Leaves	Cant	100% TS	3	104,08	0,67	45,21	40768	0,50	0,18	1,19
Radish Leaves	Cant	100% TS	4	235,20	0,83	48,12	41828	0,32	0,10	0,65
Radish Leaves	Cant	100% TS	5	212,69	1,07	56,95	47571	0,46	0,16	0,88
Radish Leaves	Cant	10% BS	1	130,19	0,48	53,19	37832	0,52	0,14	0,41
Radish Leaves	Cant	10% BS	2	303,39	0,70	38,11	42249	0,43	0,19	0,58
Radish Leaves	Cant	10% BS	3	50,19	0,54	59,16	32039	0,43	0,13	0,38
Radish Leaves	Cant	10% BS	4	286,74	0,90	53,89	38285	0,58	0,15	0,96
Radish Leaves	Cant	10% BS	5	210,34	1,05	38,63	37395	0,56	0,16	0,81
Radish Leaves	Cant	10% BS, 20% BCH	1	185,57	0,97	50,08	39802	0,48	0,14	0,58
Radish Leaves	Cant	10% BS, 20% BCH	2	136,79	0,51	58,88	37019	0,38	0,08	0,49
Radish Leaves	Cant	10% BS, 20% BCH	3	213,12	0,54	44,62	38083	0,51	<DL	0,70
Radish Leaves	Cant	10% BS, 20% BCH	4	229,55	0,54	44,62	36353	0,45	0,12	0,83
Radish Leaves	Cant	10% BS, 20% BCH	5	133,66	0,56	50,39	36870	0,46	0,08	0,47
Radish Leaves	Cant	20% BCH	1	543,78	0,58	43,01	42568	0,46	0,26	1,06
Radish Leaves	Cant	20% BCH	2	278,21	0,59	44,65	35545	0,43	0,18	0,52
Radish Leaves	Cant	20% BCH	3	218,64	0,49	45,13	37830	0,46	0,12	0,43
Radish Leaves	Cant	20% BCH	4	201,07	0,57	49,89	36865	0,31	0,09	0,39
Radish Leaves	Cant	20% BCH	5	157,75	0,64	53,26	34789	0,38	0,12	0,48
Spinach	Cant	100% TS	2	145,29	0,40	26,36	10738	0,82	0,13	0,56
Spinach	Cant	100% TS	3	83,59	0,30	28,02	10208	1,17	0,18	0,35
Spinach	Cant	100% TS	5	72,87	0,39	29,51	13148	1,91	0,29	0,25
Spinach	Cant	10% BS	1	188,77	<DL	20,58	6478	0,37	0,19	0,41
Spinach	Cant	10% BS	2	458,84	0,59	36,16	18364	2,48	0,35	0,71
Spinach	Cant	10% BS	4	129,23	<DL	29,89	9065	1,09	0,15	0,35
Spinach	Cant	10% BS	5	135,53	0,31	30,86	9017	1,74	0,10	0,29
Spinach	Cant	20% BCH	1	103,41	0,30	24,22	9905	1,18	0,19	0,32
Spinach	Cant	20% BCH	2	57,64	0,12	21,35	9869	0,74	0,10	0,30
Spinach	Cant	20% BCH	4	170,93	0,46	26,96	12972	0,55	0,10	0,43
Spinach	Cant	20% BCH	5	248,99	<DL	28,24	17161	0,63	0,15	0,65
Courgette	Cant	100% TS	1	31,58	0,25	27,07	2845	0,45	0,12	0,40
Courgette	Cant	100% TS	3	13,06	<DL	22,31	2656	2,13	0,14	0,29
Courgette	Cant	100% TS	4	19,40	0,47	23,30	2887	0,80	0,31	0,31
Courgette	Cant	100% TS	5	13,63	<DL	26,91	3948	0,47	0,26	0,53
Courgette	Cant	10% BS	2	16,10	0,15	25,61	3112	0,52	<DL	0,31

Plant	Soil	Soil variant	Rep	Al	As	B	Ca	Cd	Co	Cr
Courgette	Cant	10% BS	3	14,12	<DL	26,35	2839	0,52	0,14	0,23
Courgette	Cant	10% BS	4	14,47	0,25	26,46	3326	4,00	0,10	0,25
Courgette	Cant	10% BS, 20% BCH	1	12,35	0,23	24,94	2714	0,36	0,05	0,23
Courgette	Cant	10% BS, 20% BCH	2	15,07	<DL	22,70	2473	0,38	0,13	0,30
Courgette	Cant	10% BS, 20% BCH	3	13,06	0,16	26,14	2629	0,47	0,12	0,31
Courgette	Cant	10% BS, 20% BCH	4	15,43	<DL	24,56	3785	0,71	0,10	0,26
Courgette	Cant	10% BS, 20% BCH	5	20,69	<DL	25,90	3021	0,24	0,06	0,42
Courgette	Cant	20% BCH	1	29,21	<DL	25,65	3890	3,13	0,17	0,35
Courgette	Cant	20% BCH	2	12,75	<DL	28,76	3419	0,30	0,12	0,23
Courgette	Cant	20% BCH	3	14,12	<DL	26,10	2730	0,26	0,14	0,38
Courgette	Cant	20% BCH	4	15,73	<DL	28,24	3899	0,24	0,13	0,25
Courgette	Cant	20% BCH	5	12,92	<DL	27,83	4229	0,40	0,14	0,29
Grass, II	Cant	100% TS	1	108,04	0,54	38,13	7331	0,16	0,08	0,48
Grass, II	Cant	100% TS	2	78,11	0,38	43,95	9140	0,16	0,08	0,44
Grass, II	Cant	100% TS	3	99,57	0,20	16,07	6599	0,20	0,10	0,56
Grass, II	Cant	100% TS	4	197,65	0,68	53,65	8905	0,12	0,11	0,59
Grass, II	Cant	100% TS	5	163,28	0,38	38,98	7586	0,14	0,08	0,57
Grass, II	Cant	10% BS	1	76,13	0,70	23,61	7422	0,15	0,08	0,42
Grass, II	Cant	10% BS	2	94,04	0,81	28,27	7459	0,17	0,15	0,50
Grass, II	Cant	10% BS	3	141,55	0,46	20,75	7233	0,22	0,10	0,60
Grass, II	Cant	10% BS	4	231,57	0,61	28,10	8095	0,16	0,11	0,80
Grass, II	Cant	10% BS	5	357,62	0,85	33,38	7891	0,14	0,25	0,99
Grass, II	Cant	10% BS, 20% BCH	2	112,79	0,73	27,16	6855	0,23	0,06	0,68
Grass, II	Cant	10% BS, 20% BCH	4	152,12	0,52	35,05	6625	0,14	0,05	0,78
Grass, II	Cant	10% BS, 20% BCH	5	197,44	0,57	22,20	5579	0,15	<DL	0,69
Grass, II	Cant	20% BCH	1	117,16	0,45	31,12	6539	0,16	0,06	0,54
Grass, II	Cant	20% BCH	2	405,07	0,29	37,90	6595	0,18	0,15	1,05
Grass, II	Cant	20% BCH	3	186,51	0,35	41,19	7976	0,10	<DL	0,68
Grass, II	Cant	20% BCH	4	119,03	0,23	40,28	7198	0,11	0,08	0,60
Grass, II	Cant	20% BCH	5	232,94	0,42	35,71	7059	0,15	0,16	0,90
Grass, II	Balm	100% TS	1	89,23	<DL	3,29	4363	0,12	0,66	0,52
Grass, II	Balm	100% TS	2	54,06	<DL	3,60	4623	0,10	0,43	0,43
Grass, II	Balm	100% TS	3	73,65	0,22	1,98	4473	0,11	0,91	0,42
Grass, II	Balm	10% BS	1	65,25	0,68	7,22	6350	0,30	0,54	0,35
Grass, II	Balm	10% BS	2	111,43	0,54	6,59	6479	0,18	0,74	0,50
Grass, II	Balm	10% BS	3	73,27	0,38	3,29	5414	0,16	0,47	0,42
Grass, II	Balm	10% BS, 20% BCH	1	48,65	0,62	9,93	5761	0,13	0,51	0,33
Grass, II	Balm	10% BS, 20% BCH	2	47,23	0,75	12,39	5017	0,13	0,40	0,30
Grass, II	Balm	10% BS, 20% BCH	3	66,19	1,30	19,10	7389	0,17	0,50	0,33
Grass, II	Balm	20% BCH	1	51,79	0,61	18,99	5964	0,05	0,28	0,36
Grass, II	Balm	20% BCH	2	67,69	<DL	16,05	5288	0,06	0,32	0,56
Grass, II	Balm	20% BCH	3	80,78	0,24	22,32	5208	0,30	0,45	0,50
Beets (bulbs)	Cant	100% TS	1	82,89	0,76	10,27	1999	0,26	0,48	0,92
Beets (bulbs)	Cant	100% TS	2	41,06	0,42	13,30	1351	0,15	0,37	0,39
Beets (bulbs)	Cant	100% TS	3	35,92	0,41	7,28	1602	0,14	0,40	0,32
Beets (bulbs)	Cant	100% TS	4	19,89	<DL	14,15	1811	0,17	0,33	0,29
Beets (bulbs)	Cant	100% TS	5	41,91	0,17	15,59	1700	0,17	0,14	1,50
Beets (bulbs)	Cant	10% BS	1	30,43	0,10	14,42	1458	0,49	0,15	0,55
Beets (bulbs)	Cant	10% BS	2	30,24	0,27	12,27	1321	0,41	0,12	0,31
Beets (bulbs)	Cant	10% BS	3	32,65	0,17	12,32	1473	0,20	0,24	0,28
Beets (bulbs)	Cant	10% BS	4	43,35	<DL	13,92	1348	0,37	0,13	0,31

Plant	**Soil**	**Soil variant**	**Rep**	**Al**	**As**	**B**	**Ca**	**Cd**	**Co**	**Cr**
Beets (bulbs)	Cant	10% BS	5	32,37	<DL	12,43	1464	0,35	0,30	0,30
Beets (bulbs)	Cant	10% BS, 20% BCH	1	77,53	0,22	14,98	1642	0,27	0,10	0,26
Beets (bulbs)	Cant	10% BS, 20% BCH	2	54,39	0,30	14,93	1406	0,35	0,01	0,31
Beets (bulbs)	Cant	10% BS, 20% BCH	3	44,34	<DL	13,78	1408	0,26	0,05	0,20
Beets (bulbs)	Cant	10% BS, 20% BCH	4	39,31	0,22	12,98	1296	0,44	0,04	0,14
Beets (bulbs)	Cant	10% BS, 20% BCH	5	62,47	<DL	14,07	1429	0,33	0,10	0,26
Beets (bulbs)	Cant	20% BCH	1	35,24	0,11	11,90	1456	0,09	0,14	0,12
Beets (bulbs)	Cant	20% BCH	2	55,80	0,20	12,19	1449	0,11	0,16	0,16
Beets (bulbs)	Cant	20% BCH	3	35,00	<DL	11,68	1290	0,12	0,09	0,18
Beets (bulbs)	Cant	20% BCH	4	37,31	0,32	10,31	1511	0,14	0,14	0,21
Beets (bulbs)	Cant	20% BCH	5	40,64	0,17	13,17	1328	0,12	0,06	0,28
Beets (leaves)	Cant	100% TS	1	114,02	0,33	93,78	15738	0,60	0,58	0,38
Beets (leaves)	Cant	100% TS	2	70,15	0,32	102,57	16294	0,70	0,74	0,77
Beets (leaves)	Cant	100% TS	3	323,73	0,64	126,75	16702	0,60	0,58	0,64
Beets (leaves)	Cant	100% TS	4	125,80	0,26	147,36	28806	1,26	0,38	0,47
Beets (leaves)	Cant	100% TS	5	51,90	0,24	80,80	17274	0,72	0,23	0,21
Beets (leaves)	Cant	10% BS	1	89,91	0,25	126,86	27335	4,31	0,33	0,32
Beets (leaves)	Cant	10% BS	2	119,07	0,55	125,01	27599	4,09	0,48	0,43
Beets (leaves)	Cant	10% BS	3	124,81	0,28	125,51	27459	2,44	0,57	0,55
Beets (leaves)	Cant	10% BS	4	124,84	0,01	114,42	26523	2,45	0,37	0,40
Beets (leaves)	Cant	10% BS	5	143,74	0,01	123,83	36229	3,78	0,67	0,35
Beets (leaves)	Cant	10% BS, 20% BCH	1	99,69	0,27	105,69	22287	2,79	0,34	0,39
Beets (leaves)	Cant	10% BS, 20% BCH	2	108,43	0,01	132,17	22607	2,57	0,28	0,44
Beets (leaves)	Cant	10% BS, 20% BCH	3	57,32	0,01	100,33	22426	2,77	0,32	0,43
Beets (leaves)	Cant	10% BS, 20% BCH	4	63,81	0,34	119,67	21891	2,76	0,18	0,31
Beets (leaves)	Cant	10% BS, 20% BCH	5	101,73	0,29	107,80	30940	2,95	0,34	0,41
Beets (leaves)	Cant	20% BCH	1	157,72	0,43	128,93	30042	1,40	0,46	0,29
Beets (leaves)	Cant	20% BCH	2	112,43	0,38	141,47	24891	0,93	0,40	0,33
Beets (leaves)	Cant	20% BCH	3	76,23	0,20	101,85	23167	0,99	0,24	0,31
Beets (leaves)	Cant	20% BCH	4	110,21	0,17	118,85	24365	1,09	0,46	0,31
Beets (leaves)	Cant	20% BCH	5	50,19	0,27	115,78	18021	0,77	0,24	0,26
Tomato	Cant	100% TS	1	17,13	<DL	10,22	633	0,07	0,10	0,12
Tomato	Cant	100% TS	2	15,60	<DL	9,05	970	0,07	0,11	0,12
Tomato	Cant	100% TS	3	14,11	<DL	9,55	1116	0,09	0,07	0,09
Tomato	Cant	100% TS	4	39,69	0,22	12,92	1022	0,06	0,06	0,11
Tomato	Cant	100% TS	5	13,29	0,59	8,98	851	0,07	<DL	0,14
Tomato	Cant	10% BS	1	13,30	0,31	11,60	1481	0,07	0,06	0,16
Tomato	Cant	10% BS	2	13,86	0,34	9,91	1146	0,12	<DL	0,13
Tomato	Cant	10% BS	3	13,29	0,37	8,14	1280	0,07	0,04	0,14
Tomato	Cant	10% BS	4	17,46	0,22	9,14	1420	0,09	0,23	0,17
Tomato	Cant	10% BS	5	17,20	0,26	11,42	978	0,11	<DL	0,12
Tomato	Cant	10% BS, 20% BCH	1	16,91	0,55	9,83	1460	0,09	0,08	0,21
Tomato	Cant	10% BS, 20% BCH	2	12,17	0,45	11,99	1592	0,10	0,07	0,25
Tomato	Cant	10% BS, 20% BCH	3	22,34	0,55	11,07	1374	0,08	<DL	0,14
Tomato	Cant	10% BS, 20% BCH	4	18,40	0,37	11,18	1525	0,10	0,07	0,17
Tomato	Cant	10% BS, 20% BCH	5	15,02	<DL	11,07	914	0,07	0,07	0,18
Tomato	Cant	20% BCH	1	11,76	0,19	11,13	1675	0,08	0,08	0,18
Tomato	Cant	20% BCH	2	12,38	<DL	8,12	852	0,05	0,11	0,17
Tomato	Cant	20% BCH	3	12,75	<DL	10,68	1773	0,09	0,22	0,25
Tomato	Cant	20% BCH	4	13,34	<DL	9,37	1504	0,06	0,07	0,11
Tomato	Cant	20% BCH	5	20,89	<DL	8,83	1341	0,08	0,14	0,16

Plant	Soil	Soil variant	Rep	Al	As	B	Ca	Cd	Co	Cr
Carrots	Cant	100% TS	1	13,98	0,25	25,79	3958	0,41	0,24	0,24
Carrots	Cant	100% TS	2	11,29	0,30	22,34	3586	0,18	1,96	0,40
Carrots	Cant	100% TS	3	26,96	0,01	12,70	3645	0,24	0,27	0,45
Carrots	Cant	100% TS	4	36,85	0,24	17,27	2998	0,15	0,00	0,16
Carrots	Cant	100% TS	5	15,30	0,01	21,20	3745	0,30	0,05	0,12
Carrots	Cant	10% BS	1	23,49	0,13	19,96	3404	0,71	0,00	0,21
Carrots	Cant	10% BS	2	15,61	0,20	29,61	3768	0,88	0,43	0,37
Carrots	Cant	10% BS	3	16,19	0,16	21,30	4084	0,47	0,06	0,18
Carrots	Cant	10% BS	4	14,95	0,01	27,18	3969	0,21	0,06	0,12
Carrots	Cant	10% BS	5	12,42	0,26	33,46	3831	0,91	0,09	0,24
Carrots	Cant	10% BS, 20% BCH	1	17,12	0,01	35,59	3822	0,52	0,18	0,21
Carrots	Cant	10% BS, 20% BCH	2	16,15	0,01	18,35	3376	0,34	0,00	0,18
Carrots	Cant	10% BS, 20% BCH	3	23,45	0,29	25,08	3893	0,50	0,07	0,22
Carrots	Cant	10% BS, 20% BCH	4	22,61	0,27	22,74	4206	0,43	0,20	0,28
Carrots	Cant	10% BS, 20% BCH	5	9,10	0,01	20,25	3522	0,19	0,04	0,19
Carrots	Cant	20% BCH	1	10,41	0,13	23,49	3320	0,25	0,05	0,16
Carrots	Cant	20% BCH	2	10,87	0,24	16,17	3215	0,12	0,05	0,18
Carrots	Cant	20% BCH	3	12,27	0,23	15,34	3156	0,22	0,10	0,25
Carrots	Cant	20% BCH	4	13,13	0,01	20,44	3721	0,12	0,00	0,09
Carrots	Cant	20% BCH	5	11,74	0,01	21,25	3413	0,29	0,08	0,20
Leek (bulbs)	Cant	100% TS	1	33,32	<DL	8,00	3825	0,13	0,07	0,22
Leek (bulbs)	Cant	100% TS	2	15,13	<DL	5,85	2736	0,09	<DL	0,13
Leek (bulbs)	Cant	100% TS	3	11,68	<DL	4,20	2772	0,08	0,03	0,11
Leek (bulbs)	Cant	100% TS	4	16,00	<DL	9,54	3157	0,07	<DL	0,09
Leek (bulbs)	Cant	100% TS	5	11,11	<DL	6,16	3605	0,12	0,03	0,11
Leek (bulbs)	Cant	10% BS	1	62,70	<DL	12,38	3024	0,13	<DL	0,33
Leek (bulbs)	Cant	10% BS	2	22,43	0,13	5,59	3748	0,12	0,03	0,09
Leek (bulbs)	Cant	10% BS	3	26,88	0,32	5,03	2684	0,05	0,15	0,21
Leek (bulbs)	Cant	10% BS	4	17,69	<DL	3,19	3107	0,09	0,05	0,08
Leek (bulbs)	Cant	10% BS	5	22,28	0,15	5,91	2610	0,06	<DL	0,12
Leek (bulbs)	Cant	10% BS, 20% BCH	1	20,81	0,15	10,10	3993	0,09	0,04	0,32
Leek (bulbs)	Cant	10% BS, 20% BCH	2	17,94	<DL	9,01	2425	0,09	0,06	0,46
Leek (bulbs)	Cant	10% BS, 20% BCH	3	19,22	0,19	8,93	4655	0,10	0,06	0,18
Leek (bulbs)	Cant	10% BS, 20% BCH	4	14,41	0,17	6,70	4894	0,10	<DL	0,12
Leek (bulbs)	Cant	10% BS, 20% BCH	5	17,93	<DL	9,08	3130	0,13	0,02	0,16
Leek (bulbs)	Cant	20% BCH	1	33,59	<DL	9,01	4380	0,07	<DL	0,19
Leek (bulbs)	Cant	20% BCH	2	19,52	0,16	9,20	3353	0,03	<DL	0,15
Leek (bulbs)	Cant	20% BCH	3	19,24	<DL	7,16	3240	0,04	0,04	0,20
Leek (bulbs)	Cant	20% BCH	4	15,49	<DL	4,55	3323	0,07	<DL	0,09
Leek (bulbs)	Cant	20% BCH	5	18,19	<DL	7,38	2058	0,13	0,06	0,19
Grass, III	Cant	100% TS	1	61,28	0,29	51,07	12422	0,08	0,24	0,53
Grass, III	Cant	100% TS	2	75,19	0,14	37,30	15319	0,08	0,10	0,67
Grass, III	Cant	100% TS	3	36,95	0,51	21,58	9451	0,22	0,20	0,31
Grass, III	Cant	100% TS	4	146,19	0,40	45,48	14257	0,07	0,15	0,72
Grass, III	Cant	100% TS	5	126,19	0,40	36,44	16571	0,11	0,24	0,67
Grass, III	Cant	10% BS	1	54,39	0,31	21,42	8457	0,09	0,18	0,33
Grass, III	Cant	10% BS	2	59,84	0,21	27,58	9338	0,10	0,16	0,53
Grass, III	Cant	10% BS	3	58,15	0,45	22,07	9957	0,11	0,13	0,33
Grass, III	Cant	10% BS	4	70,33	0,30	21,83	11136	0,09	0,17	0,40
Grass, III	Cant	10% BS	5	101,38	0,15	19,40	12141	0,11	0,26	0,46
Grass, III	Cant	10% BS, 20% BCH	2	53,28	0,01	23,51	8336	0,10	0,08	0,34

Plant	Soil	Soil variant	Rep	Al	As	B	Ca	Cd	Co	Cr
Grass, III	Cant	10% BS, 20% BCH	4	52,30	0,35	21,49	11252	0,08	0,08	0,39
Grass, III	Cant	10% BS, 20% BCH	5	71,50	0,48	21,09	8609	0,10	0,11	0,35
Grass, III	Cant	20% BCH	1	35,97	0,39	35,84	14153	0,08	0,08	0,37
Grass, III	Cant	20% BCH	2	75,42	0,01	57,21	13431	0,09	0,17	0,43
Grass, III	Cant	20% BCH	3	71,31	0,49	40,05	11761	0,06	0,08	0,41
Grass, III	Cant	20% BCH	4	52,32	0,39	34,01	14980	0,09	0,13	0,40
Grass, III	Cant	20% BCH	5	83,68	0,37	33,42	12821	0,08	0,13	0,42
Grass, III	Balm	100% TS	1	66,57	<DL	6,44	6886	0,06	0,55	0,31
Grass, III	Balm	100% TS	2	38,55	<DL	5,18	6977	0,04	0,26	0,24
Grass, III	Balm	100% TS	3	36,23	<DL	7,44	6839	0,03	0,58	0,22
Grass, III	Balm	10% BS	1	92,03	0,18	7,37	9816	0,14	0,37	1,69
Grass, III	Balm	10% BS	2	42,02	0,48	11,25	10356	0,17	0,57	0,29
Grass, III	Balm	10% BS	3	57,00	0,34	29,95	8390	0,12	0,55	0,41
Grass, III	Balm	10% BS, 20% BCH	1	29,45	0,36	36,39	9479	0,16	0,47	0,37
Grass, III	Balm	10% BS, 20% BCH	2	55,35	0,56	20,43	8191	0,16	0,48	0,40
Grass, III	Balm	10% BS, 20% BCH	3	122,38	0,51	24,33	9922	0,24	0,62	0,63
Grass, III	Balm	20% BCH	1	59,03	0,64	23,30	8103	0,06	0,36	0,42
Grass, III	Balm	20% BCH	2	90,70	0,31	27,52	8928	0,10	0,39	0,42
Grass, III	Balm	20% BCH	3	76,91	0,38	33,34	10240	0,06	0,56	0,45
Corn	Cant	100% TS	1	12,90	0,17	8,65	242	0,02	<DL	0,18
Corn	Cant	100% TS	2	11,46	0,16	8,19	193	0,04	0,05	0,19
Corn	Cant	100% TS	3	22,98	<DL	17,39	2143	0,08	<DL	0,55
Corn	Cant	100% TS	4	20,36	0,40	13,24	2171	0,12	0,08	1,96
Corn	Cant	100% TS	5	13,41	0,37	7,97	174	0,00	0,08	0,21
Corn	Cant	10% BS	1	15,77	0,43	7,62	212	0,04	<DL	0,19
Corn	Cant	10% BS	2	13,45	0,25	7,78	140	0,04	0,04	0,15
Corn	Cant	10% BS	3	23,31	0,39	7,46	242	0,08	0,13	0,28
Corn	Cant	10% BS	4	21,58	<DL	8,98	367	0,05	0,14	0,25
Corn	Cant	10% BS	5	19,24	<DL	7,91	207	0,04	0,04	0,18
Corn	Cant	10% BS, 20% BCH	1	23,66	<DL	7,73	163	0,02	0,02	0,20
Corn	Cant	10% BS, 20% BCH	2	23,03	<DL	7,52	154	0,04	<DL	0,30
Corn	Cant	10% BS, 20% BCH	3	30,53	<DL	22,60	209	0,06	0,18	0,33
Corn	Cant	10% BS, 20% BCH	4	26,20	<DL	13,49	326	0,07	0,14	0,38
Corn	Cant	10% BS, 20% BCH	5	22,34	<DL	10,97	249	0,02	0,06	0,32
Corn	Cant	20% BCH	1	24,02	<DL	9,41	169	0,03	0,07	0,32
Corn	Cant	20% BCH	2	49,91	<DL	18,36	3146	0,10	<DL	0,91
Corn	Cant	20% BCH	3	22,24	0,18	11,59	320	0,04	0,15	0,27
Corn	Cant	20% BCH	4	23,59	<DL	11,55	548	0,05	0,06	0,25
Corn	Cant	20% BCH	5	21,03	<DL	9,45	335	0,02	0,02	0,32
Broccoli	Cant	100% TS	1	24,54	0,10	44,26	9974	0,04	0,38	0,29
Broccoli	Cant	100% TS	2	25,04	<DL	45,06	9825	0,02	0,18	0,30
Broccoli	Cant	100% TS	4	22,55	<DL	39,36	9291	0,03	0,12	0,29
Broccoli	Cant	100% TS	5	20,82	<DL	43,14	7530	0,04	0,40	0,28
Broccoli	Cant	10% BS	1	16,67	<DL	35,13	7572	0,05	0,39	0,33
Broccoli	Cant	10% BS	2	17,14	<DL	42,34	9830	0,01	0,07	0,29
Broccoli	Cant	10% BS	3	24,95	<DL	39,37	7216	0,07	0,24	0,36
Broccoli	Cant	10% BS	4	24,38	<DL	39,39	7822	0,10	0,27	0,26
Broccoli	Cant	10% BS	5	22,01	<DL	47,67	10835	0,03	0,10	0,28
Broccoli	Cant	10% BS, 20% BCH	2	26,43	<DL	46,21	14026	0,10	0,19	0,41
Broccoli	Cant	10% BS, 20% BCH	3	16,74	<DL	41,39	8538	0,05	0,16	0,29
Broccoli	Cant	10% BS, 20% BCH	4	14,31	<DL	44,52	10229	0,05	0,18	0,31

Plant	Soil	Soil variant	Rep	Al	As	B	Ca	Cd	Co	Cr
Broccoli	Cant	10% BS, 20% BCH	5	20,18	<DL	43,22	10088	0,06	0,53	0,40
Broccoli	Cant	20% BCH	1	16,53	<DL	36,95	5725	0,02	0,19	0,29
Broccoli	Cant	20% BCH	2	15,81	<DL	43,27	8755	0,04	0,36	0,27
Broccoli	Cant	20% BCH	3	13,60	<DL	42,34	10122	0,03	0,10	0,40
Broccoli	Cant	20% BCH	4	12,20	0,31	40,39	7227	0,03	0,27	0,27
Broccoli	Cant	20% BCH	5	16,05	0,56	38,19	12065	0,02	0,13	0,34
Broccoli	Balm	100% TS	1	16,16	0,33	15,27	7084	0,11	2,54	0,29
Broccoli	Balm	100% TS	2	21,54	0,44	15,59	9885	0,08	2,60	0,37
Broccoli	Balm	10% BS	1	14,33	<DL	16,61	5058	0,11	1,12	0,30
Broccoli	Balm	10% BS	2	13,66	<DL	20,09	7418	0,16	2,44	0,24
Broccoli	Balm	10% BS	3	15,17	0,10	25,09	7511	0,18	1,03	0,31
Broccoli	Balm	10% BS, 20% BCH	1	23,52	0,20	27,76	6259	0,15	0,42	0,29
Broccoli	Balm	10% BS, 20% BCH	2	14,72	0,36	41,84	8512	0,19	2,16	0,30
Broccoli	Balm	10% BS, 20% BCH	3	27,92	0,27	36,15	6241	0,14	0,78	0,26
Broccoli	Balm	20% BCH	1	21,07	<DL	31,63	5756	0,08	0,59	0,35
Broccoli	Balm	20% BCH	2	18,52	<DL	26,56	8193	0,06	1,66	0,34
Broccoli	Balm	20% BCH	3	14,42	<DL	31,77	4653	0,05	1,72	0,35
Manuka	Cant	100% TS	1	136,56	0,33	85,84	18105	0,17	0,16	0,60
Manuka	Cant	100% TS	2	173,21	0,27	40,90	11389	0,06	0,11	0,57
Manuka	Cant	100% TS	3	110,86	0,68	41,35	11613	0,13	0,34	0,62
Manuka	Cant	100% TS	4	185,82	0,64	41,05	15977	0,11	0,13	0,53
Manuka	Cant	100% TS	5	247,23	0,81	70,47	19912	0,12	0,19	0,73
Manuka	Cant	10% BS	1	85,77	<DL	67,88	15868	0,12	0,12	0,44
Manuka	Cant	10% BS	2	175,57	0,84	81,60	18617	0,17	0,26	0,69
Manuka	Cant	10% BS	3	228,21	0,41	69,15	15437	0,15	0,22	0,67
Manuka	Cant	10% BS	4	67,71	0,37	61,69	17926	0,24	0,12	0,64
Manuka	Cant	10% BS	5	149,65	0,30	72,90	17865	0,13	0,16	0,63
Manuka	Cant	10% BS, 20% BCH	1	53,14	<DL	56,53	16975	0,07	0,08	0,47
Manuka	Cant	10% BS, 20% BCH	2	98,24	0,43	67,04	18012	0,13	0,09	0,48
Manuka	Cant	10% BS, 20% BCH	3	218,44	0,33	89,90	21851	0,31	0,19	0,90
Manuka	Cant	10% BS, 20% BCH	4	86,60	0,35	65,73	14757	0,09	0,07	0,40
Manuka	Cant	10% BS, 20% BCH	5	139,31	0,35	68,77	20272	0,11	0,17	0,65
Manuka	Cant	20% BCH	1	97,08	<DL	93,10	14568	0,09	0,09	0,64
Manuka	Cant	20% BCH	2	637,46	0,51	78,69	16136	0,16	0,39	1,93
Manuka	Cant	20% BCH	3	153,28	<DL	111,08	16755	0,13	0,18	0,62
Manuka	Cant	20% BCH	4	150,48	0,40	63,58	14581	0,09	0,14	0,74
Manuka	Cant	20% BCH	5	107,23	0,52	52,42	13925	0,12	0,16	0,58
Manuka	Balm	100% TS	1	434,15	0,16	40,89	7399	0,10	0,68	0,82
Manuka	Balm	100% TS	2	253,22	<DL	53,66	11057	0,20	0,80	0,63
Manuka	Balm	100% TS	3	155,96	0,18	64,93	11276	0,13	0,52	0,62
Manuka	Balm	10% BS	1	154,97	<DL	52,45	13350	0,25	0,76	0,57
Manuka	Balm	10% BS	2	132,60	0,27	37,29	16220	0,40	0,57	0,40
Manuka	Balm	10% BS	3	196,78	<DL	32,12	13968	0,69	0,96	0,58
Manuka	Balm	10% BS, 20% BCH	1	116,23	0,25	63,03	17655	0,28	0,96	0,44
Manuka	Balm	10% BS, 20% BCH	2	72,08	0,44	59,34	12336	0,27	0,47	0,37
Manuka	Balm	10% BS, 20% BCH	3	72,77	0,30	47,54	12502	0,33	0,40	0,36
Manuka	Balm	20% BCH	1	69,55	<DL	40,26	11666	0,06	0,24	0,35
Manuka	Balm	20% BCH	2	115,57	<DL	66,33	13959	0,07	0,37	0,47
Manuka	Balm	20% BCH	3	129,39	0,28	46,86	11494	0,10	0,32	0,40

Plant	Soil	Soil variant	Rep	Cu	Fe	K	Mg	Mn	Mo	Na
Grass, I	Cant	100% TS	1	9,04	136,21	50005	2021	65,81	0,77	1851
Grass, I	Cant	100% TS	2	9,74	129,55	43295	2170	83,16	1,31	1747
Grass, I	Cant	100% TS	3	12,65	174,94	59409	2315	96,73	0,58	1962
Grass, I	Cant	100% TS	4	9,62	109,20	43008	1978	71,98	1,12	1672
Grass, I	Cant	100% TS	5	9,36	107,83	47043	2048	72,47	0,99	1857
Grass, I	Cant	10% BS	1	11,97	172,41	47786	2161	75,67	2,51	2056
Grass, I	Cant	10% BS	2	14,13	195,23	55399	2436	81,88	2,66	2201
Grass, I	Cant	10% BS	3	13,82	118,08	52546	2430	92,47	3,15	2056
Grass, I	Cant	10% BS	4	13,24	124,46	46277	2173	84,82	3,08	1710
Grass, I	Cant	10% BS	5	13,36	165,02	50021	2262	87,93	2,39	1853
Grass, I	Cant	10% BS, 20% BCH	2	13,92	100,19	51126	2164	61,91	3,11	2596
Grass, I	Cant	10% BS, 20% BCH	4	13,07	91,08	50335	2241	60,75	2,46	2624
Grass, I	Cant	10% BS, 20% BCH	5	12,45	104,55	49339	2239	77,03	1,45	2099
Grass, I	Cant	20% BCH	1	10,86	91,31	55070	2114	70,47	0,75	1890
Grass, I	Cant	20% BCH	2	11,17	131,46	51791	2192	84,82	0,93	2414
Grass, I	Cant	20% BCH	3	10,37	96,99	48189	2122	55,77	1,19	2306
Grass, I	Cant	20% BCH	4	9,92	89,48	48983	2274	78,40	0,87	2144
Grass, I	Cant	20% BCH	5	11,47	101,95	49360	2285	97,40	0,88	1971
Grass, I	Balm	100% TS	1	3,93	100,01	50786	2138	190,86	0,02	2027
Grass, I	Balm	100% TS	2	3,80	97,24	44340	1965	157,89	0,16	1130
Grass, I	Balm	100% TS	3	3,60	138,65	49465	1922	161,27	0,18	1425
Grass, I	Balm	10% BS	1	15,03	96,92	38536	2160	203,72	0,80	1364
Grass, I	Balm	10% BS	2	18,06	100,15	53386	1976	140,94	0,67	1831
Grass, I	Balm	10% BS	3	15,90	92,44	43077	2097	165,24	0,62	1981
Grass, I	Balm	10% BS, 20% BCH	1	15,22	93,91	46696	2133	231,06	0,54	1934
Grass, I	Balm	10% BS, 20% BCH	2	14,79	85,73	46872	1971	215,59	0,88	1869
Grass, I	Balm	10% BS, 20% BCH	3	15,24	84,11	42044	1995	202,28	0,87	2464
Grass, I	Balm	20% BCH	1	5,34	86,28	41605	2099	212,91	0,10	2359
Grass, I	Balm	20% BCH	2	6,20	107,19	46788	2260	208,13	0,11	2451
Grass, I	Balm	20% BCH	3	5,41	96,68	43177	2072	214,28	0,07	2181
Radish	Cant	100% TS	1	2,28	47,53	57027	1631	12,40	0,15	2933
Radish	Cant	100% TS	2	2,41	61,81	47615	1273	11,04	0,40	2733
Radish	Cant	100% TS	3	3,71	89,21	58649	1441	12,28	0,26	4056
Radish	Cant	100% TS	4	2,54	160,90	54437	2014	10,39	0,29	4338
Radish	Cant	100% TS	5	2,04	61,28	52489	1577	8,63	0,19	3732
Radish	Cant	10% BS	1	4,26	84,35	54828	1655	16,75	0,42	3851
Radish	Cant	10% BS	2	3,45	64,68	58250	1510	12,65	0,21	3572
Radish	Cant	10% BS	3	3,19	46,40	56495	1741	14,37	0,65	2875
Radish	Cant	10% BS	4	4,46	61,10	64161	1487	18,30	0,40	3675
Radish	Cant	10% BS	5	4,06	90,43	63207	1837	16,54	0,34	3776
Radish	Cant	10% BS, 20% BCH	1	3,13	65,12	43822	1140	9,48	0,79	3059
Radish	Cant	10% BS, 20% BCH	2	2,81	55,52	44175	1247	8,82	0,63	2553
Radish	Cant	10% BS, 20% BCH	3	3,51	62,78	53718	1778	13,40	0,71	3806
Radish	Cant	10% BS, 20% BCH	4	3,10	40,97	52028	1422	11,62	0,88	2778
Radish	Cant	10% BS, 20% BCH	5	2,98	77,47	53242	1483	12,50	0,45	4567
Radish	Cant	20% BCH	1	3,34	63,47	53048	1741	13,94	0,22	3349
Radish	Cant	20% BCH	2	3,09	68,67	55649	1821	12,78	0,27	4205
Radish	Cant	20% BCH	3	2,06	57,41	44257	1592	11,59	0,12	3189

Plant	Soil	Soil variant	Rep	Cu	Fe	K	Mg	Mn	Mo	Na
Radish	Cant	20% BCH	4	2,90	89,51	43835	1204	7,76	0,36	2669
Radish	Cant	20% BCH	5	3,21	87,33	42757	1440	11,01	0,35	1848
Radish	Cant	20% BCH	3	2,09	58,69	43339	1631	11,98	0,14	3233
Lettuce	Cant	100% TS	4	5,03	297,03	63279	2223	52,92	0,07	2376
Lettuce	Cant	100% TS	5	5,46	202,98	68703	2125	79,93	0,06	2401
Lettuce	Cant	10% BS	2	4,72	108,38	46388	1441	46,26	0,06	1918
Lettuce	Cant	10% BS	3	6,94	426,31	59193	1918	94,93	0,14	2630
Lettuce	Cant	10% BS	5	3,63	286,98	29964	1182	55,52	0,08	1512
Lettuce	Cant	10% BS, 20% BCH	1	8,21	211,65	70066	1895	53,44	0,29	2721
Lettuce	Cant	10% BS, 20% BCH	3	9,32	344,47	74564	2299	110,74	0,33	2655
Lettuce	Cant	10% BS, 20% BCH	4	7,16	221,62	70644	1944	91,50	0,25	2365
Lettuce	Cant	10% BS, 20% BCH	5	6,12	196,66	61484	2006	60,88	0,26	2532
Lettuce	Cant	20% BCH	2	6,91	341,56	74869	2394	110,43	0,16	2623
Lettuce	Cant	20% BCH	4	4,56	120,64	57249	1609	49,12	0,08	1753
Radish Leaves	Cant	100% TS	1	4,24	515,47	42079	2628	73,55	0,37	4366
Radish Leaves	Cant	100% TS	2	3,77	287,40	59779	2594	42,03	0,74	6095
Radish Leaves	Cant	100% TS	3	4,46	217,26	55630	2733	90,73	0,42	5902
Radish Leaves	Cant	100% TS	4	3,38	339,81	45329	2414	45,01	0,57	5566
Radish Leaves	Cant	100% TS	5	3,57	305,32	40947	2524	51,69	0,46	5054
Radish Leaves	Cant	10% BS	1	5,04	212,45	50869	2785	103,92	0,79	7211
Radish Leaves	Cant	10% BS	2	4,64	342,60	40841	2435	73,53	0,37	8145
Radish Leaves	Cant	10% BS	3	4,01	105,81	75043	2423	70,72	1,27	8522
Radish Leaves	Cant	10% BS	4	8,91	393,05	45979	3077	120,34	0,87	6325
Radish Leaves	Cant	10% BS	5	5,36	264,91	56085	2667	80,58	0,72	5151
Radish Leaves	Cant	10% BS, 20% BCH	1	5,64	218,49	68484	2607	52,45	3,71	9635
Radish Leaves	Cant	10% BS, 20% BCH	2	4,34	170,98	60977	2583	36,33	2,79	6503
Radish Leaves	Cant	10% BS, 20% BCH	3	5,83	228,70	48329	2670	58,25	1,78	6980
Radish Leaves	Cant	10% BS, 20% BCH	4	5,31	253,11	56608	2508	54,54	1,98	7158
Radish Leaves	Cant	10% BS, 20% BCH	5	4,89	176,70	55144	2744	51,80	0,84	8552
Radish Leaves	Cant	20% BCH	1	4,67	455,37	46071	2469	81,29	0,37	5691
Radish Leaves	Cant	20% BCH	2	4,43	266,07	38008	2646	52,00	0,38	6279
Radish Leaves	Cant	20% BCH	3	3,13	271,94	58976	2404	53,10	0,42	7948
Radish Leaves	Cant	20% BCH	4	4,54	220,86	48804	2638	28,54	0,94	6254
Radish Leaves	Cant	20% BCH	5	3,61	227,37	61680	2568	41,04	0,74	5709
Spinach	Cant	100% TS	2	4,16	159,54	41237	2564	106,12	0,34	23322
Spinach	Cant	100% TS	3	4,70	121,48	52841	2823	255,97	0,34	20667
Spinach	Cant	100% TS	5	6,77	121,24	65873	3307	543,32	0,33	15433
Spinach	Cant	10% BS	1	2,69	214,98	16233	1981	76,23	0,35	15987
Spinach	Cant	10% BS	2	9,46	515,63	56560	2449	379,20	1,11	26514
Spinach	Cant	10% BS	4	5,12	131,52	25528	2302	121,87	0,67	18672
Spinach	Cant	10% BS	5	7,47	154,98	42004	2407	132,42	1,13	24679
Spinach	Cant	20% BCH	1	5,98	139,84	71490	2926	172,16	0,58	25742
Spinach	Cant	20% BCH	2	4,98	85,90	43959	2264	82,76	0,50	22594
Spinach	Cant	20% BCH	4	5,34	235,45	53400	2141	98,76	0,52	31037
Spinach	Cant	20% BCH	5	4,74	306,26	56890	2841	78,10	0,43	18744
Courgette	Cant	100% TS	1	6,56	54,20	35846	2093	26,38	0,38	69
Courgette	Cant	100% TS	3	6,31	45,23	33970	2203	34,10	0,17	56
Courgette	Cant	100% TS	4	9,27	71,93	47784	3089	32,09	0,22	66
Courgette	Cant	100% TS	5	7,88	71,25	41703	2386	37,64	0,35	81
Courgette	Cant	10% BS	2	8,28	49,15	39220	2099	23,16	0,67	71
Courgette	Cant	10% BS	3	10,99	60,84	49049	2456	41,88	0,50	70

Plant	Soil	Soil variant	Rep	Cu	Fe	K	Mg	Mn	Mo	Na
Courgette	Cant	10% BS	4	8,79	49,66	43600	2186	24,86	0,69	82
Courgette	Cant	10% BS, 20% BCH	1	9,42	44,70	43813	2399	24,42	0,47	60
Courgette	Cant	10% BS, 20% BCH	2	7,92	41,56	37253	2205	23,25	0,58	57
Courgette	Cant	10% BS, 20% BCH	3	9,49	47,12	40321	2301	30,98	0,61	63
Courgette	Cant	10% BS, 20% BCH	4	8,34	42,71	37984	2322	23,88	0,60	95
Courgette	Cant	10% BS, 20% BCH	5	8,67	50,23	37745	2243	20,90	0,56	73
Courgette	Cant	20% BCH	1	7,83	58,00	36666	2177	32,55	0,54	76
Courgette	Cant	20% BCH	2	8,47	65,08	42568	2251	30,67	0,43	76
Courgette	Cant	20% BCH	3	7,34	54,75	40361	2079	24,54	0,35	63
Courgette	Cant	20% BCH	4	8,01	57,00	41293	2335	30,08	0,31	101
Courgette	Cant	20% BCH	5	8,55	62,32	44433	2210	26,65	0,60	80
Grass, II	Cant	100% TS	1	5,22	148,02	29258	1893	78,31	2,03	2509
Grass, II	Cant	100% TS	2	5,58	112,74	30928	2018	151,03	2,53	2847
Grass, II	Cant	100% TS	3	8,05	178,37	53420	1917	97,30	0,63	2527
Grass, II	Cant	100% TS	4	5,51	279,22	28385	2329	112,64	2,59	2269
Grass, II	Cant	100% TS	5	5,57	218,76	27780	1849	109,95	2,21	2292
Grass, II	Cant	10% BS	1	6,90	119,49	32939	1855	96,70	4,43	2733
Grass, II	Cant	10% BS	2	7,41	145,44	37974	1956	106,17	4,81	2942
Grass, II	Cant	10% BS	3	7,23	204,15	35741	1809	112,97	4,28	2595
Grass, II	Cant	10% BS	4	7,58	290,68	37321	1936	114,81	5,63	2585
Grass, II	Cant	10% BS	5	6,88	512,91	33503	1973	128,71	4,37	2586
Grass, II	Cant	10% BS, 20% BCH	2	8,46	179,23	36964	1795	48,56	4,78	3292
Grass, II	Cant	10% BS, 20% BCH	4	6,79	196,84	30197	1786	48,89	5,25	3028
Grass, II	Cant	10% BS, 20% BCH	5	9,00	258,99	40616	1768	53,04	2,55	2851
Grass, II	Cant	20% BCH	1	5,43	135,91	34179	1748	80,14	1,58	2643
Grass, II	Cant	20% BCH	2	6,34	358,02	36171	1866	71,20	1,51	3356
Grass, II	Cant	20% BCH	3	5,57	209,47	27879	2114	93,25	2,72	3250
Grass, II	Cant	20% BCH	4	5,07	154,33	28523	1852	79,03	1,94	2184
Grass, II	Cant	20% BCH	5	6,15	299,85	35418	2025	94,97	1,82	2226
Grass, II	Balm	100% TS	1	3,30	123,01	50133	1990	247,41	<DL	3403
Grass, II	Balm	100% TS	2	3,64	76,01	41758	2027	311,68	<DL	2588
Grass, II	Balm	100% TS	3	2,64	108,07	48126	2125	225,72	<DL	2219
Grass, II	Balm	10% BS	1	11,12	75,40	34547	2437	312,06	2,11	1631
Grass, II	Balm	10% BS	2	14,83	136,13	42644	2306	214,44	0,52	3349
Grass, II	Balm	10% BS	3	10,58	87,47	34025	2213	342,81	0,19	3012
Grass, II	Balm	10% BS, 20% BCH	1	11,04	75,08	42144	2284	348,41	1,51	1800
Grass, II	Balm	10% BS, 20% BCH	2	9,28	59,29	34277	2205	368,44	1,81	1342
Grass, II	Balm	10% BS, 20% BCH	3	11,65	79,34	37866	2400	391,32	6,75	1714
Grass, II	Balm	20% BCH	1	4,56	71,64	35062	2129	431,84	<DL	1377
Grass, II	Balm	20% BCH	2	4,91	89,85	37916	2217	337,86	<DL	1984
Grass, II	Balm	20% BCH	3	4,78	101,57	29400	2045	424,88	<DL	1292
Beets (bulbs)	Cant	100% TS	1	6,74	101,30	8196	1491	161,55	<DL	255
Beets (bulbs)	Cant	100% TS	2	6,02	68,62	13581	913	123,66	<DL	253
Beets (bulbs)	Cant	100% TS	3	6,13	72,07	8253	1103	94,44	<DL	290
Beets (bulbs)	Cant	100% TS	4	8,15	86,71	11361	1503	131,91	<DL	208
Beets (bulbs)	Cant	100% TS	5	7,83	73,93	20535	1700	50,90	<DL	1016
Beets (bulbs)	Cant	10% BS	1	8,64	54,00	16231	1654	84,77	<DL	522
Beets (bulbs)	Cant	10% BS	2	6,50	45,45	15950	1346	92,30	<DL	486
Beets (bulbs)	Cant	10% BS	3	9,80	86,55	12611	1084	106,05	<DL	201
Beets (bulbs)	Cant	10% BS	4	5,74	52,52	13148	1230	69,72	<DL	605
Beets (bulbs)	Cant	10% BS	5	9,06	75,35	16268	1350	100,40	<DL	694

Plant	Soil	Soil variant	Rep	Cu	Fe	K	Mg	Mn	Mo	Na
Beets (bulbs)	Cant	10% BS, 20% BCH	1	7,90	70,66	13453	1454	56,21	<DL	469
Beets (bulbs)	Cant	10% BS, 20% BCH	2	7,96	53,03	19089	1193	51,93	<DL	555
Beets (bulbs)	Cant	10% BS, 20% BCH	3	6,95	43,89	18779	1227	50,80	<DL	683
Beets (bulbs)	Cant	10% BS, 20% BCH	4	6,45	33,31	17241	1342	32,71	<DL	716
Beets (bulbs)	Cant	10% BS, 20% BCH	5	7,49	65,28	18913	946	55,72	<DL	412
Beets (bulbs)	Cant	20% BCH	1	5,68	72,12	14544	1060	49,17	<DL	282
Beets (bulbs)	Cant	20% BCH	2	5,56	66,89	16041	914	46,00	<DL	349
Beets (bulbs)	Cant	20% BCH	3	4,48	34,90	16292	790	40,89	<DL	290
Beets (bulbs)	Cant	20% BCH	4	4,93	59,80	12993	797	49,33	<DL	229
Beets (bulbs)	Cant	20% BCH	5	6,32	53,82	15251	1135	59,87	<DL	364
Beets (leaves)	Cant	100% TS	1	3,86	185,59	63342	3408	299,31	0,16	15987
Beets (leaves)	Cant	100% TS	2	4,36	163,36	63150	3925	423,51	0,30	21115
Beets (leaves)	Cant	100% TS	3	3,60	418,51	46498	3401	230,94	0,01	16677
Beets (leaves)	Cant	100% TS	4	5,85	202,50	61434	4075	570,17	0,66	24460
Beets (leaves)	Cant	100% TS	5	7,54	92,78	56292	3853	164,69	0,24	25382
Beets (leaves)	Cant	10% BS	1	12,35	119,52	47810	4062	509,51	0,97	25865
Beets (leaves)	Cant	10% BS	2	9,44	151,10	52800	3993	674,20	1,25	24349
Beets (leaves)	Cant	10% BS	3	15,81	275,66	46510	4338	744,54	0,90	21508
Beets (leaves)	Cant	10% BS	4	5,19	144,67	49138	4099	400,46	0,39	28375
Beets (leaves)	Cant	10% BS	5	11,40	405,17	48046	4234	852,14	0,74	24554
Beets (leaves)	Cant	10% BS, 20% BCH	1	16,40	145,31	59366	4183	461,28	2,00	25716
Beets (leaves)	Cant	10% BS, 20% BCH	2	12,55	187,68	59433	4049	317,24	2,82	27997
Beets (leaves)	Cant	10% BS, 20% BCH	3	14,01	105,49	59397	4119	401,38	2,48	29411
Beets (leaves)	Cant	10% BS, 20% BCH	4	13,59	90,83	56696	4115	309,09	1,85	33472
Beets (leaves)	Cant	10% BS, 20% BCH	5	12,45	166,30	54872	4263	537,93	1,72	26120
Beets (leaves)	Cant	20% BCH	1	6,23	486,36	53449	4253	532,03	0,51	32495
Beets (leaves)	Cant	20% BCH	2	5,03	189,62	52687	4172	442,45	0,89	28811
Beets (leaves)	Cant	20% BCH	3	5,98	103,85	52621	4134	300,40	1,01	33660
Beets (leaves)	Cant	20% BCH	4	4,26	255,95	44895	4247	518,30	0,20	25920
Beets (leaves)	Cant	20% BCH	5	6,06	99,49	59865	4101	248,62	0,40	27520
Tomato	Cant	100% TS	1	5,13	45,38	36414	1102	8,66	<DL	293
Tomato	Cant	100% TS	2	5,78	32,71	37954	1109	7,98	<DL	320
Tomato	Cant	100% TS	3	5,69	38,09	39579	1261	9,65	<DL	359
Tomato	Cant	100% TS	4	5,22	39,94	35925	1176	8,57	<DL	325
Tomato	Cant	100% TS	5	5,54	37,47	36619	1250	8,54	<DL	364
Tomato	Cant	10% BS	1	7,57	34,02	35928	1333	7,88	<DL	374
Tomato	Cant	10% BS	2	8,06	37,00	40396	1248	9,58	<DL	370
Tomato	Cant	10% BS	3	7,23	33,13	34747	1202	10,31	<DL	271
Tomato	Cant	10% BS	4	7,29	43,88	36370	1410	9,53	<DL	336
Tomato	Cant	10% BS	5	6,43	35,03	36795	1286	9,29	<DL	260
Tomato	Cant	10% BS, 20% BCH	1	8,06	32,37	38804	1256	8,28	<DL	289
Tomato	Cant	10% BS, 20% BCH	2	8,31	36,48	40595	1442	10,54	<DL	268
Tomato	Cant	10% BS, 20% BCH	3	8,51	32,82	43120	1309	7,30	<DL	330
Tomato	Cant	10% BS, 20% BCH	4	7,90	39,71	39449	1355	8,69	<DL	309
Tomato	Cant	10% BS, 20% BCH	5	7,72	39,97	36409	1095	7,75	<DL	313
Tomato	Cant	20% BCH	1	6,27	39,87	39561	1187	6,82	<DL	324
Tomato	Cant	20% BCH	2	4,85	25,48	34425	1165	7,35	<DL	270
Tomato	Cant	20% BCH	3	6,69	39,47	36833	1224	8,72	<DL	276
Tomato	Cant	20% BCH	4	5,80	38,15	32416	1151	8,30	<DL	257
Tomato	Cant	20% BCH	5	6,30	50,03	34054	1317	11,20	<DL	291
Carrots	Cant	100% TS	1	5,52	50,91	27059	599	53,84	<DL	2973

Plant	Soil	Soil variant	Rep	Cu	Fe	K	Mg	Mn	Mo	Na
Carrots	Cant	100% TS	2	3,98	263,94	22182	914	25,98	<DL	2988
Carrots	Cant	100% TS	3	5,24	31,88	28202	639	36,31	<DL	3933
Carrots	Cant	100% TS	4	4,03	29,00	17481	830	24,94	<DL	1625
Carrots	Cant	100% TS	5	3,87	33,59	19837	715	26,62	<DL	1982
Carrots	Cant	10% BS	1	7,22	58,78	35436	948	110,17	<DL	3618
Carrots	Cant	10% BS	2	5,16	43,74	24655	747	44,66	<DL	4052
Carrots	Cant	10% BS	3	6,24	63,48	28647	1165	36,31	<DL	10390
Carrots	Cant	10% BS	4	2,67	24,05	18661	1003	25,07	<DL	2605
Carrots	Cant	10% BS	5	8,56	37,77	32171	900	56,61	<DL	6072
Carrots	Cant	10% BS, 20% BCH	1	9,18	73,46	28534	1198	47,47	<DL	4859
Carrots	Cant	10% BS, 20% BCH	2	4,18	21,42	19835	784	18,01	<DL	2216
Carrots	Cant	10% BS, 20% BCH	3	7,16	42,81	29319	737	38,09	<DL	4990
Carrots	Cant	10% BS, 20% BCH	4	3,38	58,00	35421	950	21,94	<DL	2382
Carrots	Cant	10% BS, 20% BCH	5	7,07	48,59	28029	890	44,05	<DL	5624
Carrots	Cant	20% BCH	1	3,70	31,09	25742	748	18,67	<DL	2389
Carrots	Cant	20% BCH	2	4,36	33,87	22421	732	11,89	<DL	2363
Carrots	Cant	20% BCH	3	5,45	40,69	25339	1151	22,97	<DL	2923
Carrots	Cant	20% BCH	4	3,26	29,79	24347	925	13,97	<DL	2369
Carrots	Cant	20% BCH	5	3,30	23,30	17143	762	18,16	<DL	2279
Leek (bulbs)	Cant	100% TS	1	3,83	45,10	13735	1286	13,75	<DL	716
Leek (bulbs)	Cant	100% TS	2	4,11	34,19	16423	941	24,09	<DL	999
Leek (bulbs)	Cant	100% TS	3	3,95	28,09	11593	998	16,83	<DL	652
Leek (bulbs)	Cant	100% TS	4	3,84	22,35	16410	1009	15,49	<DL	1171
Leek (bulbs)	Cant	100% TS	5	2,57	20,83	10595	1024	20,98	<DL	1193
Leek (bulbs)	Cant	10% BS	1	2,12	26,12	12643	1119	21,39	<DL	828
Leek (bulbs)	Cant	10% BS	2	2,20	25,54	11402	865	24,73	<DL	494
Leek (bulbs)	Cant	10% BS	3	2,68	25,43	7269	891	52,52	<DL	703
Leek (bulbs)	Cant	10% BS	4	3,69	29,63	11514	734	17,41	<DL	971
Leek (bulbs)	Cant	10% BS	5	3,67	25,80	11699	877	26,30	<DL	1147
Leek (bulbs)	Cant	10% BS, 20% BCH	1	4,55	24,01	16464	968	19,15	<DL	756
Leek (bulbs)	Cant	10% BS, 20% BCH	2	3,91	28,54	18090	784	12,09	<DL	1024
Leek (bulbs)	Cant	10% BS, 20% BCH	3	5,42	36,96	13814	846	22,12	<DL	752
Leek (bulbs)	Cant	10% BS, 20% BCH	4	7,36	30,34	16249	1039	12,15	0,17	1135
Leek (bulbs)	Cant	10% BS, 20% BCH	5	7,05	52,89	14664	1107	25,09	<DL	1140
Leek (bulbs)	Cant	20% BCH	1	4,47	21,38	15056	1424	16,77	<DL	927
Leek (bulbs)	Cant	20% BCH	2	2,60	27,00	14889	1060	15,87	<DL	738
Leek (bulbs)	Cant	20% BCH	3	3,50	24,25	14451	878	12,16	<DL	512
Leek (bulbs)	Cant	20% BCH	4	1,87	17,33	13840	878	12,02	<DL	452
Leek (bulbs)	Cant	20% BCH	5	1,81	34,49	15039	837	16,59	<DL	582
Grass, III	Cant	100% TS	1	4,02	104,50	16295	2616	267,12	5,13	3642
Grass, III	Cant	100% TS	2	4,20	124,35	17277	2613	289,36	3,85	3599
Grass, III	Cant	100% TS	3	4,40	68,07	23230	1859	127,05	1,19	2261
Grass, III	Cant	100% TS	4	4,31	206,13	18333	2739	209,40	3,15	4093
Grass, III	Cant	100% TS	5	4,17	179,38	16324	2639	228,58	3,30	3582
Grass, III	Cant	10% BS	1	4,80	76,91	22578	2289	211,85	6,93	2653
Grass, III	Cant	10% BS	2	5,20	98,16	23387	2359	227,13	8,61	2992
Grass, III	Cant	10% BS	3	5,15	108,88	22507	2188	255,31	6,79	2618
Grass, III	Cant	10% BS	4	4,79	135,26	23277	2423	254,27	8,75	2926
Grass, III	Cant	10% BS	5	5,33	187,10	20741	2392	284,93	10,01	2637
Grass, III	Cant	10% BS, 20% BCH	2	5,55	84,37	25822	2533	93,96	9,12	3680
Grass, III	Cant	10% BS, 20% BCH	4	4,92	85,95	20843	2554	137,67	10,64	3586

Plant	Soil	Soil variant	Rep	Cu	Fe	K	Mg	Mn	Mo	Na
Grass, III	Cant	10% BS, 20% BCH	5	5,59	176,49	22352	2136	123,48	9,57	2757
Grass, III	Cant	20% BCH	1	4,26	52,04	18084	2637	220,23	3,72	4001
Grass, III	Cant	20% BCH	2	4,58	100,52	17663	2703	188,33	3,09	4799
Grass, III	Cant	20% BCH	3	4,65	102,89	20508	2573	206,75	4,70	4259
Grass, III	Cant	20% BCH	4	4,62	77,66	18507	2695	184,69	4,05	4016
Grass, III	Cant	20% BCH	5	4,21	104,36	15747	2504	218,07	3,72	2988
Grass, III	Balm	100% TS	1	3,12	74,77	22628	2109	508,59	<DL	1951
Grass, III	Balm	100% TS	2	3,86	56,80	21521	2158	<DL	<DL	1664
Grass, III	Balm	100% TS	3	3,57	45,21	24233	2042	533,02	<DL	1919
Grass, III	Balm	10% BS	1	6,43	94,36	20052	2366	<DL	6,24	1474
Grass, III	Balm	10% BS	2	8,81	45,41	28805	2571	<DL	3,29	2561
Grass, III	Balm	10% BS	3	7,61	68,66	22629	2644	794,84	6,03	1131
Grass, III	Balm	10% BS, 20% BCH	1	8,20	49,90	23743	2833	1007,89	9,77	2381
Grass, III	Balm	10% BS, 20% BCH	2	7,74	126,54	24492	2562	803,40	13,96	1652
Grass, III	Balm	10% BS, 20% BCH	3	9,13	126,79	27094	2720	991,10	19,19	1722
Grass, III	Balm	20% BCH	1	5,15	78,96	22734	2476	1065,03	0,54	2009
Grass, III	Balm	20% BCH	2	5,20	100,27	19774	2611	995,31	0,45	2729
Grass, III	Balm	20% BCH	3	4,74	99,80	17989	2820	1166,62	0,61	2905
Corn	Cant	100% TS	1	2,72	34,25	10090	1458	12,02	0,03	11
Corn	Cant	100% TS	2	2,34	34,72	11607	1479	9,45	0,04	8
Corn	Cant	100% TS	3	5,00	54,61	22694	3366	122,97	<DL	109
Corn	Cant	100% TS	4	4,90	53,70	24228	2074	97,93	0,07	136
Corn	Cant	100% TS	5	2,24	43,92	11345	1794	9,47	0,08	<DL
Corn	Cant	10% BS	1	2,82	37,90	10225	1487	11,28	0,11	<DL
Corn	Cant	10% BS	2	2,84	29,45	8913	1177	7,34	<DL	8
Corn	Cant	10% BS	3	3,14	32,70	11536	1442	10,83	<DL	11
Corn	Cant	10% BS	4	4,57	47,75	13755	1892	16,01	0,11	10
Corn	Cant	10% BS	5	2,49	30,15	9777	1261	7,99	<DL	<DL
Corn	Cant	10% BS, 20% BCH	1	2,18	24,92	8899	895	4,98	0,30	11
Corn	Cant	10% BS, 20% BCH	2	2,90	28,46	8780	1150	6,60	0,09	<DL
Corn	Cant	10% BS, 20% BCH	3	2,64	34,74	10137	999	5,86	0,12	20
Corn	Cant	10% BS, 20% BCH	4	3,99	52,01	12353	1740	12,53	0,13	18
Corn	Cant	10% BS, 20% BCH	5	3,05	54,40	13050	1664	10,53	<DL	21
Corn	Cant	20% BCH	1	2,46	29,30	9497	1140	6,07	<DL	17
Corn	Cant	20% BCH	2	6,09	58,35	22041	2984	117,41	0,05	100
Corn	Cant	20% BCH	3	5,20	49,90	17266	1852	13,76	<DL	23
Corn	Cant	20% BCH	4	5,29	55,53	16611	1898	19,21	<DL	30
Corn	Cant	20% BCH	5	3,49	44,36	13731	1973	13,23	<DL	23
Broccoli	Cant	100% TS	1	6,39	90,45	28957	1882	41,77	1,48	887
Broccoli	Cant	100% TS	2	6,09	55,90	29512	1865	28,39	1,51	839
Broccoli	Cant	100% TS	4	4,73	51,19	29080	1501	23,08	1,15	1153
Broccoli	Cant	100% TS	5	6,28	85,55	29798	1776	35,96	1,27	720
Broccoli	Cant	10% BS	1	4,60	45,65	28758	1558	22,12	3,24	666
Broccoli	Cant	10% BS	2	5,24	50,06	34683	1715	23,50	1,57	934
Broccoli	Cant	10% BS	3	6,73	66,74	35846	1618	27,49	1,74	823
Broccoli	Cant	10% BS	4	9,94	75,61	29572	1712	36,66	2,13	794
Broccoli	Cant	10% BS	5	5,64	58,20	28060	1768	37,43	1,69	782
Broccoli	Cant	10% BS, 20% BCH	2	5,39	50,45	36240	1923	22,99	4,51	968
Broccoli	Cant	10% BS, 20% BCH	3	6,86	64,21	28937	1811	24,47	1,89	626
Broccoli	Cant	10% BS, 20% BCH	4	7,08	74,57	29827	1924	32,71	2,39	845
Broccoli	Cant	10% BS, 20% BCH	5	6,68	82,35	31948	1835	30,36	2,65	743

Plant	Soil	Soil variant	Rep	Cu	Fe	K	Mg	Mn	Mo	Na
Broccoli	Cant	20% BCH	1	5,40	76,52	30003	1637	21,09	1,25	661
Broccoli	Cant	20% BCH	2	6,34	100,62	29066	1676	38,26	1,20	844
Broccoli	Cant	20% BCH	3	4,86	52,89	31497	1618	23,16	1,33	735
Broccoli	Cant	20% BCH	4	5,66	76,40	28359	1811	25,39	1,14	645
Broccoli	Cant	20% BCH	5	2,95	35,02	36075	1524	23,66	1,31	1559
Broccoli	Balm	100% TS	1	3,71	150,61	28802	2170	140,19	0,58	945
Broccoli	Balm	100% TS	2	4,16	149,61	27535	2607	182,81	0,71	1511
Broccoli	Balm	10% BS	1	13,85	93,44	27667	2040	119,28	0,77	850
Broccoli	Balm	10% BS	2	14,57	91,06	26824	2068	147,23	0,86	1245
Broccoli	Balm	10% BS	3	15,36	113,60	27131	2155	143,07	0,82	1053
Broccoli	Balm	10% BS, 20% BCH	1	13,66	76,34	29248	1978	76,30	1,36	816
Broccoli	Balm	10% BS, 20% BCH	2	15,01	83,42	27727	2185	133,53	1,22	1283
Broccoli	Balm	10% BS, 20% BCH	3	12,08	83,98	24350	1921	84,24	1,78	932
Broccoli	Balm	20% BCH	1	4,43	77,03	28648	2130	100,36	0,38	1181
Broccoli	Balm	20% BCH	2	5,10	109,43	29709	2046	89,54	0,89	1416
Broccoli	Balm	20% BCH	3	4,38	98,50	26967	2000	84,99	0,40	1010
Manuka	Cant	100% TS	1	6,91	211,50	6981	2299	334,50	4,37	2115
Manuka	Cant	100% TS	2	6,18	231,79	5450	1977	399,52	4,59	2431
Manuka	Cant	100% TS	3	6,34	166,10	7091	1937	258,08	5,51	2241
Manuka	Cant	100% TS	4	6,81	214,95	6438	2137	302,33	3,66	2641
Manuka	Cant	100% TS	5	8,01	322,47	7973	2604	190,38	4,26	2586
Manuka	Cant	10% BS	1	9,48	141,66	7899	2341	354,30	5,51	2746
Manuka	Cant	10% BS	2	8,42	262,72	2526	3095	494,61	8,54	2332
Manuka	Cant	10% BS	3	11,37	306,42	5001	2478	671,19	8,87	2219
Manuka	Cant	10% BS	4	13,74	126,74	10959	2158	379,93	3,59	2942
Manuka	Cant	10% BS	5	15,28	222,96	6312	2789	401,54	12,25	2516
Manuka	Cant	10% BS, 20% BCH	1	16,38	115,62	10931	2331	129,63	16,47	2233
Manuka	Cant	10% BS, 20% BCH	2	7,58	186,96	7293	2134	116,19	3,32	3031
Manuka	Cant	10% BS, 20% BCH	3	12,13	308,22	6575	2752	457,41	14,64	3216
Manuka	Cant	10% BS, 20% BCH	4	11,16	143,27	6410	2275	89,05	7,97	2374
Manuka	Cant	10% BS, 20% BCH	5	12,85	192,81	8817	2391	167,29	12,73	2540
Manuka	Cant	20% BCH	1	6,43	153,32	7528	1931	154,03	2,46	1899
Manuka	Cant	20% BCH	2	5,47	754,76	5662	2300	306,22	6,47	2324
Manuka	Cant	20% BCH	3	5,59	206,74	6762	2237	235,37	4,06	2990
Manuka	Cant	20% BCH	4	6,55	205,92	5757	2509	193,43	6,07	2092
Manuka	Cant	20% BCH	5	7,51	227,25	7320	2079	124,49	3,95	1978
Manuka	Balm	100% TS	1	7,18	404,89	10182	2242	1130,59	0,78	1050
Manuka	Balm	100% TS	2	6,36	293,94	4561	2487	1632,88	0,42	1035
Manuka	Balm	100% TS	3	5,81	318,57	7646	2450	693,96	0,74	1191
Manuka	Balm	10% BS	1	11,35	185,34	7016	2246	920,88	0,94	1290
Manuka	Balm	10% BS	2	13,78	190,62	4922	2568	1211,47	1,22	1357
Manuka	Balm	10% BS	3	12,36	198,19	8685	2542	1153,28	1,11	1688
Manuka	Balm	10% BS, 20% BCH	1	15,01	144,43	6670	2944	1285,08	4,24	1577
Manuka	Balm	10% BS, 20% BCH	2	12,37	108,19	9419	2336	601,01	1,43	2394
Manuka	Balm	10% BS, 20% BCH	3	9,56	118,39	8213	1996	770,77	1,16	1740
Manuka	Balm	20% BCH	1	6,28	194,75	5452	2369	569,63	0,28	1524
Manuka	Balm	20% BCH	2	7,88	311,67	3845	2375	708,88	0,35	1565
Manuka	Balm	20% BCH	3	6,81	135,45	6812	2388	546,41	0,90	2552

Plant	Soil	Soil variant	Rep	Ni	P	Pb	S	Tl	Zn	Se
Grass, I	Cant	100% TS	1	1,15	2550	0,412	2822	0,24	55,10	
Grass, I	Cant	100% TS	2	0,65	3169	0,345	3095	<DL	50,34	
Grass, I	Cant	100% TS	3	0,83	4161	0,369	3160	0,94	53,33	
Grass, I	Cant	100% TS	4	0,47	3079	0,183	3346	<DL	53,28	
Grass, I	Cant	100% TS	5	0,58	2544	0,214	3117	<DL	51,26	
Grass, I	Cant	10% BS	1	0,81	3951	0,246	3541	<DL	101,24	
Grass, I	Cant	10% BS	2	0,90	4368	0,343	3113	0,54	87,17	
Grass, I	Cant	10% BS	3	0,80	4818	0,375	3245	<DL	98,10	
Grass, I	Cant	10% BS	4	0,85	4188	0,249	3471	<DL	86,93	
Grass, I	Cant	10% BS	5	0,81	4118	<DL	3471	0,74	91,93	
Grass, I	Cant	10% BS, 20% BCH	2	0,98	4227	<DL	3330	0,28	118,77	
Grass, I	Cant	10% BS, 20% BCH	4	0,77	3689	0,193	3061	0,46	103,49	
Grass, I	Cant	10% BS, 20% BCH	5	0,93	4015	0,233	2710	0,44	113,06	
Grass, I	Cant	20% BCH	1	0,53	3346	0,246	2988	0,79	56,31	
Grass, I	Cant	20% BCH	2	0,54	3580	0,319	3086	<DL	62,12	
Grass, I	Cant	20% BCH	3	0,51	3358	0,585	2768	0,39	55,09	
Grass, I	Cant	20% BCH	4	0,57	3387	0,230	2988	0,51	55,76	
Grass, I	Cant	20% BCH	5	1,01	3757	<DL	3253	0,58	60,80	
Grass, I	Balm	100% TS	1	1,04	3407	<DL	3880	0,37	28,38	
Grass, I	Balm	100% TS	2	0,76	2367	0,123	5008	0,58	27,31	
Grass, I	Balm	100% TS	3	1,07	3598	<DL	4723	0,89	30,58	
Grass, I	Balm	10% BS	1	2,42	3405	<DL	6352	0,68	168,61	
Grass, I	Balm	10% BS	2	2,68	4024	<DL	5037	0,48	188,86	
Grass, I	Balm	10% BS	3	2,37	3217	<DL	5079	0,49	168,18	
Grass, I	Balm	10% BS, 20% BCH	1	2,00	2941	0,149	7054	0,50	182,43	
Grass, I	Balm	10% BS, 20% BCH	2	2,19	2946	<DL	7531	0,34	180,66	
Grass, I	Balm	10% BS, 20% BCH	3	3,05	3693	0,123	8173	0,57	208,95	
Grass, I	Balm	20% BCH	1	0,84	2709	<DL	5059	0,53	30,65	
Grass, I	Balm	20% BCH	2	0,84	2847	0,194	4216	0,51	28,79	
Grass, I	Balm	20% BCH	3	0,93	2838	<DL	5555	<DL	30,23	
Radish	Cant	100% TS	1	0,45	4731	<DL	4119	0,29	32,94	
Radish	Cant	100% TS	2	0,64	4416	0,070	5104	<DL	31,62	
Radish	Cant	100% TS	3	0,40	4253		5575	<DL	38,04	
Radish	Cant	100% TS	4	0,24	3142	0,278	4953	0,38	29,22	
Radish	Cant	100% TS	5	0,45	3711	0,175	4213	0,59	32,67	
Radish	Cant	10% BS	1	0,95	5236	0,282	5724	0,56	103,39	
Radish	Cant	10% BS	2	1,07	3966	0,192	4381	0,27	92,12	
Radish	Cant	10% BS	3	0,82	5898	0,084	5618	<DL	111,16	
Radish	Cant	10% BS	4	0,66	5794	<DL	4714	0,47	120,20	
Radish	Cant	10% BS	5	1,74	5691	<DL	5856	0,24	129,27	
Radish	Cant	10% BS, 20% BCH	1	0,74	5073	0,139	4872	0,46	72,82	
Radish	Cant	10% BS, 20% BCH	2	0,54	4763	<DL	5360	<DL	91,65	
Radish	Cant	10% BS, 20% BCH	3	0,41	4883	<DL	6511	0,68	95,81	
Radish	Cant	10% BS, 20% BCH	4	0,34	4460	<DL	4549	<DL	89,00	
Radish	Cant	10% BS, 20% BCH	5	0,36	4164	<DL	4835	<DL	72,58	
Radish	Cant	20% BCH	1	0,37	4940	0,339	4285	<DL	94,69	
Radish	Cant	20% BCH	2	0,70	4863	<DL	5254	0,50	48,68	
Radish	Cant	20% BCH	3	0,16	3393	<DL	4104	0,80	56,74	

Plant	Soil	Soil variant	Rep	Ni	P	Pb	S	Tl	Zn	Se
Radish	Cant	20% BCH	4	0,48	3662	<DL	4457	<DL	28,63	
Radish	Cant	20% BCH	5	0,26	4671	<DL	5457	0,73	43,13	
Radish	Cant	20% BCH	3	0,29	3296	<DL	4085	<DL	55,12	
Lettuce	Cant	100% TS	4	0,40	2197	0,487	2637	0,49	42,75	1,02
Lettuce	Cant	100% TS	5	0,53	2323	0,390	2511	<DL	47,79	0,90
Lettuce	Cant	10% BS	2	0,43	2044	0,191	1366	0,59	30,19	0,96
Lettuce	Cant	10% BS	3	0,97	2692	0,770	2750	<DL	122,75	0,87
Lettuce	Cant	10% BS	5	0,71	2290	0,408	1022	<DL	32,39	0,70
Lettuce	Cant	10% BS, 20% BCH	1	0,87	3559	0,417	2947	0,21	144,18	1,01
Lettuce	Cant	10% BS, 20% BCH	3	0,52	3680	0,498	3545	<DL	178,83	0,87
Lettuce	Cant	10% BS, 20% BCH	4	0,90	3343	0,535	3479	<DL	186,41	0,70
Lettuce	Cant	10% BS, 20% BCH	5	0,42	2828	0,219	2826	0,58	112,91	0,51
Lettuce	Cant	20% BCH	2	0,65	2614	0,537	2846	0,42	69,06	0,77
Lettuce	Cant	20% BCH	4	0,40	2504	0,318	1504	<DL	35,78	0,65
Radish Leaves	Cant	100% TS	1	0,54	2887	0,727	6868	<DL	46,73	0,94
Radish Leaves	Cant	100% TS	2	0,60	2603	0,386	8932	0,86	80,71	0,70
Radish Leaves	Cant	100% TS	3	0,48	2865	0,262	8086	1,08	56,14	1,20
Radish Leaves	Cant	100% TS	4	0,58	2659	0,601	5427	0,91	42,93	1,02
Radish Leaves	Cant	100% TS	5	0,67	2302	0,333	6491	0,80	41,82	0,98
Radish Leaves	Cant	10% BS	1	0,54	3159	0,186	6275	0,59	202,38	0,84
Radish Leaves	Cant	10% BS	2	0,55	2835	0,375	6890	1,37	148,28	1,47
Radish Leaves	Cant	10% BS	3	0,52	4954	0,232	10301	0,69	169,50	1,25
Radish Leaves	Cant	10% BS	4	0,68	4098	0,528	9484	0,79	265,29	1,24
Radish Leaves	Cant	10% BS	5	0,71	3383	0,304	7428	0,83	170,66	0,98
Radish Leaves	Cant	10% BS, 20% BCH	1	0,83	3236	0,386	12196	0,35	170,90	1,18
Radish Leaves	Cant	10% BS, 20% BCH	2	0,39	3827	0,209	14368	1,04	148,69	0,60
Radish Leaves	Cant	10% BS, 20% BCH	3	0,41	3327	0,319	11449	<DL	152,41	0,97
Radish Leaves	Cant	10% BS, 20% BCH	4	92,12	3101	0,489	9112	0,81	126,04	1,08
Radish Leaves	Cant	10% BS, 20% BCH	5	0,44	3217	0,564	7800	0,44	100,98	1,09
Radish Leaves	Cant	20% BCH	1	0,63	3307	0,674	7317	<DL	91,36	0,65
Radish Leaves	Cant	20% BCH	2	0,56	3502	0,476	6890	<DL	38,61	0,97
Radish Leaves	Cant	20% BCH	3	0,39	2821	0,479	7502	0,90	38,76	1,26
Radish Leaves	Cant	20% BCH	4	0,37	2673	0,574	8157	0,92	35,91	<DL
Radish Leaves	Cant	20% BCH	5	0,41	2795	0,269	10106	0,68	74,82	1,38
Spinach	Cant	100% TS	2	0,75	2288	0,287	2024	<DL	55,56	0,88
Spinach	Cant	100% TS	3	0,54	2365	<DL	2159	0,70	74,81	0,79
Spinach	Cant	100% TS	5	0,78	3229	0,289	3095	<DL	100,36	0,55
Spinach	Cant	10% BS	1	0,48	1358	0,564	1252	<DL	27,10	0,61
Spinach	Cant	10% BS	2	1,09	3160	0,961	3245	0,47	323,10	0,99
Spinach	Cant	10% BS	4	0,62	1755	0,216	1888	<DL	156,54	0,67
Spinach	Cant	10% BS	5	0,60	2394	0,264	3181	0,65	202,17	0,96
Spinach	Cant	20% BCH	1	0,65	3011	0,363	2459	<DL	66,93	1,18
Spinach	Cant	20% BCH	2	0,34	2584	<DL	1530	<DL	48,23	1,00
Spinach	Cant	20% BCH	4	0,39	2709	0,441	2361	0,78	37,35	0,71
Spinach	Cant	20% BCH	5	0,43	2670	0,532	3244	0,54	39,34	1,40
Courgette	Cant	100% TS	1	0,98	5717	0,156	1595	<DL	49,80	0,84
Courgette	Cant	100% TS	3	1,12	5039	0,123	1441	0,26	50,77	0,61
Courgette	Cant	100% TS	4	0,96	7533	<DL	2312	0,91	64,95	1,49
Courgette	Cant	100% TS	5	0,62	6163	0,285	1695	<DL	55,43	0,85
Courgette	Cant	10% BS	2	1,24	6338	0,235	1667	<DL	78,91	0,55
Courgette	Cant	10% BS	3	1,25	8256	0,153	2373	0,22	86,10	0,90

Plant	Soil	Soil variant	Rep	Ni	P	Pb	S	Tl	Zn	Se
Courgette	Cant	10% BS	4	1,38	6841	0,268	1797	<DL	84,66	0,79
Courgette	Cant	10% BS, 20% BCH	1	0,99	6525	0,152	1923	<DL	81,94	0,83
Courgette	Cant	10% BS, 20% BCH	2	1,52	5891	0,350	1643	<DL	89,15	0,97
Courgette	Cant	10% BS, 20% BCH	3	1,02	6793	0,670	1955	0,21	85,46	0,76
Courgette	Cant	10% BS, 20% BCH	4	1,19	6128	0,306	1653	<DL	84,33	0,80
Courgette	Cant	10% BS, 20% BCH	5	0,97	6116	<DL	1668	<DL	78,84	0,81
Courgette	Cant	20% BCH	1	1,27	6204	0,253	1589	<DL	51,79	0,75
Courgette	Cant	20% BCH	2	0,79	6889	0,211	1942	<DL	55,99	0,85
Courgette	Cant	20% BCH	3	0,90	5996	0,241	1817	<DL	49,31	0,58
Courgette	Cant	20% BCH	4	34,36	6575	<DL	1739	<DL	59,00	0,84
Courgette	Cant	20% BCH	5	0,67	7567	<DL	1902	0,45	55,14	0,75
Grass, II	Cant	100% TS	1	0,31	3039	0,538	2583	0,37	34,16	0,64
Grass, II	Cant	100% TS	2	0,39	3148	0,345	3792	<DL	29,64	1,15
Grass, II	Cant	100% TS	3	0,60	2970	0,286	3378	0,50	44,51	1,24
Grass, II	Cant	100% TS	4	0,37	3461	0,805	4684	<DL	34,37	0,84
Grass, II	Cant	100% TS	5	0,96	3237	0,451	3294	0,31	33,60	0,93
Grass, II	Cant	10% BS	1	0,52	4000	0,223	4392	<DL	60,24	1,15
Grass, II	Cant	10% BS	2	0,49	3997	1,371	3660	<DL	63,15	1,22
Grass, II	Cant	10% BS	3	0,69	3894	0,278	3836	<DL	55,21	0,84
Grass, II	Cant	10% BS	4	0,67	4293	0,473	4411	<DL	54,32	1,05
Grass, II	Cant	10% BS	5	0,58	3619	0,623	3667	<DL	61,04	1,06
Grass, II	Cant	10% BS, 20% BCH	2	0,65	4078	0,381	3447	<DL	79,62	0,88
Grass, II	Cant	10% BS, 20% BCH	4	0,43	3444	0,323	3176	0,40	51,89	0,71
Grass, II	Cant	10% BS, 20% BCH	5	0,80	2912	0,309	3291	<DL	85,80	1,13
Grass, II	Cant	20% BCH	1	3,91	3266	<DL	2938	0,62	29,80	0,55
Grass, II	Cant	20% BCH	2	0,54	2886	0,490	2773	<DL	33,18	0,64
Grass, II	Cant	20% BCH	3	0,43	3332	0,501	3258	0,33	28,76	0,69
Grass, II	Cant	20% BCH	4	0,45	2835	0,185	2526	<DL	26,70	0,99
Grass, II	Cant	20% BCH	5	0,62	3173	0,617	2863	<DL	32,08	1,18
Grass, II	Balm	100% TS	1	0,99	2765	0,166	6948	<DL	28,55	0,41
Grass, II	Balm	100% TS	2	0,80	1821	<DL	5157	0,62	29,29	0,45
Grass, II	Balm	100% TS	3	1,02	2517	<DL	7056	<DL	27,69	0,54
Grass, II	Balm	10% BS	1	3,04	3243	0,265	6385	<DL	131,70	0,82
Grass, II	Balm	10% BS	2	3,77	3506	0,123	7292	<DL	243,65	0,82
Grass, II	Balm	10% BS	3	2,91	2407		5328	<DL	174,58	0,01
Grass, II	Balm	10% BS, 20% BCH	1	2,58	3597	0,272	7622	<DL	161,57	0,59
Grass, II	Balm	10% BS, 20% BCH	2	2,31	2621		5641	<DL	149,09	0,51
Grass, II	Balm	10% BS, 20% BCH	3	3,68	4310	0,352	8117	<DL	195,72	0,54
Grass, II	Balm	20% BCH	1	0,66	2445	0,351	5352	<DL	25,06	1,00
Grass, II	Balm	20% BCH	2	0,73	2132	0,226	4819	<DL	24,93	0,76
Grass, II	Balm	20% BCH	3	2,70	2266	<DL	4696	<DL	24,18	0,44
Beets (bulbs)	Cant	100% TS	1	1,30	1925	<DL	845	<DL	84,84	0,82
Beets (bulbs)	Cant	100% TS	2	0,64	2551	<DL	818	<DL	53,21	<DL
Beets (bulbs)	Cant	100% TS	3	0,62	2258	<DL	839	<DL	64,94	0,52
Beets (bulbs)	Cant	100% TS	4	0,81	2923	<DL	1094	<DL	76,48	0,48
Beets (bulbs)	Cant	100% TS	5	1,01	3153	<DL	1468	<DL	63,14	0,80
Beets (bulbs)	Cant	10% BS	1	1,15	3282	<DL	924	<DL	288,56	<DL
Beets (bulbs)	Cant	10% BS	2	0,66	2881	0,278	737	<DL	195,97	0,19
Beets (bulbs)	Cant	10% BS	3	2,06	2987	0,286	1171	<DL	180,36	<DL
Beets (bulbs)	Cant	10% BS	4	2,15	2469	0,093	928	<DL	235,83	0,37
Beets (bulbs)	Cant	10% BS	5	1,04	3002	0,169	998	<DL	175,64	<DL

Plant	Soil	Soil variant	Rep	Ni	P	Pb	S	Tl	Zn	Se
Beets (bulbs)	Cant	10% BS, 20% BCH	1	0,94	3365	0,235	1121	<DL	209,58	<DL
Beets (bulbs)	Cant	10% BS, 20% BCH	2	0,46	3422	0,185	809	<DL	165,24	0,51
Beets (bulbs)	Cant	10% BS, 20% BCH	3	0,45	3848	<DL	887	<DL	178,31	0,38
Beets (bulbs)	Cant	10% BS, 20% BCH	4	0,55	3343	<DL	793	<DL	192,13	0,62
Beets (bulbs)	Cant	10% BS, 20% BCH	5	0,64	3523	<DL	734	<DL	146,13	0,24
Beets (bulbs)	Cant	20% BCH	1	0,53	2756	0,187	763	<DL	24,19	<DL
Beets (bulbs)	Cant	20% BCH	2	0,56	3036	0,181	702	<DL	34,17	0,72
Beets (bulbs)	Cant	20% BCH	3	0,39	2828	<DL	612	<DL	40,20	0,45
Beets (bulbs)	Cant	20% BCH	4	0,92	2647	0,198	703	0,12	29,27	0,50
Beets (bulbs)	Cant	20% BCH	5	0,43	3162	<DL	1037	<DL	47,64	<DL
Beets (leaves)	Cant	100% TS	1	0,62	7093	0,418	3451	0,50	172,44	0,60
Beets (leaves)	Cant	100% TS	2	0,96	3631	0,332	4658	<DL	202,41	0,67
Beets (leaves)	Cant	100% TS	3	0,96	4861	0,439	4278	<DL	118,74	1,05
Beets (leaves)	Cant	100% TS	4	1,03	5569	0,617	4939	0,47	262,94	0,84
Beets (leaves)	Cant	100% TS	5	0,43	3075	0,003	5027	0,40	140,74	0,29
Beets (leaves)	Cant	10% BS	1	1,44	4832	0,333	6735	0,48	1425,83	0,88
Beets (leaves)	Cant	10% BS	2	1,01	3687	0,612	6036	<DL	1185,95	1,35
Beets (leaves)	Cant	10% BS	3	1,18	3137	0,338	6162	0,40	1081,95	1,11
Beets (leaves)	Cant	10% BS	4	1,31	2935	0,312	5328	1,15	902,71	0,78
Beets (leaves)	Cant	10% BS	5	1,02	3152	0,910	4878	<DL	1295,12	1,32
Beets (leaves)	Cant	10% BS, 20% BCH	1	1,23	6726	0,334	7642	0,99	1450,78	1,01
Beets (leaves)	Cant	10% BS, 20% BCH	2	1,46	7734	0,600	5434	1,21	992,90	0,72
Beets (leaves)	Cant	10% BS, 20% BCH	3	0,60	5652	0,003	8128	0,61	1193,48	0,78
Beets (leaves)	Cant	10% BS, 20% BCH	4	0,79	6068	0,178	6799	1,14	1219,59	0,75
Beets (leaves)	Cant	10% BS, 20% BCH	5	0,99	6914	0,437	6703	0,73	1142,74	1,01
Beets (leaves)	Cant	20% BCH	1	0,42	2810	0,738	6106	0,90	205,92	1,57
Beets (leaves)	Cant	20% BCH	2	0,56	4698	0,383	5232	0,84	194,82	0,60
Beets (leaves)	Cant	20% BCH	3	0,35	3180	0,310	6412	0,93	206,33	0,01
Beets (leaves)	Cant	20% BCH	4	0,38	3132	0,517	5966	1,01	226,12	1,02
Beets (leaves)	Cant	20% BCH	5	0,33	4689	0,355	3883	0,99	174,19	1,08
Tomato	Cant	100% TS	1	0,07	2284	0,150	1165	0,34	16,93	0,24
Tomato	Cant	100% TS	2	0,29	2808	<DL	1314	0,45	15,19	0,64
Tomato	Cant	100% TS	3	0,41	2571	0,207	1341	0,40	18,14	0,48
Tomato	Cant	100% TS	4	0,00	2644	<DL	1271	0,59	15,50	1,22
Tomato	Cant	100% TS	5	0,20	2854	0,402	1240	<DL	16,67	0,85
Tomato	Cant	10% BS	1	0,55	3370	0,172	1448	<DL	19,61	0,78
Tomato	Cant	10% BS	2	0,75	3130	0,118	1457	<DL	26,27	1,22
Tomato	Cant	10% BS	3	0,68	2720	<DL	1302	0,65	24,18	0,79
Tomato	Cant	10% BS	4	14,12	2943	<DL	1269	<DL	22,18	0,96
Tomato	Cant	10% BS	5	0,80	2453	<DL	1221	0,55	22,03	1,45
Tomato	Cant	10% BS, 20% BCH	1	0,40	3548	<DL	1389	0,48	22,21	0,63
Tomato	Cant	10% BS, 20% BCH	2	1,97	3841	<DL	1395	0,28	28,39	1,64
Tomato	Cant	10% BS, 20% BCH	3	1,04	3569	<DL	1414	<DL	20,98	0,79
Tomato	Cant	10% BS, 20% BCH	4	0,46	3617	<DL	1371	<DL	30,70	1,14
Tomato	Cant	10% BS, 20% BCH	5	0,42	3168	<DL	1275	<DL	29,71	0,92
Tomato	Cant	20% BCH	1	0,51	3278	<DL	1330	<DL	16,45	0,57
Tomato	Cant	20% BCH	2	0,33	2636	<DL	1081	<DL	11,40	<DL
Tomato	Cant	20% BCH	3	1,16	3167	0,096	1249	0,66	19,31	0,91
Tomato	Cant	20% BCH	4	0,68	2937	<DL	1302	<DL	16,42	0,58
Tomato	Cant	20% BCH	5	0,78	2602	0,203	1370	0,40	16,43	0,69
Carrots	Cant	100% TS	1	0,93	2854	0,290	764	0,26	37,10	0,84

Plant	Soil	Soil variant	Rep	Ni	P	Pb	S	Tl	Zn	Se
Carrots	Cant	100% TS	2	162,20	2850	0,003	666	<DL	30,08	0,79
Carrots	Cant	100% TS	3	0,73	3835	0,787	679	0,74	35,58	2,05
Carrots	Cant	100% TS	4	2,44	2351	0,138	765	<DL	23,57	0,83
Carrots	Cant	100% TS	5	0,47	2434	0,171	573	<DL	21,93	0,74
Carrots	Cant	10% BS	1	0,85	3358	0,503	1589	<DL	80,82	0,69
Carrots	Cant	10% BS	2	1,33	2869	0,516	1177	<DL	64,99	0,01
Carrots	Cant	10% BS	3	1,18	3603	0,382	2224	<DL	102,71	0,37
Carrots	Cant	10% BS	4	0,32	2344	0,003	718	<DL	25,21	0,01
Carrots	Cant	10% BS	5	1,90	3617	0,549	1229	<DL	66,43	1,01
Carrots	Cant	10% BS, 20% BCH	1	6,26	3840	0,538	1471	<DL	63,10	0,85
Carrots	Cant	10% BS, 20% BCH	2	0,92	2796	0,003	785	<DL	45,38	0,83
Carrots	Cant	10% BS, 20% BCH	3	3,61	3511	0,360	1111	<DL	60,80	0,01
Carrots	Cant	10% BS, 20% BCH	4	26,68	3721	0,357	751	<DL	36,59	0,91
Carrots	Cant	10% BS, 20% BCH	5	0,45	3770	0,549	1357	<DL	44,41	0,01
Carrots	Cant	20% BCH	1	0,28	2742	0,003	867	<DL	25,89	0,65
Carrots	Cant	20% BCH	2	0,42	2629	0,289	767	<DL	27,13	1,05
Carrots	Cant	20% BCH	3	0,66	3444	0,598	758	<DL	23,91	0,89
Carrots	Cant	20% BCH	4	0,26	2396	0,511	741	<DL	22,21	0,77
Carrots	Cant	20% BCH	5	0,41	2542	0,003	934	<DL	27,29	0,01
Leek (bulbs)	Cant	100% TS	1	1,98	1525	<DL	1404	0,76	19,09	0,70
Leek (bulbs)	Cant	100% TS	2	0,43	1902	<DL	1314	<DL	12,18	0,85
Leek (bulbs)	Cant	100% TS	3	0,30	2086	<DL	1277	<DL	15,80	0,43
Leek (bulbs)	Cant	100% TS	4	0,28	2128	<DL	1248	<DL	16,05	0,47
Leek (bulbs)	Cant	100% TS	5	0,22	1596	0,215	1197	0,60	14,11	0,79
Leek (bulbs)	Cant	10% BS	1	0,72	1789	<DL	1338	<DL	39,28	0,67
Leek (bulbs)	Cant	10% BS	2	0,55	1729	<DL	985	<DL	21,94	0,01
Leek (bulbs)	Cant	10% BS	3	2,10	1201	0,382	838	<DL	13,95	0,91
Leek (bulbs)	Cant	10% BS	4	5,50	1465	<DL	1006	<DL	13,41	0,92
Leek (bulbs)	Cant	10% BS	5	0,26	1558	<DL	828	<DL	13,21	0,39
Leek (bulbs)	Cant	10% BS, 20% BCH	1	1,08	1696	0,177	1439	<DL	20,35	0,59
Leek (bulbs)	Cant	10% BS, 20% BCH	2	0,43	2582	<DL	1656	<DL	30,26	0,01
Leek (bulbs)	Cant	10% BS, 20% BCH	3	0,27	2337	<DL	1415	<DL	24,92	0,77
Leek (bulbs)	Cant	10% BS, 20% BCH	4	0,37	2336	<DL	1466	<DL	37,44	0,38
Leek (bulbs)	Cant	10% BS, 20% BCH	5	0,87	2438	<DL	1829	<DL	35,81	0,35
Leek (bulbs)	Cant	20% BCH	1	0,93	2325	<DL	1424	<DL	25,55	0,01
Leek (bulbs)	Cant	20% BCH	2	0,29	1898	0,126	1232	<DL	16,62	0,43
Leek (bulbs)	Cant	20% BCH	3	0,39	1579	<DL	1406	<DL	18,84	0,50
Leek (bulbs)	Cant	20% BCH	4	0,64	1399	<DL	926	<DL	19,31	0,36
Leek (bulbs)	Cant	20% BCH	5	6,03	1831	<DL	1316	<DL	18,27	0,01
Grass, III	Cant	100% TS	1	0,73	2364	0,003	4866	0,46	35,21	0,67
Grass, III	Cant	100% TS	2	0,59	2543	0,003	6196	0,42	34,03	0,87
Grass, III	Cant	100% TS	3	4,16	2469	0,118	3135	<DL	28,58	0,85
Grass, III	Cant	100% TS	4	0,57	2908	0,556	6952	<DL	30,54	0,68
Grass, III	Cant	100% TS	5	0,63	2570	0,536	7168	<DL	30,86	0,94
Grass, III	Cant	10% BS	1	0,87	2843	0,003	4481	<DL	59,33	0,69
Grass, III	Cant	10% BS	2	0,62	2791	1,609	5412	<DL	72,06	0,86
Grass, III	Cant	10% BS	3	3,42	2848	0,219	4345	<DL	49,00	1,09
Grass, III	Cant	10% BS	4	0,49	2839	0,353	5078	<DL	54,96	0,68
Grass, III	Cant	10% BS	5	0,70	2760	0,629	5120	<DL	72,58	1,06
Grass, III	Cant	10% BS, 20% BCH	2	0,64	3130	0,003	5375	<DL	69,88	0,82
Grass, III	Cant	10% BS, 20% BCH	4	0,60	3002	0,160	5561	<DL	52,15	0,98

Plant	Soil	Soil variant	Rep	Ni	P	Pb	S	Tl	Zn	Se
Grass, III	Cant	10% BS, 20% BCH	5	3,05	2662	0,467	3863	0,39	60,43	1,17
Grass, III	Cant	20% BCH	1	0,38	2421	0,283	6489	<DL	33,16	0,87
Grass, III	Cant	20% BCH	2	0,63	2373	0,374	6847	0,65	34,13	0,81
Grass, III	Cant	20% BCH	3	0,54	3040	0,320	5956	<DL	28,38	0,64
Grass, III	Cant	20% BCH	4	1,04	2797	0,259	7110	1,18	30,31	0,59
Grass, III	Cant	20% BCH	5	0,50	2261	0,275	4824	<DL	27,32	0,91
Grass, III	Balm	100% TS	1	0,71	1756	<DL	4820	<DL	19,86	<DL
Grass, III	Balm	100% TS	2	1,68	1616	0,289	4327	0,49	25,20	0,91
Grass, III	Balm	100% TS	3	1,19	1766	<DL	4836	<DL	22,50	0,99
Grass, III	Balm	10% BS	1	2,61	2291	0,379	5379	0,65	94,50	0,88
Grass, III	Balm	10% BS	2	3,39	2950	0,217	7626	<DL	195,56	1,34
Grass, III	Balm	10% BS	3	3,10	2524	<DL	8405	<DL	130,21	1,32
Grass, III	Balm	10% BS, 20% BCH	1	3,23	3214	0,295	8884	0,71	164,69	1,23
Grass, III	Balm	10% BS, 20% BCH	2	3,87	3177	0,347	6562	1,17	139,30	1,18
Grass, III	Balm	10% BS, 20% BCH	3	4,48	3846	0,379	10321	0,99	226,36	1,01
Grass, III	Balm	20% BCH	1	1,83	2630	0,223	5858	<DL	28,96	0,95
Grass, III	Balm	20% BCH	2	1,48	2247	<DL	7233	<DL	26,35	1,13
Grass, III	Balm	20% BCH	3	2,31	2224	0,243	8414	<DL	27,77	1,45
Corn	Cant	100% TS	1	0,90	3703	<DL	1491	<DL	34,18	<DL
Corn	Cant	100% TS	2	1,00	3754	<DL	1464	<DL	33,64	<DL
Corn	Cant	100% TS	3	1,42	5354	<DL	2423	<DL	110,58	1,00
Corn	Cant	100% TS	4	3,29	4353	0,164	1777	<DL	66,38	0,39
Corn	Cant	100% TS	5	0,85	4385	<DL	1949	<DL	42,10	0,36
Corn	Cant	10% BS	1	1,91	3735	<DL	1499	0,72	46,75	0,20
Corn	Cant	10% BS	2	0,82	3361	<DL	1260	<DL	39,80	0,77
Corn	Cant	10% BS	3	<DL	3973	0,112	1617	0,68	52,90	0,46
Corn	Cant	10% BS	4	0,97	4725	<DL	2031	<DL	61,08	0,49
Corn	Cant	10% BS	5	1,20	3630	<DL	1354	<DL	39,41	0,76
Corn	Cant	10% BS, 20% BCH	1	0,67	3118	<DL	1253	0,56	29,11	<DL
Corn	Cant	10% BS, 20% BCH	2	1,17	3505	<DL	1305	<DL	36,26	<DL
Corn	Cant	10% BS, 20% BCH	3	8,26	3304	<DL	1434	<DL	31,70	<DL
Corn	Cant	10% BS, 20% BCH	4	7,79	4643	<DL	2280	<DL	56,66	<DL
Corn	Cant	10% BS, 20% BCH	5	4,39	4681	<DL	2170	<DL	47,88	<DL
Corn	Cant	20% BCH	1	7,69	3539	<DL	1478	0,79	26,66	<DL
Corn	Cant	20% BCH	2	1,66	5288	<DL	2394	<DL	87,84	0,57
Corn	Cant	20% BCH	3	1,58	4945	<DL	2686	<DL	56,42	0,60
Corn	Cant	20% BCH	4	1,53	4978	0,138	2337	<DL	52,35	0,56
Corn	Cant	20% BCH	5	0,65	5271	<DL	2331	<DL	47,27	<DL
Broccoli	Cant	100% TS	1	1,28	6083	<DL	14388	0,34	65,90	0,61
Broccoli	Cant	100% TS	2	1,17	6446	<DL	13963	<DL	49,89	0,74
Broccoli	Cant	100% TS	4	1,00	5129	<DL	9943	<DL	37,94	0,85
Broccoli	Cant	100% TS	5	1,08	6738	<DL	13381	<DL	66,60	0,63
Broccoli	Cant	10% BS	1	2,35	5316	<DL	9602	0,47	50,42	1,07
Broccoli	Cant	10% BS	2	1,43	6053	<DL	11223	<DL	40,60	<DL
Broccoli	Cant	10% BS	3	1,31	6398	0,166	12198	0,70	79,40	0,51
Broccoli	Cant	10% BS	4	3,59	6397	0,228	12817	<DL	135,93	0,52
Broccoli	Cant	10% BS	5	0,76	6986	<DL	14584	0,65	57,59	1,28
Broccoli	Cant	10% BS, 20% BCH	2	1,27	8579	0,160	16224	0,82	90,34	0,75
Broccoli	Cant	10% BS, 20% BCH	3	1,23	7077	<DL	14626	<DL	81,82	0,52
Broccoli	Cant	10% BS, 20% BCH	4	1,36	6835	<DL	14712	<DL	86,93	0,69
Broccoli	Cant	10% BS, 20% BCH	5	9,45	8516	<DL	15215	0,47	91,85	0,66

Plant	Soil	Soil variant	Rep	Ni	P	Pb	S	Tl	Zn	Se
Broccoli	Cant	20% BCH	1	1,61	5269	0,219	11399		48,08	0,54
Broccoli	Cant	20% BCH	2	1,86	6079	<DL	13621	0,61	65,45	0,66
Broccoli	Cant	20% BCH	3	0,79	6435	<DL	13404	1,20	46,49	0,76
Broccoli	Cant	20% BCH	4	4,98	6080	<DL	13529	0,64	60,96	0,73
Broccoli	Cant	20% BCH	5	0,44	7299	0,254	11699	1,00	33,54	1,08
Broccoli	Balm	100% TS	1	3,63	7192	0,179	16411	0,93	88,60	1,26
Broccoli	Balm	100% TS	2	2,94	8339	<DL	17305		80,50	1,14
Broccoli	Balm	10% BS	1	6,16	7281	<DL	15082	0,78	143,39	0,58
Broccoli	Balm	10% BS	2	7,22	6953	0,086	15889	0,59	175,64	0,97
Broccoli	Balm	10% BS	3	8,09	6799	<DL	15195	<DL	215,02	0,56
Broccoli	Balm	10% BS, 20% BCH	1	5,64	7607	0,392	15213	0,47	124,60	0,66
Broccoli	Balm	10% BS, 20% BCH	2	8,00	6875	<DL	16065	<DL	174,08	0,75
Broccoli	Balm	10% BS, 20% BCH	3	12,92	5658	0,098	12662	<DL	129,95	0,56
Broccoli	Balm	20% BCH	1	2,95	7014	<DL	15249	0,41	61,61	0,94
Broccoli	Balm	20% BCH	2	1,98	7072	0,124	14482	<DL	72,57	0,47
Broccoli	Balm	20% BCH	3	2,35	5687	<DL	13821	1,44	50,42	0,01
Manuka	Cant	100% TS	1	1,33	2087	0,788	1931	0,53	40,13	1,26
Manuka	Cant	100% TS	2	0,85	1308	0,696	1714	0,51	44,96	0,60
Manuka	Cant	100% TS	3	0,81	2117	0,178	1753	0,01	51,09	0,79
Manuka	Cant	100% TS	4	1,16	1757	0,642	1714	0,58	45,55	0,70
Manuka	Cant	100% TS	5	1,23	2363	0,730	2115	0,84	54,14	0,51
Manuka	Cant	10% BS	1	0,97	2474	0,224	2012	0,50	62,88	0,92
Manuka	Cant	10% BS	2	0,89	2298	0,603	2167	1,97	70,24	1,34
Manuka	Cant	10% BS	3	1,06	2117	0,627	2328	1,12	71,39	1,02
Manuka	Cant	10% BS	4	4,24	2821	0,546	3361	0,61	98,16	1,10
Manuka	Cant	10% BS	5	4,61	3302	0,271	2539	1,37	90,85	0,98
Manuka	Cant	10% BS, 20% BCH	1	1,03	3078	0,003	3064	0,90	63,34	0,80
Manuka	Cant	10% BS, 20% BCH	2	1,02	1894	0,391	2351	0,01	41,79	0,75
Manuka	Cant	10% BS, 20% BCH	3	1,56	5069	0,929	2837	1,73	68,44	1,37
Manuka	Cant	10% BS, 20% BCH	4	0,85	1997	0,445	1974	1,26	67,16	0,58
Manuka	Cant	10% BS, 20% BCH	5	0,96	4179	0,502	2555	0,01	83,22	1,02
Manuka	Cant	20% BCH	1	1,67	2179	0,451	1499	1,42	26,94	0,01
Manuka	Cant	20% BCH	2	7,80	2826	1,657	1775	1,09	36,07	0,60
Manuka	Cant	20% BCH	3	2,42	2383	0,353	2028	1,49	38,45	1,26
Manuka	Cant	20% BCH	4	1,35	2679	0,265	1492	0,52	35,67	0,01
Manuka	Cant	20% BCH	5	1,61	1685	0,471	1810	1,44	39,59	0,33
Manuka	Balm	100% TS	1	4,61	2402	0,512	2729	<DL	38,02	1,40
Manuka	Balm	100% TS	2	2,81	1994	0,623	3277	0,71	27,59	1,88
Manuka	Balm	100% TS	3	1,33	2163	0,371	3132	0,29	40,96	1,06
Manuka	Balm	10% BS	1	2,60	1838	0,278	3285	0,94	164,46	0,85
Manuka	Balm	10% BS	2	1,78	2126	0,162	3502	0,85	242,82	1,52
Manuka	Balm	10% BS	3	8,64	2715	0,627	3562	0,92	252,42	1,88
Manuka	Balm	10% BS, 20% BCH	1	1,91	2807	0,433	4209	0,50	244,77	1,23
Manuka	Balm	10% BS, 20% BCH	2	2,06	2373	<DL	3864	0,42	198,96	0,96
Manuka	Balm	10% BS, 20% BCH	3	1,57	1444	0,348	3242	0,97	175,74	0,95
Manuka	Balm	20% BCH	1	1,72	1418	<DL	2080	<DL	21,70	1,15
Manuka	Balm	20% BCH	2	1,35	1852	0,146	2458	<DL	28,17	1,44
Manuka	Balm	20% BCH	3	1,28	1617	0,19	2371	0,67	29,09	1,13