Czech University of Life Sciences Prague

Faculty of Environmental Sciences

BACHELOR THESIS

Improvement of Empovered soils through the use of cricket frass based fertilizers

Sebastian Adriano Castelo Nuñez del Prado

Supervisor: Ing. Jiřina Száková, CSc.

CZECH UNIVERSITY OF LIFE SCIENCES PRAGUE

Faculty of Environmental Sciences

BACHELOR THESIS ASSIGNMENT

Sebastian Adriano Castelo Nuñez del Prado

Environmental Engineering

Thesis title

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Objectives of thesis

The current production and utilization of fertilizers to fulfill the ever growing demand, is having a huge impact in the degradation, lost of nutrients, and lost for water retention capacity in soils; leaving us in need for an actual sustainable source. The cultivation of edible insects such as cicket (Acheta domesticus) rise rapidly at the present time and substantial amount of cricket excrements is produced. This waste could be used as the alternative organic fertilizer. The goal for this thesis is to show the positive impact that organic materials such as crickets frass have in the enrichment of soil fetility. Hypothesis: The cricket frass can be sufficiently used as the effective alternative organic fertilizer.

Methodology

1) A model pot experiment will be established where cricket frass will be applied on two rates. For comparison, vermicompost and NPK applications will be provided in the rates representing the amount of nitrogen equal to the cricket frass. Corn (Zea mays) will be planted in the pots

2) The available nutrient contents in the soil as well as the nutrient contents in the plant biomass will be determined after termination of the experiment

3) The data will be evaluated by using the adequate statistical methods and interpreted

The proposed extent of the thesis

30 pages

Keywords

cricket frass, fertilizer, nutrients, effectivity

Recommended information sources

Ferruzca-Campos, E.A.; Rico-Chavez, A.K.; Guevara-González, R.G.; Urrestarazu,M.;Cunha-Chiamolera, T.P.L.; Reynoso-Camacho, R.; Guzmán-Cruz, R. 2023 Biostimulant and Elicitor Responses to Cricket Frass (Acheta domesticus) in Tomato (Solanum lycopersicum L.) under Protected Conditions. Plants 12: 1327.

Kagata, H. and Ohgushi, T., 2012. Positive and negative impacts of insect frass quality on soil nitrogen availability and plant growth. Population Ecology 54: 75-82.

Magara, H. J. O. et al. 2021. Edible crickets (Orthoptera) around the world: Distribution, nutritional value, and other benefits—A review. Frontiers in Nutrition 7: 1–23.

Ogaji SO, Watako AO, Nyongesah JM, Peter B. 2022. Effects of Cricket Frass Biofertilizer on Growth of Spring Onion (Allium Fistulosum L.) and Physicochemical Properties of Soil. J Mod Agric Biotechnol, 1(3): 14.

Quilliam, R.S., Nuku-Adeku, C., Maquart, P., Little, D., Newton, R. and Murray, F., 2020. Integrating insect frass biofertilisers into sustainable peri-urban agro-food systems. Journal of Insects as Food and Feed 6: 315-322

Radzikowska-Kujawska D, Sawinska Z, Grzanka M, Kowalczewski PŁ, Sobiech Ł, Świtek S, et al. 2023. Hermetia illucens frass improves the physiological state of basil (Ocimum basilicum L.) and its nutritional value under drought. PLoS ONE 18(1): e0280037.

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The Bachelor Thesis Supervisor

prof. Ing. Jiřina Száková, CSc.

Supervising department

Department of Agrienvironmental Chemistry and Plant Nutrition

Advisor of thesis

Ing. Michael Asare Opare, Ph.D.

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prof. Ing. Pavel Tlustoš, CSc., dr. h. c.

Head of department

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prof. RNDr. Michael Komárek, Ph.D.

Dean

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Declaration

I declare that I have worked on my bachelor thesis titled "Qualitative comparison of DNA isolation methods from insect specimen" by myself and I have used the sources mentioned at the end of the thesis. As the author of the bachelor thesis, I declare that the thesis does not break copyrights.

In Prague on 22.03.2024

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Sebastian Adriano Castelo Nuñez del Prado

Abstract

Cricket frass production worldwide is growing alongside the demand for protein, which is lately starting to be satisfied with insects, since these are a great source for it. The remainder of the production is frass, which consists of chitin from the exoskeletons and the insect's feces may be a viable source of nutrients for plants.

Some of the most used fertilizers today, can have a negative long-term impact on soils, such as water and air pollution, soil degradation, reduce the microbial activity and may increase the cost of crop production for farmers.

The aim of this study is to assess the impact of the cricket frass fertilizer on corn plants, their final nutrient content and compare them with other more conventional types of fertilizers.

The selected species for this experiment was *Acheta domesticus* (Linneaus, 1758) (Orthoptera: Gryllidae), more commonly known as House Cricket, due to it's fast breeding rate. Model pot experiment was conducted as follows: 648g of material was collected to treat 27 kg of soil in 2 different concentrations, 3 pots of 4.5 kg of soil with low concentration (72g) cricket frass per pot and 3 pots of 4.5 kg of soil with high concentration (144g) of cricket frass per pot. These treatments were compared to NPK treatment, vermicompost (also in 2 different concentrations) and untreated soil.

The results showed that there is not a significant difference among variants when comparing these treatments, but a trend is visible, and it should be the focus of further research.

The findings are very promising and showed that cricket frass could eventually compete with NPK treatment to be used as a viable fertilizer.

Key words: cricket frass, fertilizer, nutrients, effectivity

Abstrakt

V poslední době celosvětově roste poptávka po hmyzu jako alternativním zdroji bílkovin ve výživě člověka. To také vede ke zvýšené produkci odpadu z umělého chovu jednotlivých hmyzích druhů. Tento odpad se v případě chovu cvrčka domácího skládá z chitinu z exoskeletů a výkalů hmyzu a existuje předpoklad, ž by mohl být například zdrojem živin pro rostliny.

Některá z dnes nejpoužívanějších hnojiv mohou mít negativní dlouhodobý dopad na půdu, jako je znečištění vody a ovzduší, degradace půdy, snížení mikrobiální aktivity a mohou pro zemědělce zvyšovat náklady na produkci plodin.

Cílem této studie je posoudit vliv hnojiva z odpadu z chovu cvrčků na růst rostlin kukuřice a obsah živin v biomase v porovnání s jinými konvenčnějšími typy hnojiv.

Vybraným druhem pro tento experiment byl *Acheta domesticus* (Linneaus, 1758) (Orthoptera: Gryllidae), běžněji známý jako cvrček domácí, výhodný zejména pro jeho rychlé rozmnožování. Byl proveden modelový nádobový vegetační pokus následovně: 648 g odpadního materiálu bylo použito pro ošetření 27 kg půdy ve 2 různých koncentracích, 3 nádoby se 4,5 kg zeminy s nízkou koncentrací (72 g) cvrččího odpadu na nádobu a 3 nádoby se 4,5 kg zeminy s vysokou koncentrací (144 g) cvrččího odpadu na nádobu. Tato opatření byla porovnána s hnojením NPK, vermikompostem (také ve 2 různých koncentracích) a neošetřenou půdou. .

Výsledky ukázaly, že při porovnání těchto opatření není významný rozdíl mezi variantami, ale je patrný trend, na který by se měl zaměřit další výzkum.

Zjištění jsou velmi slibná a ukázala, že cvrččí trus by mohl při vhodné aplikaci konkurovat ošetření NPK, aby mohl být použit jako účinné hnojivo.

Klíčová slova: odpad z chovu cvrčků, hnojivo, živiny, účinnost

Contents

1. INTRODUCTION

Soil is a key element in human development and a source of nutrients for crops worldwide. Agriculture as a practice, has developed alongside human history, it has been a source of food, it has shaped our landscape, it has been an important part of the economy of many countries for many years, and has been the central component for a major part of the living activity on our planet. This is why sustainable soil management practices are necessary, to make sure that such an important resource is not drained.

Soils in Perú are very poorly studied, and there is little information when it comes to nutrient content, which in many regions seems to be rather poor, since it appears that soils in the Andes region are relatively new.

Enrichment of soils using fertilizers has always been done to help achieve crops of better quality and greater yield. The effectiveness of different types of treatments and their effects on soil have been the focus of many studies, although, over the past few years, more eco-friendly options for soil amendment have arisen, the effectiveness of these is still not totally clear when it comes to the time and cost it would take to produce the required amount for soil treatment.

With the growing demand to satisfy the need for protein sources, insects have made an appearance at a global scale. This has left behind a substantial amount of insect waste, known as frass, which includes sheds (exoskeletons made from chitin), feces, and urine.

This study is focused on the use of cricket frass as a source of necessary nutrients for plant growth and development.

Corn was the chosen plant subject to analysis, given its importance as a globally exploited crop.

2. OBJECTIVES

The current production and utilization of fertilizers to fulfill the ever-growing demand, is having a huge impact in the degradation, loss of nutrients, and lost for water retention capacity in soils, leaving us in need for an actual sustainable source. The cultivation of edible insects such as cricket (Acheta domesticus) rise rapidly at the present time and substantial amount of cricket excrements is produced. This waste could be used as the alternative organic fertilizer. The goal for this thesis is to show the positive impact that organic materials such as crickets frass have in the enrichment of soil fertility. Hypothesis: The cricket frass can be sufficiently used as the effective alternative organic fertilizer.

3. THEORETICAL BACKGROUND

3.1 Studied Insect species

Acheta domesticus (Linnaeus, 1758) (Orthoptera: Gryliidae) was the species chosen for this experiment. Commonly known as House Cricket, it is a species from southeast Asia that has expanded throughout the world (Massa et al. 2012). This species of cricket is commonly used as food for domestic pets, like amphibians, arthropods, birds, and reptiles. This species is mainly found in and near buildings, but it also occurs on dumping grounds and near farms.

A. domesticus is usually 16 to 21 mm in length, gray or brownish in color, and the antenna can be as big as the length of its body (Figure 1). They have long hind wings as they reach the adult stage, but sometimes they shed them later. Male crickets rub their hind wings together to produce songs. The song used to attract females is species-specific and they use chemoreceptors in their antennae to identify whether another individual is a male or a female. Body dimorphism can be observed between males and females, being the females normally bigger than the males. (Mariod et al. 2017).

They are mainly nocturnal and crepuscular. Domestic cricket is often attracted by warm and dark places; hence they can be found beneath refrigerators, kitchens, basements, etc. in urban areas (Galloway, Vickie 1998).

Even though there are several species of crickets used for commercial production, such as ***Gryllus campestris*** (Linneaus, 1758) (Orthoptera: Gryliidae), *A. domesticus* was chosen due to the ease of breeding and high reproductive rates. There are some key differences that make *A. domesticus* a better species to be studied for the purpose of this study: While *Gryllus campestris*, usually dark to brown in coloration, are slightly larger, measuring 20 to 33 millimeters in length, they are known to exhibit territorial and aggressive behavior, which makes it harder to breed them in captivity in larger quantities, unlike *A. domesticus*, which are known to breed readily in captivity, and are also an omnivorous species that feeds on a variety of plant matter as well as other insects and are often used as feeder insects for reptiles or amphibians. When it comes to the habitat, House crickets are commonly found in human dwellings, agricultural areas, and other warm, moist environments worldwide. Field crickets prefer grassy areas, fields, meadows, and forests. They are widespread across Europe, North Africa, and parts of Asia. Field crickets are also omnivorous, but they tend to feed more on plant matter. Both species produce chirping sounds, primarily by rubbing their wings together, but the patterns and frequencies of these may differ between species (Desutter-Grandcolas, 2003).

When it comes to breeding of *A. domesticus,* the optimum temperature is between 20 to 32 ^{o}C. The incubation period lasts approximately two weeks. Under normal conditions, the house crickets take between 2 to 3 months to complete their life cycle. They have no overwintering stage, but survive winter around buildings and dumps, where the heat from fermentation may sustain them (Kaplan, 2014). Throughout its life, this species goes through 7 sheds.

Edible crickets, belonging to the Orthoptera family, are recognized as one of the types of edible insects. Species like *Gryllus bimaculatus, Gryllodes sigillatus, Gryllus assimilis,* and *Acheta domesticus* have become a very popular and sustainable source of protein, containing around 60 to 70% protein by dry weight, and contain low carbohydrate content. Crickets serve as a great source of aminoacids that are essential to human development, polyunsaturated fatty acids such as omega-3 and omega-6, which are essential for various bodily functions including brain health and hormone regulation, and micronutrients such as vitamins and minerals, including B vitamins, such as B12 and B6 (Zafar et al. 2024). The calcium content in an adult individual varies from 132 to 210, average potassium content is 1126.6, magnesium 109.42, phosphorus is 958, sodium 435, iron 11.2, zinc 21.8, manganese 3.73, copper 2.01, and selenium 0.06 mg/100g respectively.

A.domesticus adult individuals are normally consumed as a deep-fried snack in some countries, or as a protein powder or protein extract. House crickets are capable of transforming poultry manure into a protein-rich feedstuff for poultry on an economically competitive basis (Mariod et al. 2017).

Figure 1: An adult female house cricket, *Acheta domesticus* (Linneaus), with hindwings intact. (Choate, 1999 https://entnemdept.ufl.edu/creatures/misc/crickets/adomest.html.).

3.2 Corn

Commonly known as maize (*Zea mays L.*) belongs to the family of grass i.e. Poaceae is an annual crop. Corn is native to South America but is extensively cultivated in various other countries. It is considered the earliest cultivar of the New World and is the most widely distributed plant. Maize is a crop that has a short life cycle and requires warm weather. It is highly valued due to its uses, like food for livestock, human food, and raw material for several industries.

Pollens and seeds are the nutritious edible parts of the plant. On top of being a good source of carbohydrates, it contains vitamins B_1 (thiamine), B_2 (niacin), B_3 (riboflavin), B_5 (pantothenic acid) and B_6 from B-complex. It also contains vitamin C, A and K as well as a large amount of carotene. When compared to other cereals it shows a higher content of protein and fat (Kumar et Jhariya, 2013).

Corn is the most popular crop in the world, with the United States and China being the largest producers, both of these countries produce half of the international corn market. The before-mentioned are also the biggest consumers of deep-processed corn products. Due to many years of experience in China in the development of this segment, the technological chain of products of corn deep processing, as well as the greatest diversity in the processing of food crops. Export of corn and its use as raw material, brings quick currency earnings to agricultural producers, these earnings depend on the world demand. Nowadays, after deep processing, we can find corn in 2000 different types of products, 100 of which are found in all aspects of human life. International analysts have found that the deep processing global market will grow by 25% and reach 1.191 Billion tons by 2026; Demand in Asian countries for corn will increase by 53% estimated by 2026. Consumption of corn products in North and South America is estimated to increase by 38% in 2026. According to the United States Department of Agriculture (USDA) and the Food and Agriculture Organization of the United Nations (FAO), a rapid growth in consumption and production of corn began in 2013 (Figure 2) (Tanklevska et al. 2020).

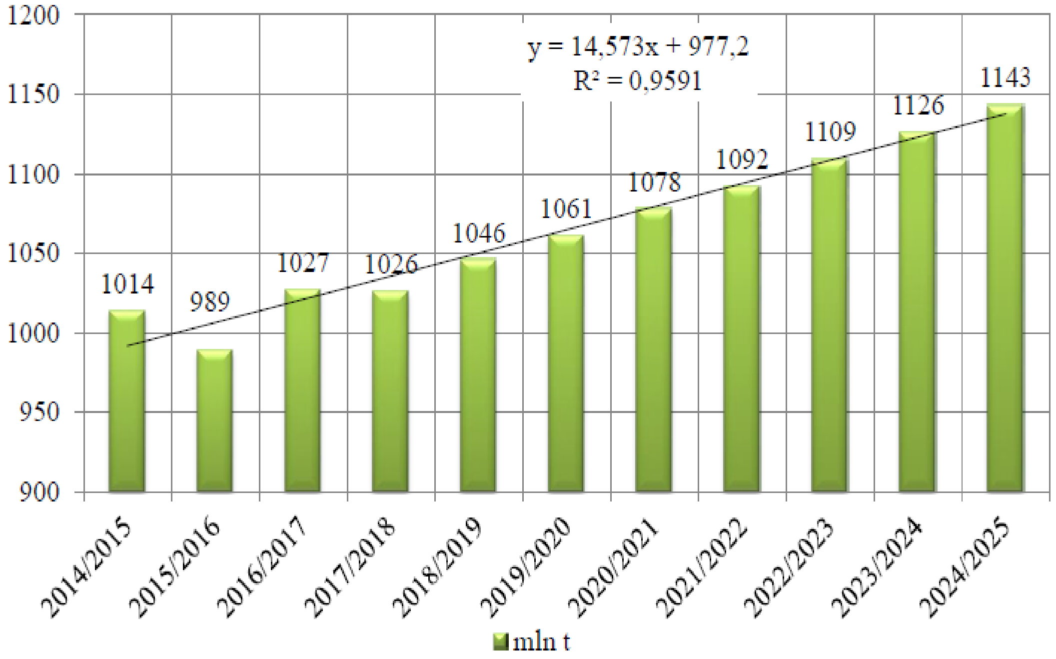

Figure 2: World corn production, taking into consideration the forecast for the 2024/2025 agricultural year, mln t. (Tanklevska et al. 2020 http://are-journal.com).

3.2.1 Corn in Peru

Corn is a key element in Peruvian agriculture and economy, it provides people with food security, being a staple food for a large portion of the population. In the agricultural sector, corn is grown both by small-scale farmers and larger agricultural enterprises, it also contributes to small households' income specially during the rainy season, which takes place from October to April; It is a key component in the local cuisine and occurs in numerous different varieties (Figure 3). Government policies influence the production and trade with subsidies and incentives, according to the National Institute of Statistics and Informatics, In July of 2022, the exportation of Peruvian yellow corn reached 78 thousand 285 tons which represented a 25% increment over 2021 period.

Figure 3: Different varieties of Peruvian corn (Huillca Expedition https://www.huillcaexpedition.com/blog/peruvian-corn).

3.3 Nutrients

The function of some elements in the biochemical behavior and physiological function of the plants are divided into groups. The first group are the major constituents of organic plant material: carbon, hydrogen, oxygen, sulfur and nitrogen. They constitute amino acids, enzymes, proteins and nucleic acids, the base of life. The uptake of all these nutrients by plants is linked to oxidation-reduction processes. Boron, silicon, and phosphorus are part of a second group of elements that share some similarities when it comes to biochemical behavior. The assimilation of these comes up from soil solution as inorganic anions or acids, this is the form they occur in plant cells or bound by hydroxyl groups of sugars to constitute borate, silicate esters, and phosphate. The third group is constituted by Ca, Na, Mg, Mn, Cl, and K, these are all uptaken from the soil in their ionic form. These can also be found in their ionic form in the plant cell where they have non-specific functions (Marschner, 2011). Risk elements are known to be pollutants and they are toxic or poisonous even at lower concentrations, there are, however, a few which are also known to be essential for plants and animals (Rout et Sahoo, 2015).

Nitrogen: It is used by all plants in the form of NO_3^- and NH_4^+. It is the most important element when it comes to plant development and growth, by playing a vital role in physiological and biochemical functions. All vital processes are associated with protein, of which nitrogen is an essential constituent (built from amino acids that is involved in the catalyzation of chemical responses and electron transport), it also enables photosynthesis. It is responsible for dark-green coloration in plants, and promotes the development and growth of leaves, stems, and other vegetative parts. It stimulates root growth, improves fruit quality, and enhances the growth of leafy vegetables; Helps the uptake and use of other nutrients. Deficiency causes growth reduction, chlorosis appearances (change of color in leaves from green to yellow), presence of purple and red spots on the leaves, and poor growth of the lateral bud (leaves, stem and branches develop from here). Deficiency usually appears on older leaves first (Leghari et al. 2016).

Calcium: Calcium helps plants by being a key component for it provides structural support to the cell walls. It also provides information about the physical or biochemical stress of the plants. Calcium is normally not deficient in alkaline soils. Any deficiency symptoms may include: death at the growing point, foliage greener than normal, weakened stems, the shedding of the flowers and any other combination of the above mentioned (Oldham, 2019). When the content of Ca is higher, plants may suffer from Ca intoxication, which may prevent the germination of seeds and affect plant growth rates (White et Broadley, 2003).

Magnesium: It is the central atom in between four nitrogen atoms in the chlorophyll molecule, involved therefore in photosynthesis. It helps activate many enzymes that are necessary for the normal plant growth process, it also helps stabilize the nucleic acids. One of the symptoms of the deficiency of Magnesium in corn is Interveinal chlorosis, which may cause a yellowing between the veins, while the veins remain green. The leaves curl upward along the margins and adopt a pink to light red coloration (Oldham, 2019).

Sulfur: It is needed in large quantities by most crops. It is a very important building block in chlorophyll and the synthesis of proteins. SO_4 is the is the ion form primarily absorbed by plants. Sulfate is soluble and gets lost from soils easily through leaching. The symptoms of sulfur deficiency are first shown in young leaves. they appear green to yellow. The plants are thin and small with retarded growth and delayed fruiting (Oldham, 2019).

Potassium: This inorganic nutrient is essential for every living organism (White et Karley, 2010). Although it does not have any structural functions, it acts as the main osmoregulator in plant cells, it is a key element for photosynthesis by its role in CO_2 uptake and transpiration, controlling the stomatal conductance, functions in the transport of sugars, activation of enzymes and resistance to draught (Mengel et Kirkby, 2001, Wang et al. 2013). Apart from nitrogen, potassium is the most used inorganic nutrient in plant growth that limits primary productivity in any system, natural or cropping, unless this is supplied as a fertilizer (Fageria, 2009). And although many soils have large quantities of potassium, there is only a small portion that is phytoavailable, making areas potassium deficient with available K. As a result of the ever-growing agriculture activity and the introduction of the yielding varieties, the soils are becoming poor in K at a faster rate, this is why K deficiency is becoming one of the major constraints to crop production (White et al., 2010). Most of the described visual symptoms of potassium deficiency include chlorosis (yellowing of the plant due to a reduction on chlorophyll formation process) or necrosis of the leaves at the margin, older or located at the lower level of the plant (Bly et al., 2002).

Copper: Is an essential element in plants. It plays a key role in the photosynthetic and respiratory electron transport chains, ethylene sensing, metabolism of the cell wall and the protection of the oxidative stress and biogenesis. Plants need Cu for their normal growth and development, when deficient, plants develop very specific symptoms related to the lack of this element, most of which affect reproductive organs and young leaves. However, the same redox properties that make Cu an essential element, can also contribute to the toxicity of the element. The production of toxic hydroxyl radicals can be catalyzed by the redox cycling between Cu^{2+} and Cu^{+} this is harmful for cells at a level of proteins, nucleic acids, lipids, membranes, and other biomolecules. Cu can initiate oxidative damage and affect more important cellular processes such as photosynthesis, plasma membrane permeability, pigment synthesis, and other metabolic mechanisms, causing a strong inhibition of plant development. Plants grown under a high nitrogen supply require larger quantities of copper; the bioavailability of Cu is dependent on the soil pH, for example, it tends to be higher in acidic soils (Yruela, 2009).

Iron: essential micronutrient for its role in metabolic processes like DNA synthesis, photosynthesis, and respiration. It is also one of the most limiting nutrients when it comes to plant growth and metabolism, because of the low solubility of the oxidized ferric form in environments with low to no access to oxygen. It is involved in the synthesis of chlorophyll and is very important when it comes to the maintenance of the chloroplast structure and function. It has a limited bioavailability in environments with neutral to alkaline pH and under aerobic conditions. Its deficiency affects the development of the plant, and the excess is toxic in the cells (Rout et Sahoo, 2015).

Manganese: It is a very important element when it comes to plant growth since it serves as a cofactor for enzymes that are involved in photosynthesis, the synthesis of antioxidants, and defense against pathogens. It is also involved in root growth, nutrient uptake, and soil microbial communities. Its availability is determined by factors such as mineralogy, redox potential, organic matter content, and soil pH (it can occur in more acidic soils). It is normally required in smaller amounts when compared to macronutrients such as potassium, nitrogen, or phosphorus. The deficiency of this element can lead to stunted root growth and a reduced nutrient uptake, and the excess can be toxic by inhibiting nutrient uptake and creating physiological disorders in plants (Khoshru et al., 2023).

Phosphorus: It is a vital element when it comes to plant growth and productivity. It ranges between 0.05% and 0.5% in concentration of the total plant dry material. Plants often face the problem of deficiency because their fixation in soils in the form of calcium/magnesium phosphates or aluminium/iron phosphates makes them unavailable for plant uptake. Its deficiency is hard to diagnose since there are no visual symptoms at an early stage and is often confused with that of N deficiency, given that veins on young leaves appear red in both circumstances. Even then, no significant chlorosis can be observed in plants with phosphorus deficiency. When P is deficient in plants it causes reduced plant growth attributed to an increase in energy investment or a decrease in photosynthesis. If there is an excess of P, this may cause Pi toxicity by accumulating on the older leaves, it also produces more N uptake which delays the formation of reproductive organs (Malhotra, 2018).

Zinc: It is a micronutrient involved in many physiological functions, it is an important component of different enzyme catalyzers for many metabolic reactions in plants. Some of the symptoms of Zn deficiency are chlorosis of the leaves, from green to light green, yellow or even white, necrotic spots on leaves, bronzing of leaves (chlorotic areas may turn bronze colored), rosetting of leaves, stunting of plants and dwarf or malformed leaves (Rudani et al., 2018).

Organic Matter: part of the soil that consists of partially or totally decomposed animal, or vegetal material, It is the result of microbial and chemical transformations of organic debris. This process, known as the humification process, is what results in humus, which has a substantial degree of resistance to further microbial attack. It contains carbon, which should comprise about 50% of the soil's organic content on average. It regulates the release of nutrients from soil to plants by acting as a storehouse, increases nutrient exchange, provides soil aggregation, retains moisture, reduces surface crusting, reduces compaction and helps increase the sorption capacity of the soil. It has a direct impact on the growth and development of certain species, it supplies energy and building constituents. Its formation is a result of C input and decomposition. For crop management, the amount of soil organic matter depends on how much organic matter enters the soil and how fast it decomposes (Gurmu, 2019). Organic matter can be affected by climate, clay mineralogy, and soil texture. In warm and humid climates the organic material will decompose faster than in colder climates (UNL ©2014). Some of the practices to improve the organic matter content in soil include more complex crop rotation, reduced tillage, intensive use of cover crops, and the use of organic amendments, such as manure application, which has to be changed every year to avoid exposing the flora and fauna to the same type of residues; this would help develop select organisms that might be harmful to the plants (Magdoff et Weil. 2004).

Vermicompost is one of the amendments that has gained popularity over the years due to its composition (Table 1) it is the conversion of solid waste or crop residues into organic eco-friendly fertilizer.

Table 1: Nutrient content in vermicompost

Nutrient	Content
C	9.15 to 17.98 %
N	1.5 to 2.1 %
P	1 to 1.5 %
K	0.60%
Ca and Mg	22 to 70 m.e/100g
S	128 to 548 ppm
Cu	100 ppm
Fe	1800 ppm
Zn	50 ppm

Table 1: Nutrient composition of vermicompost (Kale 1983).

Some of the advantages of vermicompost include the improvement of fertility and water resistance and health of soil, its physical structure, improves root and plant development as well as plant growth, germination rate of seed and crop yield. It helps neutralize soil pH and is at the same time, free of pathogens, insects and harmful materials.

Among the disadvantages, vermicompost is a time-consuming process, requiring at least 6 months on average from organic matter into fertilizer material, high maintenance and monitoring of humidity levels; the amount of application dose required is almost double when compared to other fertilizers like Urea (Gupta et al., 2003).

3.4 Soil

According to the Ministry of Agrarian Development and Irrigation of Peru (MIDAGRI), depending on their geography and regional weather conditions, different regions can be described, where the most common types of soils for each region are listed:

Yermosolic region:

In the coastal region. In the irrigated valleys the more common soils are fluvisols, very fertile and of high quality, due to the mineral sediments deposited by the rivers flowing down from the andes. In the deserts, the most predominant are regosols, solonchaks and in the dry river beds dry fluvisols, not so fertile soils. In the hills and more rocky mountains lithosols are more commonly found. In the north coast region of Perú, vertisols can be found, these are more alkaline and clayey. In the south coast region, andosols can be observed, these are volcanic and of a neutral reaction

Paramosolic or Andosolic region:

Located in the high Andean region, located between 4000 and 5000 m.a.s.l. it has a smooth relief since the whole region was a glacier in the past. Paramosols are predominant, acid, and rich in organic matter content. Paramo andosols are similar, but derived from volcanic clayey rocks. There is also a presence of litosols and chernozems, which are dark, neutral, and clayey soils. Close to the lakes and bogs, histosols can be found, which are soils rich in organic material.

Kastanozoic region:

Located in the high and intermediate Andean valleys between 2200 and 4000 m.a.s.l. There are many types of soil, like calcic kastanozems, of a medium texture, alkaline, and red or brown in color. The luvic kastanozems are similar, but clayey; like deep soils with fine texture (phaeozems). In the regions with a greater slope, rocky and calcareous soils are more common. In the high plains, planosols, which originate from lakes, are more common as well as gleysols, which have poor drainage.

Lito-cambisolic region:

Located in the superior part of the high Peruvian jungle. Between 2200 and 3600 m.a.s.l. The terrain is poor and largely exposed to erosion. Superficial soils and relatively newly developed are more common, like cambisols, with a yellowy superficial horizon.

Acrisolic region:

Located in the high Peruvian jungle. Between 500 and 2200 m.a.s.l. Soils come from the lito-cambisolic region but are deeper in comparison. It is a region with strong weathering or parental rock decomposition and with an acidic reaction. Acrisols are more predominant in this region, which are deep, yellow, and red in coloration, and with a good drainage capacity. In the lower part of the high Peruvian jungle, plinthic acrisols can be found, which are clayey soils with good content of Iron. And in the valleys, there is a greater predominance of fluvisols, gleysols and vertisols.

Curly acrisolic region:

This is the largest geodafic region and includes the lower Peruvian jungle, normally located at a lower altitude than 500 m.a.s.l. More acidic with low fertility soils are common, and depending on their drainage capacity, can be fluvisols or gleysols. Humic podzols are sandy soils with organic matter content and iron that are located far from rivers.

Litosolic region:

Constitutes the occidental region of the Andes. It is located between 1000 and 5000 m.a.s.l. They have a big slope and litosols are predominant, which are superficial soils as well as the exposed rock. In the east and more intermediate part luvic yermosols, clayey and limy; xerosols have a dark cover and lime, and the kastanozems or brown soils. In the lower part sandy with lime in the sub-soil, called calcic yermosols and sandy soils called regosols can be found.

(MIDAGRI)

3.4.1 Regosols

Regosols are described as poorly developed mineral soils in unconsolidated materials. These soils do not have a mollic or umbric horizon, they are not very thin or very rich in coarse fragments (Leptosols), not sandy (Arenosols), and not with fluvic materials (Fluvisols). They occupy a large terrain in eroding lands and accumulation zones, most especially in arid and semiarid areas as well as in mountainous terrain (FAO/UN 2015).

Management and Use of Regosols

Regosol in areas with rainfall of 500-1000 mm/year need irrigation for satisfactory crop production. The low moisture-holding capacity of this type of soil makes irrigation a very costly option. In places where rain exceeds 750 mm/year, the profile reaches its water holding capacity early in the rain season, and improvement of dry farming practices may be better than expensive irrigation facilities installation. Regosols on colluvial deposits in the loess belt of Europe are mostly cultivated normally with small grains, sugar beet, and fruit trees, while Regosols in mountainous regions are delicate (FAO/UN 2015). In the Andes region of Peru, some of the most popular crops include corn, quinoa, amaranth, and a large variety of potatoes.

Skeletic (sk) soils (from Greek skeletos, dried out): having ≥ 40% (by volume) coarse fragments averaged over a depth of 100 cm from the soil surface.
Can be distributed in:

- Akroskeletic (kk) (from Greek akra, top): it has ≥ 40% of the soil surface covered by fragments that have the largest dimension ≥ 6 cm (stones, boulders or large boulders).
- Orthoskeletic (ok) (from Greek orthos, right): having: ≥ 40% of the soil surface covered by fragments that have the greatest dimension ≥ 6 cm (stones, boulders or large boulders), and ≥ 40% (by volume) coarse fragments averaged over a depth of 100 cm from the soil surface or to continuous rock, technic hard material or a cemented or indurated layer, whichever is shallower.

- Technoskeletic (tk) (from Greek techne, art): having ≥ 40% (by volume) coarse fragments, that meet the criteria of artifacts, averaged over a depth of 100 cm from the soil surface or technic hard material, a cemented or indurated layer, continuous rock, whichever is shallower (FAO/UN 2015).

3.4.2 Luvisols

Luvisols normally have a lower clay content in the topsoil than in the subsoil, as a result of pedogenetic processes (like clay migration) leading to an argic subsoil horizon. Luvisols have a high base saturation in the 50-100 cm depth and high-activity clays throughout the argic horizon (FAO/UN 2015).

Management and use of Luvisols

Most Luvisols are very fertile soils, suitable for a very wide range of agricultural uses. When luvisols have a high silt content, they are susceptible to structure impoverishment when tilled, when wet, or disturbed with heavy machinery. When on steep slopes, Luvisols require erosion control measures. In some places, the dense subsoil causes temporary reducing conditions with stagnic properties. In the temperate zone, Luvisols are commonly sown with small grains, sugar beet, and fodder; in sloping areas, they are normally used for orchards, forests and/or grazing. Luvisols In the Mediterranean region, are common in colluvial collectors of limestone weathering, where lower slopes are sown with wheat and/or sugar beet and the more commonly eroded upper slopes are used for grazing or planted with tree crops. Luvisols tend to have a pH ranging from slightly acidic to neutral, typically between 5.5 and 7.5. However, this may have local variations. When it comes to the sorption capacity, luvisols normally have moderate to high sorption capacity due to their clay-rich nature.

According to the Ministry of Agrarian Development and Irrigation of Peru (MIDAGRI), soils in Peru are exposed to heavy metal pollution from mining activities such as excavation or ore processing, industrial activities such as metal smelting, manufacturing and waste disposal, agricultural practices, untreated wastewater or sewage sludge used for irrigation, urbanization and landfill, transportation and traffic, and natural causes such as volcanic activities, erosion of geological formation and weathering of mineral deposits.

4. MATERIALS AND METHODS

4.1 Cricket frass

The cricket frass was provided by Ing. Martin Kulma, Ph.D. from the Department of Zoology and Fisheries of the Agrobiology, Food and Natural Resources faculty, Czech University of Life Sciences Prague. The subjects were hatched on March 20th 2023, and the frass was harvested on May 11th of the same year, when all of the subjects reached the adult stage.

When raising the crickets, the weight of the unhatched eggs was measured, with each one of them weighing around 0.9-1.1 grams of fresh crickets (max. 24 hours old). The crickets were placed in between egg trays inside plastic containers (volume = 45 liters).

An approximate of 250 grams of cricket frass was harvested from each container, when the feed conversion ratio was about 1.5 g of food for 1g of insect biomass.

A net was placed near the bottom of the containers, which served as enclosures, to ease the harvesting of the frass.

The subjects were fed with modified chicken food based on wheat and soybean, provided by the Czech University of Life Sciences Prague, and then placed on Petri dishes inside the enclosures. During the first 20 days of the harvesting process, the food on the Petri dishes was replaced every 4 days. After this first period, the food was replaced every 3 days. The Petri dishes with food were removed from the enclosures and the subjects were starved for 24 hours prior to the harvesting process.

Eleven trays were initially used, but for the harvesting of the frass, only nine were harvested; around 1kg of frass was produced in the 52 days, harvesting from around 180g to 290g from each enclosure.

The experiments using *A. domesticus* frass as a fertilizer were performed on two separate sets, each containing three buckets, with different sets containing different concentrations. These were compared to two other fertilizers: Mineral (NPK) and vermicompost, alongside a control (untreated) set of pots.

4.2 Selected soil

The soil was selected based on properties of soil commonly found in the Peruvian Andes. Three samples were brought from the region of Cusco at 3429 m.a.s.l. at “El Huerto” area in Peru (13°31’57.8’’ S and 71°51’45.72’’ W) and from the Limatambo area at 2823 m.a.s.l. (13°27’27.19’’ S and 72°25’11.88’’ W) in February 2023 and were determined to be Eutri-Skeletic Regosols.

4.2.1 Analytical procedures

The pH measurement was done by weighing 5 grams of each sample and adding 50 ml solution of $CaCl_2$. The samples were shaken for 1 hour and then let to rest for 1 more hour. After this time had passed, the pH was measured using a pH meter.

The pseudo total contents of elements in the soils were determined in the digests obtained by the following decomposition procedure: Aliquots (~0.5 g) of air-dried soil samples were decomposed in a digestion vessel with 10 ml of aqua regia (i.e. nitric and hydrochloric acid mixture in a ratio of 1:3). The mixture was heated in an Ethos 1 (MLS GmbH, Germany) microwave-assisted wet digestion system for 33 minutes at 210 °C. After cooling, the digests were transferred into a 25-ml glass tube, topped up with deionized water, and kept at laboratory temperature until measurements were taken. Inductively-coupled plasma-optical emission spectrometry (ICP-OES, Agilent 720, Agilent Technologies Inc., USA) was used for the determination of elements (As, Be, Cd, Co, Cr, Cu, Ni, Pb, V, Zn) in soil extracts.

The cation exchange capacity (CEC) was calculated as the sum of extractable Ca, Mg, K, Na, Fe, Mn and Al in 0.1 mol L^{-1} $BaCl_2$ (ISO 1994). The samples were shaken to be fully mixed for 2 hours and immediately afterward centrifuged to 5000 rounds per minute, for 10 minutes. The supernatant was used for the analysis. The element contents in the extracts were determined by ICP-OES.

The Mehlich III extraction procedure was performed by shaking the extractant (0.2 Mol L^{-1} CH_3COOH, 0.25 mol L^{-1} NH_4NO_3, 0.013 mol L^{-1} HNO_3, 0.015 mol L^{-1} NH_4F and 0.001 mol L^{-1} EDTA at a ratio 1:10 (w/v)) and soil was shaken for 10 minutes (Mehlich 1984). Inductively coupled plasma-optical emission spectrometry (ICP-OES), and flame atomic absorption spectrometry (F-AAS; Varian 280FS; Varian, Victoria, Australia) were used for the determination of elements in soil extracts. To determine total carbon and nitrogen in soils, a CHNS Vario MACRO cube (Elementar Analysensysteme GmbH, Germany) analyzer was used.

According to the results, a soil with properties similar to those found in the samples in Peru was chosen here in the Czech Republic for the experiment in the greenhouse. The chosen soil came from the region of Hněvčeves in the Czech Republic (50^{o}18’46’’ N and 15^{o}43’3’’ E) at 273 m.a.s.l. (Kulhánek et al. 2016).

4.3 Selected corn species

For the experiment, the species of corn selected was the Hybrid RGT Attraxxion. It has been registered in the Czech Republic since 2019 in the early grain category. Based on results from trials performed in several European countries, it became the leading hybrid in the segment of early corn. It is a versatile hybrid that achieves very good results when it comes to the harvesting of green biomass and grain yield. It stands out with very good tassel pollination and very good health. The RGT Attraxxion hybrid has a good tolerance to drought, which was evidenced by the results from trials in drier years (Neckář, 2022).

4.4 Outdoor weather-controlled vegetation hall experiment

4.4.1 Experimental design

The pot experiment was performed from June to September 2023, for a period of 15 weeks. The samples of corn were placed outside, under a retractable roof for protection from direct precipitation. At the site of the experiment, the temperature was not regulated in order to simulate normal growing conditions. Distilled water was used for watering throughout the whole process, to avoid contamination from any compound present in other sources of water.

Samples were distributed in nineteen pots, each pot was filled with 4.5 kg of previously sieved soil from the region of Hněvčeves, determined to be Luvisol, the structure of the soil is normally clayey loam, which was determined to have the most similar structure to the one in the high Andes of Peru.

The experimental design was as follows:

1. Two pots were used as untreated control;
2. three pots had low-concentration mineral fertilizer NPK (50ml NH_4NO_3 + K_2HPO_4 solutions, at a reason of 0.16g of P and 0.4g of K per 4.5kg of soil);
3. three pots contained high-concentration mineral fertilizer NPK (100ml NH_4NO_3 + K_2HPO_4 solutions, at a reason of 0.16g of P and 0.4g of K per 4.5kg of soil);
4. three pots contained a lower dose concentration of vermicompost (72g);
5. only two pots were treated with a higher concentration of vermicompost (144g) each, this was due to the lack of proper soil;
6. three pots treated with a low dose (72g) of cricket frass (CrF_{Low});
7. and three pots treated with a high dose (144g) of cricket frass (CrF_{High}).

The fertilizer doses were calculated to achieve a comparable dose of nitrogen.

On May 25th, 2023, The pot experiment started without pots 10 through 15 because of the lack of soil. On the 29th the first sprouts of corn were noticed in all of the pots, with the exception of pots 10 through 15, the pots with the sprouts were relocated to a place where they would get direct sunlight. On the 30th of May, it was noticed that the amount of soil was not enough to cover all 21 of the pots, it was then decided to give pot number 3 a treatment with Vermicompost fertilizer of higher concentration and to have only two pots with a higher concentration treatment of Vermicompost, numbers 13 and 14. On June 2nd, the first sprouts on pots 10, 11, 12, 13 and 14 could be appreciated, so they were relocated as well to an area where they would get direct sunlight (Figures 4 and 5).

At the beginning of the experiment, 8 seeds of RGT Atraxxion corn, bred in the Czech Republic, were planted in each pot to maximize the probability of successfully sprouting the corn plants, but only 5 should remain in order to ensure correct nutrition. After sprout, 3 were removed by hand until a maximum of 5 remained in each pot. In pots number 6 and 7, 4 plants were successfully sprouted; in pot number 9, 2 plants were successfully sprouted. All other pots were able to sprout 5 or more plants.

The pots were regularly watered with distilled water, measurements of the height of the plants on each pot were taken bi-weekly.

During the experiment, it was noted that even though pots number 10 through 14, those with the vermicompost treatment, showed a more accelerated growth than the rest during the first weeks, this rapid acceleration stopped at around the 4th week, it was also noticed that the overall color of the plants was clearly paler and the steam development seemed to be deficient, given that the stem itself was thinner compared to other treatments. The coloration on the base of the stems for this particular treatment in both concentrations was dark red.

Figure 4: Pots number 17 through 21 showed a much greener coloration in the stems and the leaves throughout the whole experiment.

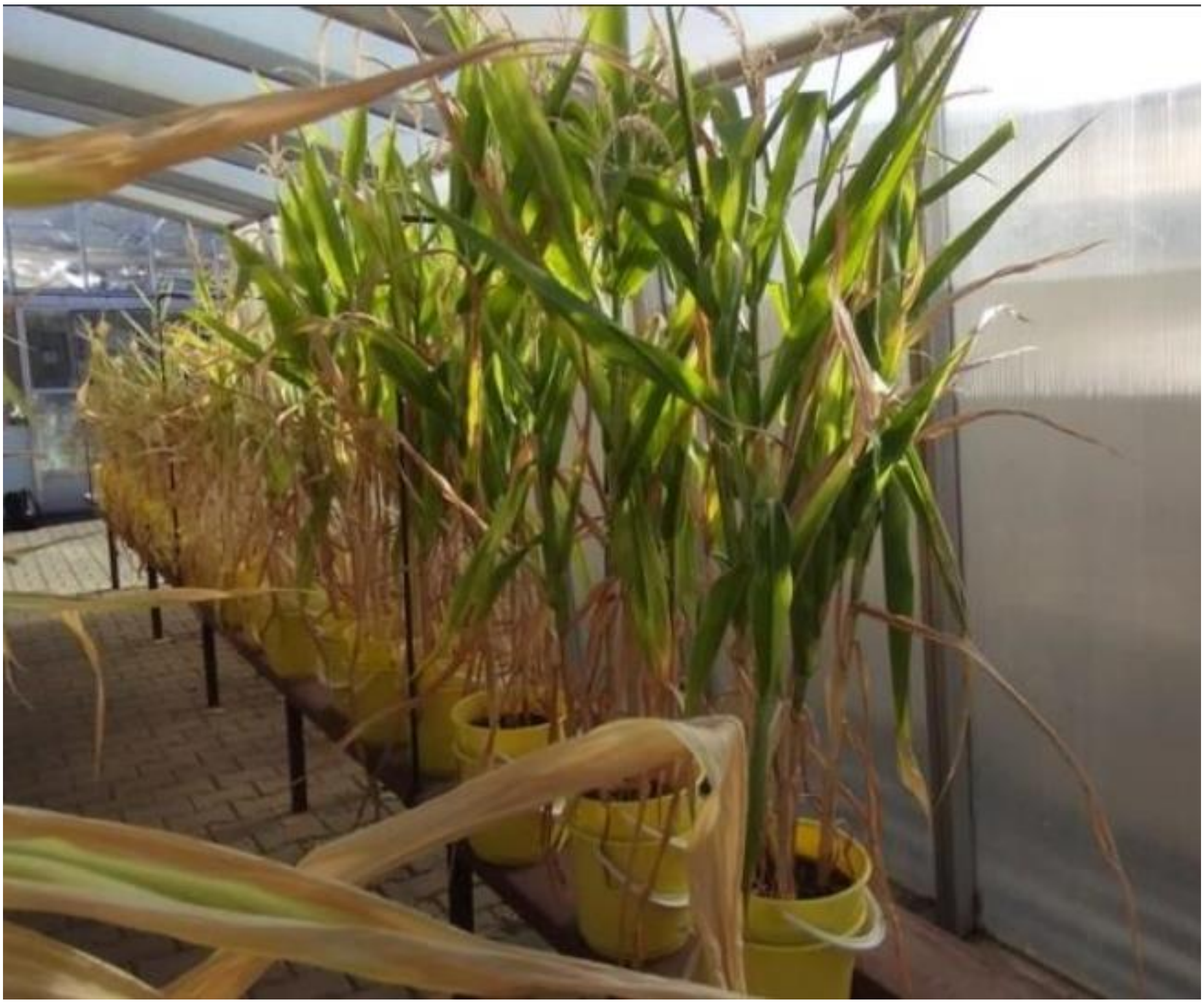

Figure 5: Outdoor weather-controlled vegetation hall experiment.

After 14 weeks of treatment, the plants were harvested. The number of plants on each pot was counted one last time as well as the number of fruits produced by each plant. For the harvesting process, the stems were cut at the base, just above the first visible roots and then weighted.

The leaves were separated from the stems of each one of the plants of corn for analysis and then were both first placed under the sun to dry for 5 days and then placed on a drier at a temperature between 50^o-55^oC until constant weight was reached.

The roots were carefully washed and all of the soil was removed, first with regular tap water and then with demineralized water. After this, the roots were weighted and placed under the sun to dry for 7 days. After this period of time, the roots were placed in the drier at a temperature of 50^o-55^oC until they were able to reach a constant weight.

The preparation for the digestion was done by grinding the samples, this process was done in 2 stages. The samples were ground and sieved using a filter of 4 mm. The second time the samples were ground, a smaller mill was used that allowed the samples to be sieved using a 1mm filter.

For the determination of element contents in plant biomass, the samples were mineralized by the dry ashing procedure (Mader et al. 1998) as follows: 0.5 g of sample biomass is weighed in a 50 mL quartz glass reaction vessel covered with a watch glass, inserted onto a cold hot plate. Temperature of 170°C is first selected. After 1h, it is changed to 230°C, after another hour to 290°C and after another hour to 380°C. This temperature is maintained for 1 h, hot plate is switched off, watch glasses are removed and beakers are transferred to cold muffle furnace. The furnace is then closed and the temperature regulator is switched to 350°C. After 1h the regulator is switched to 450°C and after another 1h to 500°C. Then it is left in this position for approx. 16 h (overnight). The next morning, exactly 1 mL HNO_3 (67%) is added to each beaker. Beakers are transferred to the cold hot plate at 120°C and left on just until all excess HNO_3 has evaporated. Beakers are again returned to the muffle furnace at 500°C for 1h. About 5 mL diluted HNO_3 (1.5%) is put into each beaker and the ash is dissolved by using an ultrasonic bath. The content of each beaker is quantitatively transferred into a calibrated test tube (20 mL) and filled with 1.5% HNO_3 until the required volume. The element contents in the digests were determined by ICP-OES.

4.5 Statistical analysis

The statistical analysis of the samples was done in the R Studio program, version 2023.12.0 +369. To assess the significance in the variables of each treatment, the Bartlett’s test was used, which assumes that the homogeneity of the variables of two or more groups is equal.

Figure 6: Beakers on top of hot plate.

The determination of total nitrogen, carbon and hydrogen was done using a CHNS Vario MACRO cube (Elementar Analysensysteme GmbH, Germany).

5. RESULTS

5.1 Nutrient content of soil

The total and available content of nutrients, cation exchange capacity and pH of the samples of soil brought from Perú, as well as in the Czech soil, is shown in the tables 2-6 as follows:

Table 2: Total nutrient content in the soil samples brought from Peru and the Czech soil chosen for the experiment, data is presented as mean ± standard deviation

	Nutrient content			
	Mn (mg/kg)	P (mg/kg)	S (mg/kg)	Zn (mg/kg)
Huerto 1	135.21 ± 7.11	25.73 ± 1.87	26.23 ± 0.12	12.74 ± 3.18
Huerto 2	150.21 ± 0.65	76.85 ± 0.02	86.36 ± 3.08	12.52 ± 0.18
Huerto 3	119.63 ± 6.32	168.41 ± 3.17	50.92 ± 0.14	16.8 ± 0.03
Limatambo	184.42 ± 6.61	60.12 ± 5.92	42.63 ± 2.38	18.84 ± 0.34
Hněvčeves	567 ± 421	617 ± 435	133 ± 4	64.7 ± 6

Table 3: Total nutrient content in the soil samples brought from Peru and the Czech soil selected for the experiment, data is presented as mean ± standard deviation

	Nutrient content				
	Ca (mg/kg)	Cu (mg/kg)	Fe (mg/kg)	K (mg/kg)	Mg (mg/kg)
Huerto 1	4888.44 ± 13.96	7.6 ± 0.15	71.97 ± 4.68	991.68 ± 26.72	795.41 ± 4.8
Huerto 2	6711.97 ± 105.79	9.42 ± 0.03	103.22 ± 2.8	953.23 ± 15.64	976.46 ± 18.57
Huerto 3	8136 ± 236.46	6.94 ± 0.25	117.85 ± 5.65	1172.35 ± 41.25	722.4 ± 22.8
Limatambo	6908.07 ± 305.95	9.68 ± 0.6	206.08 ± 6	1061.57 ± 60.65	448.56 ± 24.51
Hněvčeves	3403 ± 94	13.5 ± 1.6	20322 ± 4900	5562 ± 142	3882 ± 180

Table 4: Mehlich III extractable contents in the soil samples brought from Peru, data is presented as mean ± standard deviation

	Mehlich III extractable contents			
	Mn (mg/L)	P (mg/L)	S (mg/L)	Zn (mg/L)
Huerto 1	5.56 ± 0.31	1.06 ± 0.08	1.08 ± 0.001	0.52 ± 0.13
Huerto 2	6.08 ± 0.06	3.11 ± 0.02	3.49 ± 0.1	0.51 ± 0.004
Huerto 3	4.94 ± 0.32	6.95 ± 0.21	2.1 ± 0.03	0.69 ± 0.01
Limatambo	7.59 ± 0.18	2.47 ± 0.21	1.75 ± 0.08	0.78 ± 0.02
Hněvčeves	122 ± 5	108 ± 4	8.43 ± 1.95	6.28 ± 1.95

Table 5: Mehlich III extractable contents in the soil samples brought from Peru, data is presented as mean ± standard deviation

	Mehlich III extractable contents				
	Ca (mg/L)	Cu (mg/L)	Fe (mg/L)	K (mg/L)	Mg (mg/L)
Huerto 1	201.23 ± 1.23	0.31 ± 0.007	2.96 ± 0.2	40.82 ± 1.23	32.74 ± 0.3
Huerto 2	271.6 ± 2.47	0.38 ± 0.001	4.18 ± 0.14	38.57 ± 0.37	39.51 ± 0.49
Huerto 3	335.8 ± 13.58	0.28 ± 0.01	4.86 ± 0.29	48.39 ± 2.25	29.82 ± 1.28
Limatambo	284.57 ± 9.26	0.4 ± 0.02	8.49 ± 0.15	43.72 ± 1.98	18.47 ± 0.79
Hněvčeves	2139 ± 168	456 ± 1.01	337 ± 17	191 ± 23	124 ± 7

Table 6: Total content of N, C, H, CEC and pH of the soil samples brought from Peru and the Czech soil chosen for the experiment, data is presented in percentage as mean ± standard deviation

	Total amount				
	N (%)	C (%)	H (m%)	pH	CEC (mmol/kg)
Huerto 1	0.22 ± 0.01	2.54 ± 0.035	0.62 ± 0.02	6.5	161 ± 1
Huerto 2	0.29 ± 0.01	3.39 ± 0.01	0.73 ± 0.03	6.6	181 ± 3
Huerto 3	0.21 ± 0.01	2.305 ± 0.165	0.59 ± 0.03	6.7	138 ± 2
Limatambo	0.4 ± 0.01	3.155 ± 1.06	0.88 ± 0.01	6.4	193 ± 4
Hněvčeves	0.11 ± 0.01	1.03 ± 0.00	0.478±0.022	6.5	180 ± 1

Nutrient content in Czech soil was retrieved from unpublished data and CEC according to ISO (1994).

5.2 Height, yield, and nutrient content of corn

5.2.1 Height

The following curve shows the tendency of growth for each treatment, the measurements were taken bi-weekly over the course of 14 weeks.

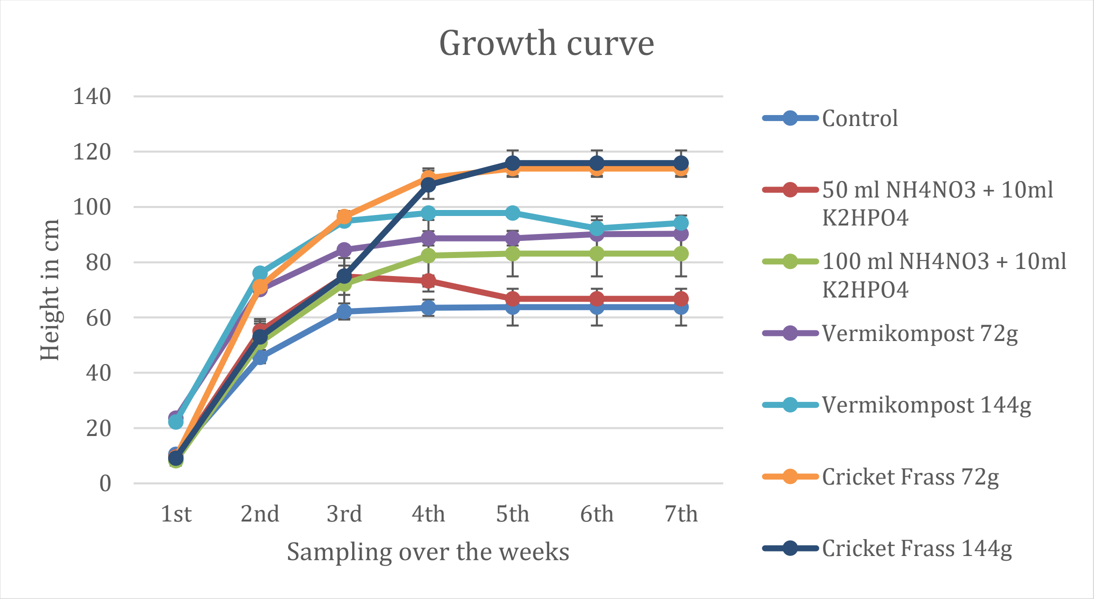

Figure 7: Growth curve and error bars of each treatment.

The statistical analysis was done in RStudio, by testing the hypothesis of the homogeneity of variables using Bartlett's test. With a p-value of 0.5348 the statistical analysis does not support the evidence of a significant difference among the variables, but we can identify a trend between the different treatments.

5.2.2 Yield

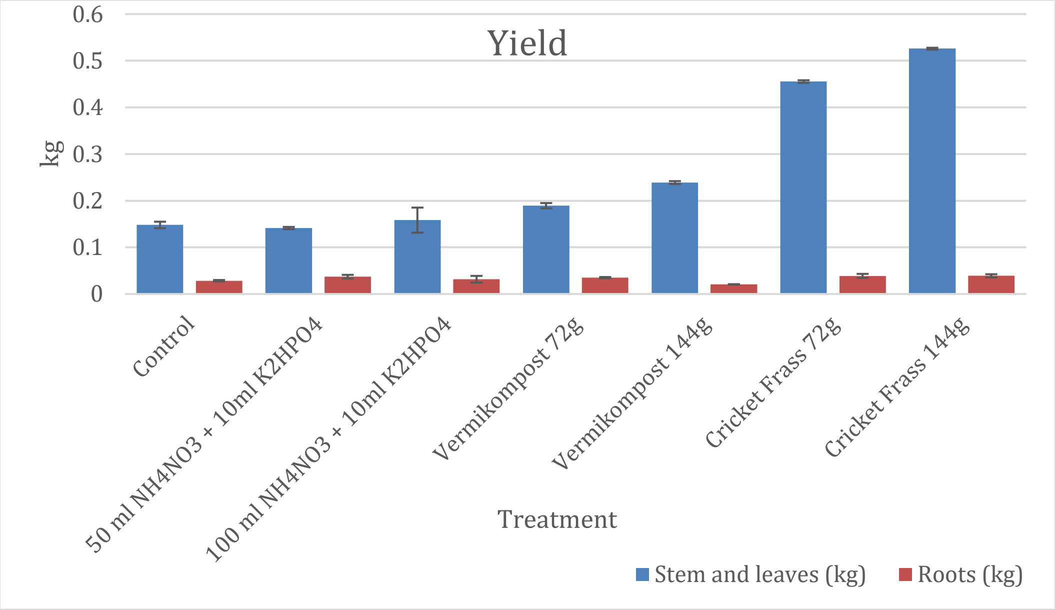

Figure 8: Total yield of corn plants in the end of the experiment.

After the harvest, each treatment was weighted in two different parts; the stem and leaves, and the roots. The statistical analysis showed that, with a p-value = 0.352, the difference among the variables is not significant, although a trend is visible.

5.2.3 Nutrients

The analysis of the samples was done using Windows Excel to show the differences of the nutrient content, standard deviation, and error bars for every treatment. The statistical analysis was performed in RStudio using the Bartlett's test to analyze the homogeneity of the variables and the significance of any variations.

5.2.3.1 Nitrogen

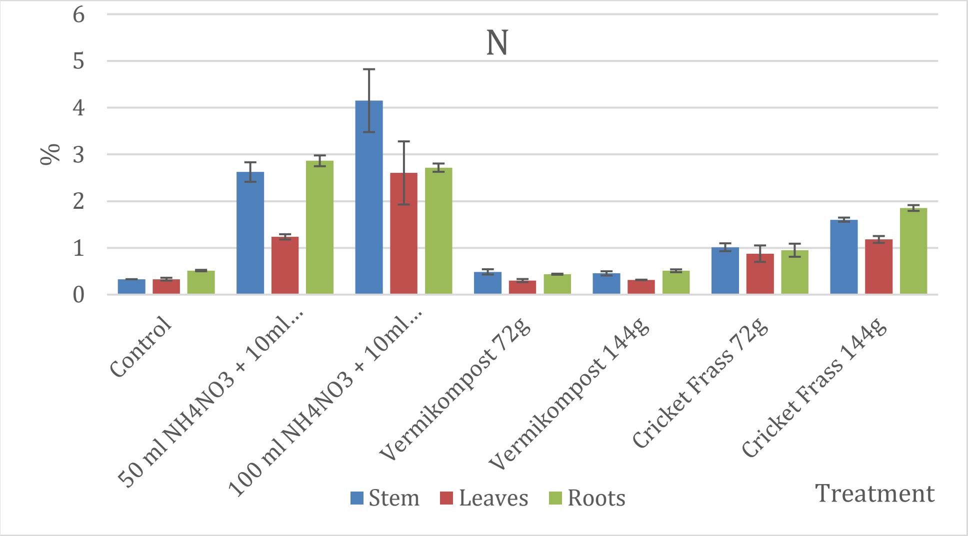

Figure 9: Nitrogen content in the corn plants.

When performing the statistical analysis on the stem and leaves, the results obtained showed that the difference among the variables is significant. Showing a greater nitrogen content in both NPK treatments compared to the organic fertilizers.

5.2.3.2 Potassium

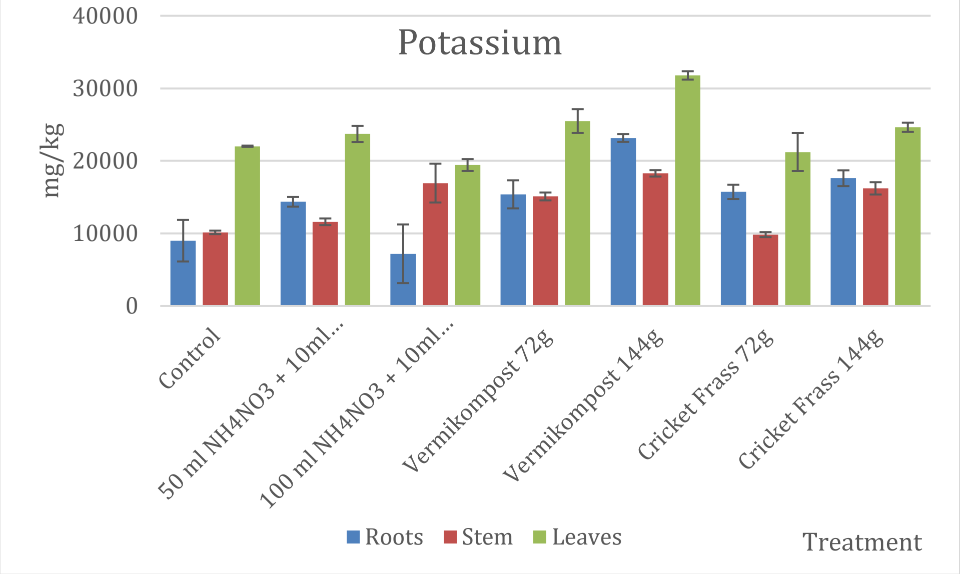

Figure 10: Potassium content in the corn plants.

When analyzing the potassium content, no statistically significant difference was observed, and rather more homogeneous results throughout the treatments.

5.2.3.3 Calcium

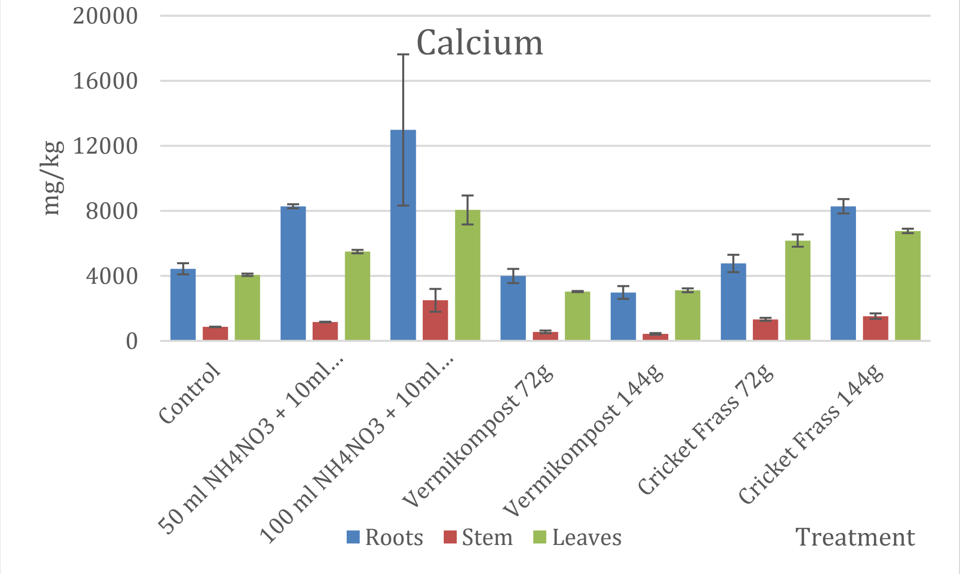

Figure 11: Calcium content in the corn plants.

The statistical analysis supports a significance in the variables of the samples. The NPK treatment shows higher content of Ca compared to the organic fertilizers.

5.2.3.4 Copper

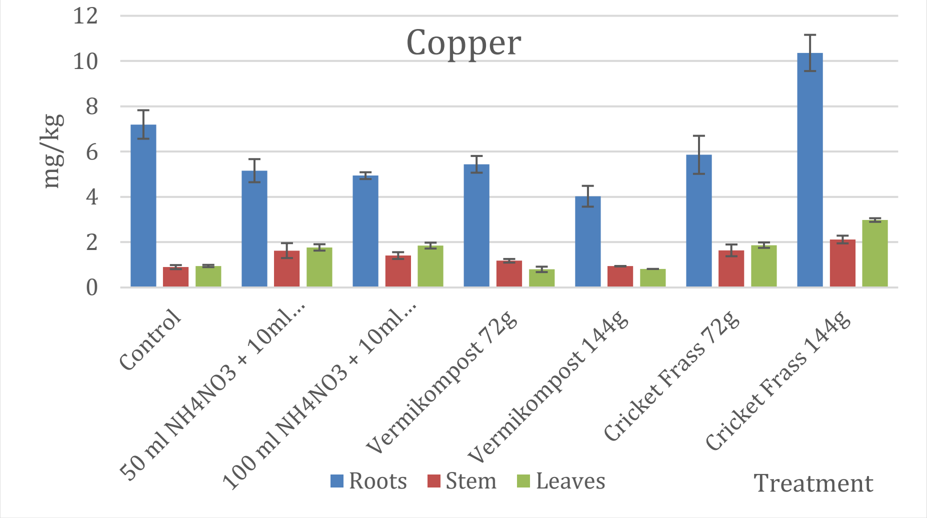

Figure 12: Copper content in the corn plants.

Other than the Cu content in leaves, the statistical analysis does not support the significance in the variables among treatments.

5.2.3.5 Magnesium

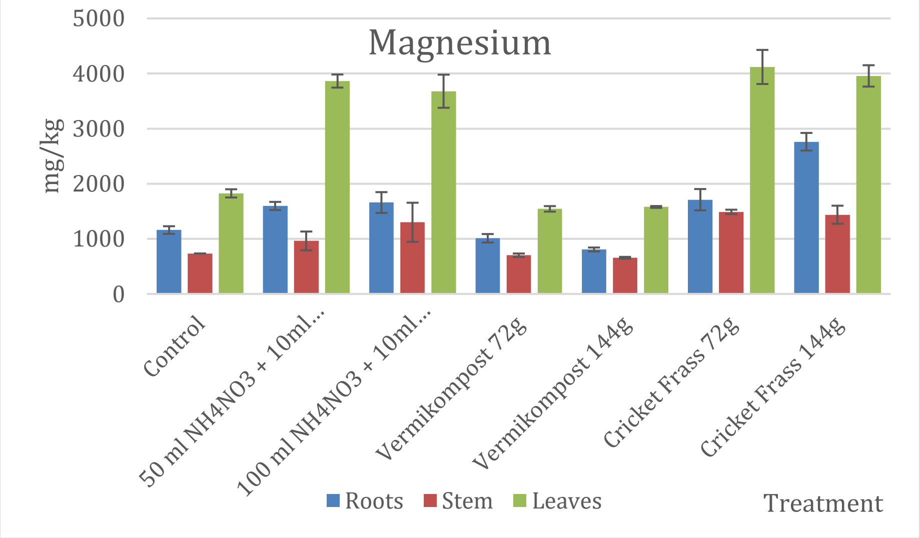

Figure 13: Magnesium content in the corn plants.

The statistical analysis does not support a significance in the variables, but a trend is identifiable.

5.2.3.6 Iron

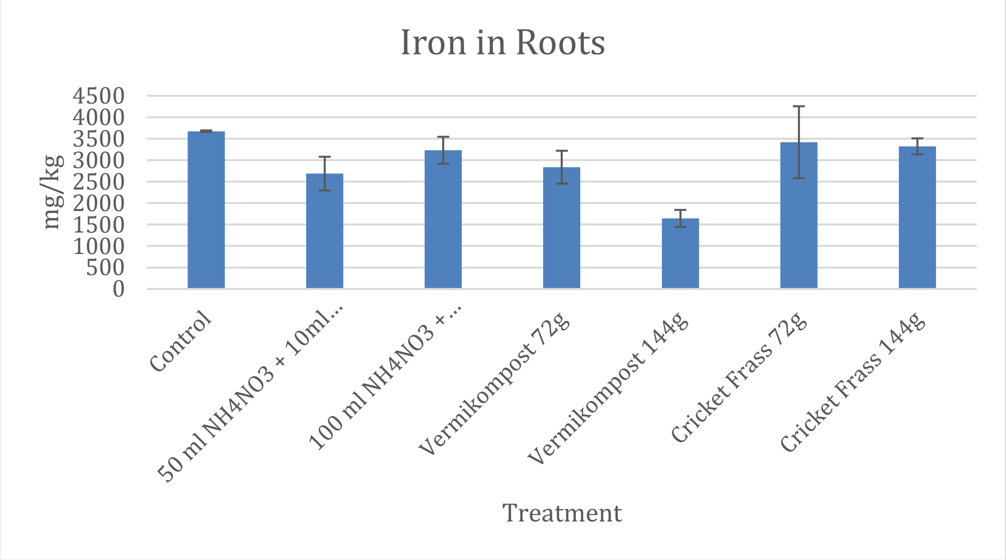

Figure 14: Iron content in roots of corn.

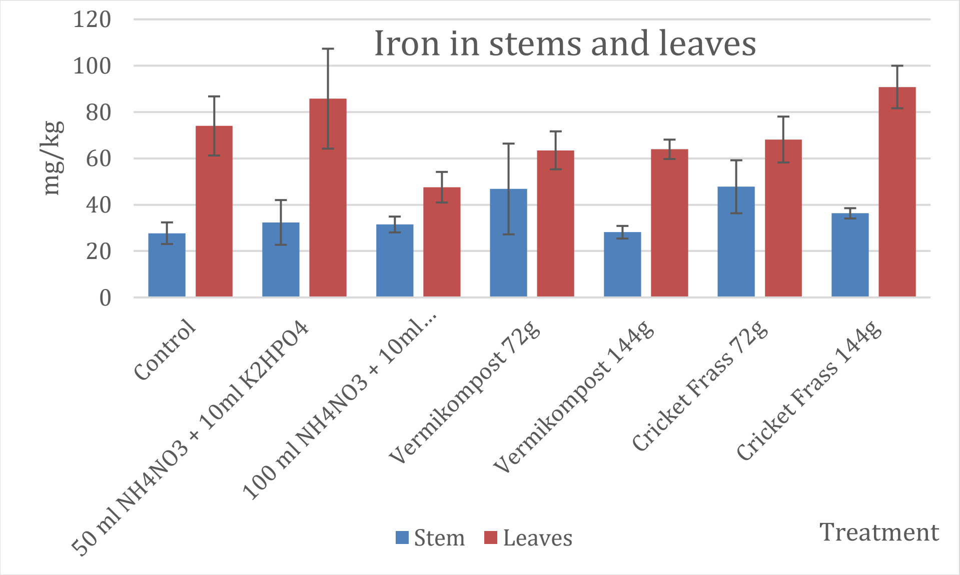

Figure 15: Iron content in stem and leaves of corn.

The statistical analysis does not support a significant difference between the variables across the different treatments.

5.2.3.7 Manganese

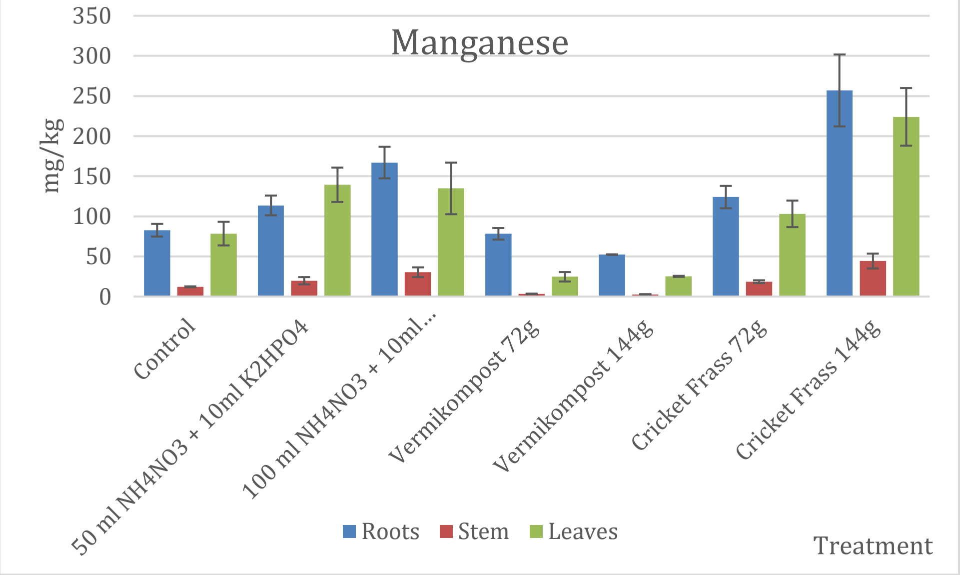

Figure 16: Manganese content in the corn plants.

The significance of the variables between the treatments is not statistically supported, but a trend is visible.

5.2.3.8 Phosphorus

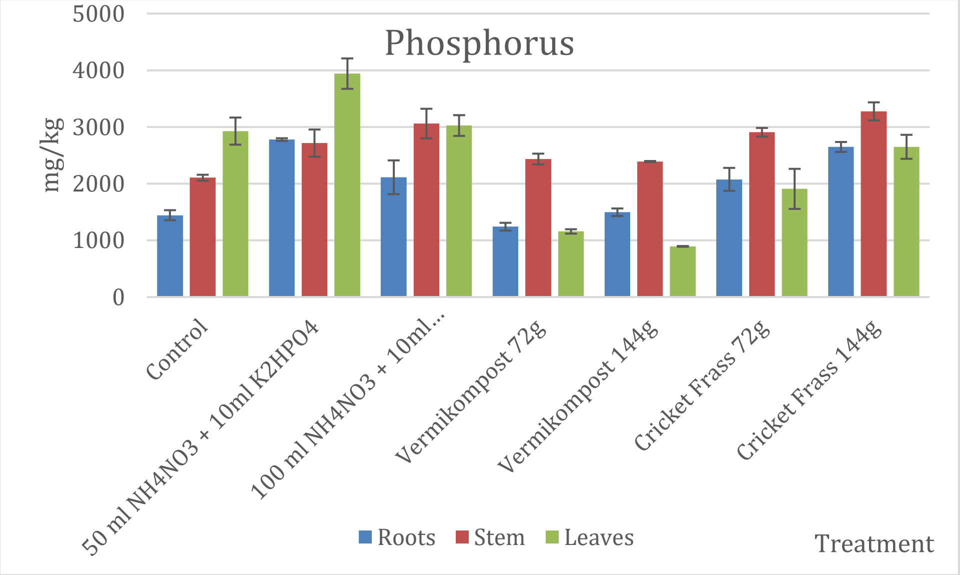

Figure 17: Phosphorus content in the corn plants.

Based on Bartlett's test results, there is no significant evidence to suggest that the variables of the treatments differ significantly from each other.

5.2.3.9 Sulfur

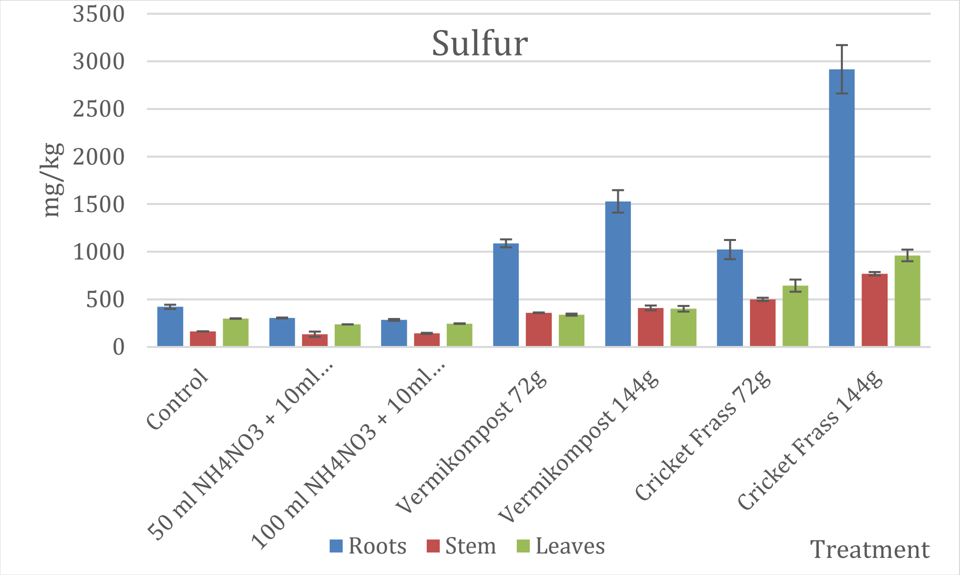

Figure 18: Sulfur content in the corn plants.

The statistical analysis showed that there is a significant difference of S content in the roots and leaves, however, the difference in the variables is not significant in the steams.

5.2.3.10 Zinc

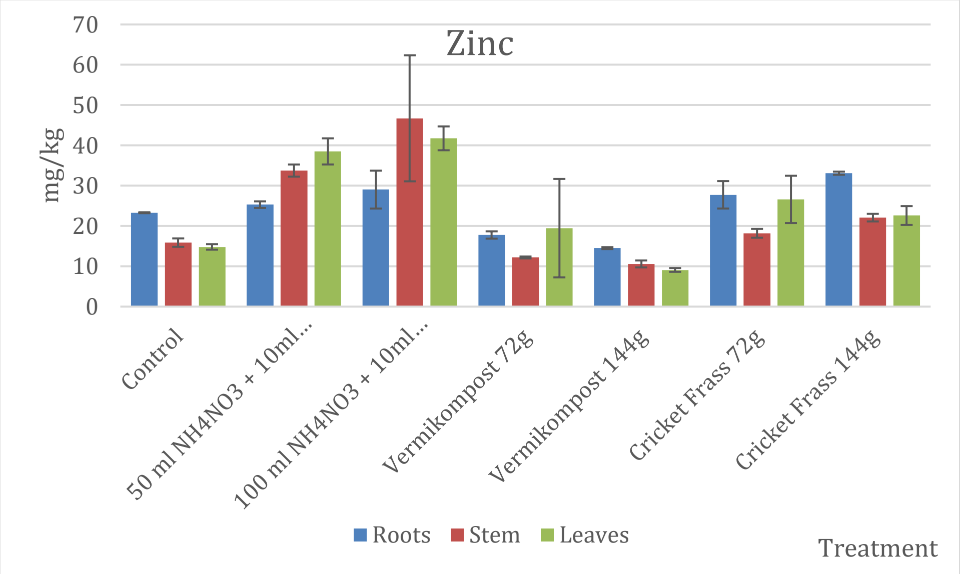

Figure 19: Zinc content in the corn plants.

Based on Bartlett's test there is no significant evidence that suggests that the variables differ significantly from each other.

6. DISCUSSION

The aim of this experiment is to demonstrate that, through the use of cricket frass fertilizer, soil can be treated to achieve better crop growth, development, quality, and production.

When compared to NPK fertilizer and vermicompost, being these last two treatments for soil greatly accepted, cricket frass fertilizer showed interesting results.

Concerning the plant growth, even though the results are not statistically proven, a trend could be noticed, where, week by week a difference can be observed, where the corn plants treated with cricket frass were the tallest. Corn threated with vermicompost, had a very fast grow rate at the beginning, but could not maintain the same growth rhythm throughout the 14 weeks as shown in Figure 8.

At week 7 of the experiment, it was noted that the stem of the corn plants treated with both concentrations of cricket frass fertilizer were thicker in comparison to the rest of the treatments, this will have to be analyzed in detail in further experiments. When harvested, the weight of the plants of each treatment was measured. There is a clear difference between the plants treated with cricket frass fertilizer and the rest, but this difference is not confirmed by the statistical analysis. The number of ears produced by every corn plant was higher in the plants treated with the cricket frass fertilizer (data not shown), although this was not the objective of this study, this will have to be analyzed further in other experiments.

The results of the statistical analysis showed that the plants of corn treated with NPK had a significantly greater nitrogen content. Corn needs a significant amount of N to produce high yields, soil microorganisms must mineralize the organic fraction, making it highly dependent on temperature, soil conditions and moisture (Darby et al. 2017). Other organic amendments such as Black Soldier frass fertilizer, were proven to release insufficient N during high nitrogen demand periods, but had more mineral N in the topsoil, it remains a topic of interest to determine if cricket frass fertilizer has the same behavior (Beesigamukama, 2020). It was also noticeable that the soil treated with the cricket frass fertilizer retained water much more efficiently than other treatments, this may be due to the amount of chitin present in the cricket's exoskeleton, which show very favorable similarities when they are compared to commercial shrimps. It would be object for further studies to determine whether this affects the plant growth and development and if it has a positive or a negative impact (Abidin et al., 2020).

The amount of calcium content found in the corn plants treated with both NPK treatments is the largest. Excess of calcium can affect the plant growth and development.

The copper content in the corn plants with the cricket frass treatment was significantly larger, particularly in the roots. Plants that grow under large N supply require larger quantities of Cu; this may be affecting the development of corn under NPK treatment.

A trend can be observed in the difference between the treatments in the manganese content, although not supported by the statistical analysis. The manganese excess can inhibit the nutrient uptake and the deficiency may cause stunted root growth as well as affect the nutrient uptake.

There is a significant difference between the treatments, supported by the statistical analysis. Sulfur is needed in large quantities in many crops and its deficiency can be the cause for a difference in coloration, especially in young leaves.

The phosphorus content is not significantly different among the treatments, this differs when compared to similar experiments where the P content in leaves is significantly higher in leaves of Pakchoi (*Brassica rapa* L.) (Agustiyani et al, 2021).

Although the difference between the variables amongst the treatments is not supported by the statistical analysis, a trend can be identified, the corn plants with the highest content of magnesium are the ones under NPK and cricket frass treatments. Magnesium is the key element for chlorophyll, which may explain the difference in coloration amongst the plants, being the corn plants under both cricket frass treatments the ones slightly but noticeable greener, as documented by figure 20.

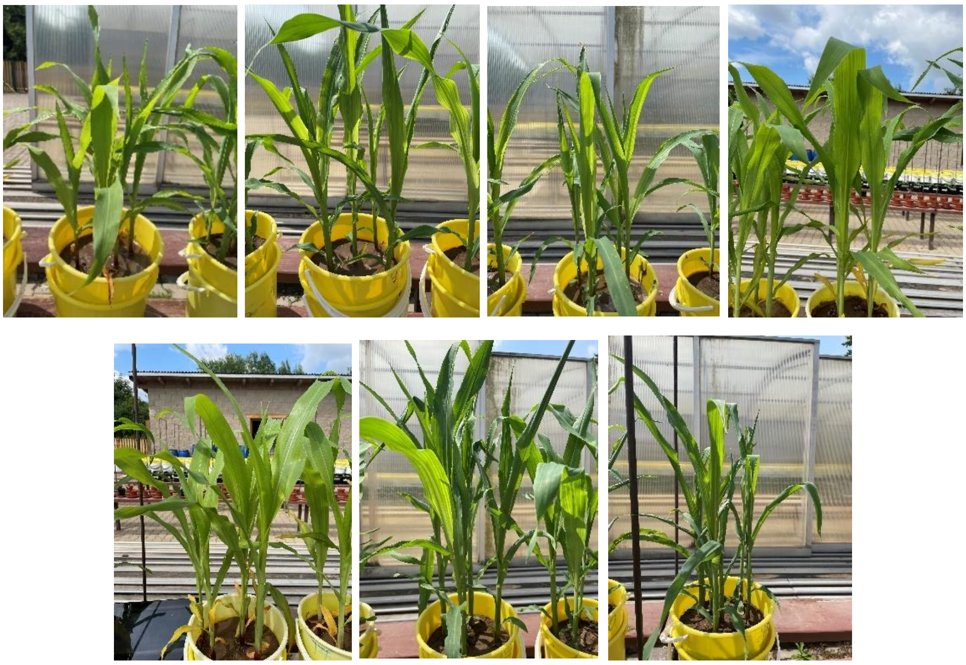

Figure 20: Pictures taken at the 8th week of the experiment.

The difference amongst the treatments is not statistically significant, and all of the treatments, including the control, showed very similar amounts of these elements.

It could be said that the amount of nutrient content in the plants with cricket frass treatment is quite balanced and that no very high or very low quantities were found. For further studies it can be compared with Black Soldier Fly frass fertilizer which was proven to improve plant growth and soil biochemical properties (Agustiyani et al., 2021).

Further studies may also focus on the amount of time required to produce a substantial quantity for soil treatment or the cost of producing it.

7. CONCLUSION

- The pot experiment was done to compare cricket frass to vermicompost and mineral fertilizer; determine nutrient content in corn and determine its viability as an option to increase the fertility in soils.
- In general, for some nutrients it was found that there is a difference when compared to more classical soil amendments, such as vermicompost, and for some other nutrients, the results were more homogeneous.
- The Czech soil from the location Hněvčeves was chosen for their similar physicochemical properties such as pH, CEC, and total nitrogen levels. However, the analyses showed that the Peruvian soils are poor in the other nutrient contents (Ca, K, Mg, P, S, Mn, Cu, Zn) compared to the Czech soil. Therefore, the effect of cricket frass application could be more considerable in the real conditions of the nutrient deficient soils in Perú.

- The application of cricket frass as fertilizer to increase the fertility of soils showed very promising results, which will require further investigation.

8. BIBLIOGRAPHY

- Abidin N.A.Z., Kormin F., Anuar N.A.F.M., and Bakar M.F.A., 2020: The Potential of Insects as Alternative Sources of Chitin: An Overview on the Chemical Method of Extraction from Various Sources. International Journal of Molecular Sciences. 25. Pp 1-9.

- Agustiyani D., Agandi R., Arinafril, Nugroho A.A., Antonius S., 2021: The effect of application of compost and frass from Black Soldier Fly Larvae (*Hermetia illucens* L.). In growth of Pakchoi (*Brassica rapa* L.). ISIBIO 762. 10. Pp. 1-9.

- Beesigamukama D., Mochoge B., Korir N., Musyoka M.W., Fiaboe K.K.M., Nakimbugwe D., Khamis F.M., Subramanian S., Dubois T., Ekesi S., Tanga C.M., 2020: Nitrogen Fertilizer Equivalence of Black Soldier Frass Fertilizer and Synchrony of Nitrogen Mineralization for Maize Production (on-line) (on-line) [cit. 2024.03.21], available at <www.mdpi.com/journal/agronomy>.

- Bly A,. Gelderman R.H., Gerwing J., and Murrell T.S., 2002: Symptoms Associated with Potassium Deficiency in Corn, Northcentral. Better Crops, 86. Pp 12-15.

- Darby H., Gupta A., Cummings E., Ruhl L., and Ziegler K., 2017: Cricket Frass as a Potential Nitrogen Fertility Source (on-line) [cit. 2024.03.18], available at <https://scholarworks.uvm.edu/nwcsp/86>.

- Desutter-Grandcolas, L. 2003: Phylogeny and the evolution of acoustic communication in extant Ensifera (Insecta, Orthoptera). Zoologica Scripta, 32. Pp. 525-561.

- Fageria, N.K 2008. The use of nutrients in crop plants. CRC Press. Boca Raton, FL.

- Galloway, V., (1998): A Novice Raises Crickets Acheta Domesticus Oder Orthoptera, Family Gryllidae (on-line) [cit. 2023.07.11], available at <https://crawford.tardigrade.net/bugs/cricketsuppl.html>.

- Gupta A.K., Chaudhary A., Panthi B., Chaudhary A.K., Gautam E., Badhai S., 2003: Vermicomposting, i TECH MAG (on-line) [cit. 2024.03.09] available at <http://doi.org/10.26480/itechmag.04.2022.29.30 >.

- Gurmu G., 2019: Soil Organic Matter and its Role in Soil Health and Crop Productivity Improvement. Academic research Journal of Agricultural Science and Research 7. Pp 475-476.

- ISO 11260. 1994. Standard of Soil Quality – Determination of Effective cation Exchange Capacity and Base Saturation Level Using Barium Chloride Solution. International Organization for Standardization.

- IUSS Working Group WRB. 2015. World Reference Base for Soil Resources 2014, update 2015. International soil classification system for naming soils and creating legends for soil maps.World Soil Resources Reports No. 106. FAO, Rome.

- Kaplan M, 2014: Breeding and Raising the House Cricket (on-line) [cit. 2023.12.16] available at <http://www.anapsid.org/crickets.html>.
- Khoshru B., Mitra D., Nosratabad A.F., Reyhanitabar A., Mandal L., Farda B., Djebaili R., Pellegrini M., Guerra-Sierra B.E., Senapati A., Paneerselvam P., and Mohapatra P.K.D. 2023: Enhancing Manganese Availability for Plants through Microbial Potential: A sustainable Approach for Improving Soil Health and Food Security. Bacteria 2. Pp 129-130.

- Kulhánek M., Balík J., Černý J., Vašák F,. Shejbalová Š., 2016: Evaluating of soil sulfur forms changes under different fertilizing systems during long-term field experiments. Plant soil Environment. Vol 62. 2016. Pp. 408-415.

- Kumar D, and Jhariya A.N., 2013: Nutritional, Medicinal and Economical Importance of Corn: A Mini Review. Research Journal of Pharmaceutical Sciences 2. Pp 1-6.

- Leghari S.J., Wahocho N.A., Laghari G.M., Laghari A.H., Bhabhan G.M., Talpur K.H., Bhutto T.A., Wahocho S.A., and Lashari A.A., 2016 Role of Nitrogen for Plant Growth Development: A Review. Advances in Environmental Biology 10. Pp 209-211.

- Mader, P., Száková, J., & Miholová, D. (1998). Classical dry ashing of biological and agricultural materials. Part II. Losses of analytes due to their retention in an insoluble residue. Analusis, 26, 121–129, DOI: 10.1051/analusis:1998121.

- Magdoff F., and Weil R.R., 2004: Soil Organic Matter Management Strategies. In: Magdoff F., Weil R.R. (eds) Soil Organic Matter in Sustainable Agriculture. Boca Raton.

- Malhotra H., Vandana, Sharma S., Pandey R, 2018: Phosphorus Nutrition: Plant Growth in Response to Deficiency and Excess. In: Hasanuzzaman, M., Fujita, M., Oku, H., Nahar, K., Hawrylak-Nowak, B. (eds) Plant Nutrients and Abiotic Stress Tolerance. Springer, Singapore.

- Mariod A.A., Mirghani M.E.S., Hussein I., 2017: Unconventional Oilseeds and Oil Sources. Elsevier Science, Amsterdam.

- Marschner H., 2012, Marschner's Mineral Nutrition of Higher Plants, 3rd Edition, Elsevier. London.

- Massa B., Fontana P., Buzzetti M.F., Kleukers R., and Baudewijn O., 2012: Fauna D’Italia XLVIII Orthoptera. Edizioni Calderini, Bologna 563 pp.

- Mehlich A. 1984. Mehlich 3 Soil test extractant: A modification of Mehlich 2 extractant, Commun Soil Sci Plant Anal. 15:1409-1416.

- Mengel, K. and Kirkby, E.A. 2001. Principles of Plant Nutrition. Kluver academic pub. London.
- MIDAGRI, ©1985: Clasificación de suelos (on-line), retrieved [cit. 2024.03.16] available at <https://www.midagri.gob.pe/portal/43-sector-agrario/suelo/330-clasificacion>.
- Neckář K., 2022: Nabídka hybridů kukuřice RAGT. AgroImpulsy December 2022. Pp 1-4.
- Oldham, L. 2019. Secondary plant nutrients: calcium, magnesium, and sulfur. Mississippi State University information sheet 1039. Pp 1-2.
- Rout G.R., and Sahoo S., 2015: Role of Iron in Plant growth and metabolism. Reviews in Agricultural Science 3. Pp 1-3.
- Rudani K., Patel V., and Prajapati K., 2018: The Importance of Zinc in Plant Growth – A Review. International Research Journal of Natural and Applied Sciences 5. Pp 38-45.
- Tanklevska N., Petrenko V., Karnaushenko A., Melnykova K., 2020: World Corn Market: Analysis, Trends and Prospects of its Deep Processing (on-line) [cit. 2024.03.04] available at <http://are-journal.com >.
- University of Nebraska Lincoln, 2014: Soil Organic Matter, Soil Health - Guide for Educators (on-line) [16/03/2024] available at <https://cropwatch.uni.edu./documents/USDA_NRCS_OM_guide.docx>.
- Wang, M., Zheng, Q., Shen, Q. and Guo, S, 2013: The critical role of potassium in plant stress response. International Journal of Molecular Science, 14, Pp 7370-7390.
- White P.J., and Broadley M.R., 2003: Calcium in Plants. Annals of Botany 92. Pp 487-511.

- White, P.J., and Karley, A.J. 2010: Potassium. In: Hell R., Mendel R. (eds.): Cell biology of metals and nutrients in plants. Springer, Berlin, Pp 199-205. Springer Science & Business Media, 2010.

- White, P.J., Hammond, J.P., King, G.J., Bowen, H.C., Hayden, R.M., Meacham, M.C. Spracklen, W.P. and Broadley M.R, 2010: Genetic analysis of potassium use efficiency in Brassica oleracea. Annals of Botany, 105. Pp 1199-1210.

- Yruela I, 2009: Copper in Plants: acquisition, transport and interactions. Functional Plant Biology 36. Pp 409-410.

- Zafar A., Shaheen M., Bin Tahir A., Gomes da Silva A.P., Manzoor H.Y., Zia S. 2024: Unraveling the nutritional, biofunctional, and sustainable food application of edible crickets: A comprehensive review. Trends in Food Science & Technology 143.Pp 2.

9. ON-LINE FIGURE SOURCES

- Figure 1: An adult female house cricket, *Acheta domesticus* (Linneaus), with hindwings intact. Choate, P.M., Walker T.J., Featured Creatures (on-line) [cit. 2024.01.10], available at <https://entnemdept.ufl.edu/creatures/misc/crickets/adomest.html>.

- Figure 2: World corn production, taking into consideration the forecast for the 2024/2025 agricultural year, mln t. Tanklevska N., Petrenko V., Karnaushenko A., Melnykova K., World Corn Market: Analysis, Trends and Prospects of its Deep Processing (on-line) [cit. 2024.03.04] available at <http://are-journal.com >.

- Figure 3: Different varieties of Peruvian corn (Huillca Expedition https://www.huillcaexpedition.com/blog/peruvian-corn).

- Table 1: Nutrient composition of vermicompost (Kale, 1983: Vermicompost. In: AgroBios).