**Dažādu vietējo zālaugu sugu sabiedrību smago metālu akumulācijas spēja modelētā kārklu-zālaugu agromežsaimniecības sistēmā ar sadzīves bioatkritumu kompostos**

Heavy metal accumulation capacity of various local herbaceous species communities willow-herbaceous plant agroforestry system with municipal biowaste soil amendment in modeled environment



2.2. Sampling of soil and plant biomass or chemical analysis, providing recommendations for improving soil fertility

2.2. Augsnes un biomasas paraugu ievākšana ķīmisko analīžu veikšanai Ievākto paraugu ķīmiskās analīzes, rekomendācijas augsnes ielabošanas pasākumu veikšanai

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mazāk pieprasīto kūdras frakciju maisījumiem ielabotās marginālās minerālaugsnēs**

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Intorduction

The increasing demand for food today is creating increased pressure on agricultural areas. Although already in several regions, both at the European and global level, the scarcity of agricultural land leads to the conversion of other ecosystems into agricultural areas for the cultivation of food and biomass crops, much of the former agricultural area is unmanaged and uncultivated. In Europe alone, abandoned areas account for 15% of total land use. Abandonment and non-farming of agricultural land may have several reasons: inadequate hydrological regime, nutrient incompatibility, soil compaction and difficult land treatment, economically underdeveloped region and urbanization of labour force, as well as land ineligibility for food crops due to heavy metal contamination. Soils contaminated by heavy metals not only have reduced economic value, but also pose additional risks to the environment, with heavy metal pollution leaching out of the soil and into other parts of the ecosystem chain.

A possible solution for restoring heavy metal-contaminated soils is phytoremediation, or using plant species as crops, which accumulate heavy metals in their above-ground parts. There are many studies available in the scientific literature on certain plant species which are described as superaccumulants, such as vetiver, silvergrass, cattail, willows, and poplar, which are often fast-growing species that annually accumulate a large amount of biomass, thus also able to accumulate larger amounts of heavy metals. But they are often non-native flora species (vetiver, silvergrass) and in the context of the ecosystem, it is better to select native flora species adapted to native environmental conditions, and pathogens, and which are already inclusive parts of the native flora and fauna. It is also important to note that not all superaccumulants are suitable for a wide variety of growth conditions and there are species suitable only for phytoremediation under specific growth conditions, e.g. cattail is suitable for growth in moist or wet growing conditions.

In the context of the increase in consumption today, it is essential to find new solutions to make municipal waste management more efficient and to increase the life of this waste product. Municipal biowaste contains a lot of minerals and could theoretically be used as a fertilizer, but also it often contains a lot of heavy metals. For either land remediation, that is already polluted with heavy metals, or alternative uses of nutrient-rich byproducts – municipal biowaste, tree-herbaceous plants agroforestry system can be a suitable solution for increasing the economic value of the unmanaged land and byproduct. When growing plants for biomass purposes, for example, short rotation agroforestry systems, that are not intended to be used for food consumption, the heavy metal content in the product due to the polluted substrate is not the biggest threat, but there is a risk of heavy metal further exposure to the environment. To eliminate this risk fast-growing tree plantations with herbaceous plants can be planted for phytoremediation of heavy metals. To obtain the best economic option, it is recommended, based on estimates, to plant fast-growing trees from which financial benefits can be obtained after a couple of years and between trees herbaceous plants that can be used for bioenergy, seed cultivation or as nectar plants. If the concentration of heavy metals in the substrate is considered toxic, the first two options should be used.

The aim of this study was to test the ability of selected fast-growing tree and herbaceous species to grow in a substrate rich in minerals and heavy metals, as well as to determine the phytoaccumulation in different cultivated and local grassland plant species and how it is affected by the presence of construction debris in the soil. We hypnotized that construction debris will decrease soil pH value and improve granulometric composition which improves root growth.

# Methods

The experiment was carried out in a semi-controlled greenhouse at the Latvian State Forestry Research Institute Silava, Salaspils, Latvia (N 56 870081’’E 24 347465’’). The average annual temperature in Latvia is +5.9°C and the average annual precipitation is 667 mm. We selected a total of 20 herbaceous species, as well as poplar and willow vegetative cuttings (20 cm long stem cuttings) to create seven different species communities which can be used for the creation of tree-herbaceous plants agroforestry system. We created a total of seven different species communities’ groups with herbaceous plants that can be grown together and have either taxonomy, morphological or application similarities (Table, Figure 1).

Table 1.

Herbaceous species communities created based on group characteristics

|  |  |  |
| --- | --- | --- |
| No | Species | Group characteristic |
| 1 | *Festuca ovina*  *Poa pratensis*  *Festuca rubra* | Medium height grasses |
| 2 | *Festulolium*  *Festuca arundinacea*  *Lolium multiflorum* | High height grasses |
| 3 | *Trifolium repens*  *Trifolium hybridum*  *Trifolium pretense* | Clover species |
| 4 | *Sinapis alba*  *Raphanus sativus subsp. Oleiferus*  *Dactylis glomerate* | Forage crops |
| 5 | *Lolium perenne*  *Festuca pratensis*  *Phleum pretense* | Grassland forage crops |
| 6 | *Fagopyrum esculentum*  *Vicia faba* | Crops |
| 7 | *Onobrychis vicifolia*  *Medicago sativa*  *Lotus corniculatus* | Legume forage crops |

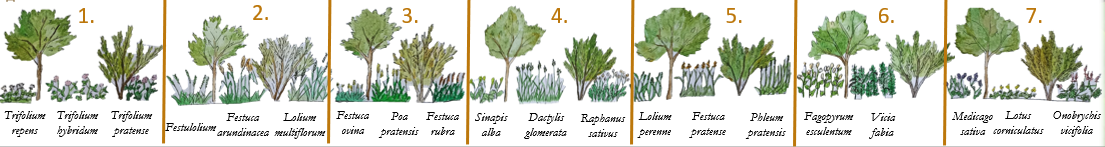


Figure 1. Illustration of possible tree-herbaceous plants agroforestry system based on in table 1. created species communities.

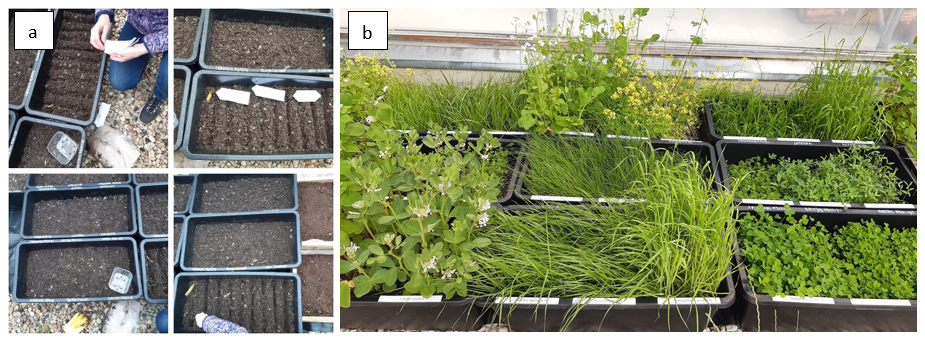


Figure 2. Setting up (a) and maintaining (b) the experiment

Herbaceous plants were planted in two repetitions in plastic tub containers (760x300x470 mm) in outside conditions with an automated irrigation system (Figure 2). Biowaste compost from municipal waste with and without construction debris was used as substrate. Soil analyses were carried out before planting (Table 2, 3). Chemical analyses were carried out also for the plant's dry above-ground biomass. We also measured the grass height, biomass of above-ground plant biomass and root depth growth (Figure 3). Another soil chemical analysis was carried out after one rotation, to determine changes in the soil chemical structure

Table 2

Biowaste compost chemical analyses at the beginning of study, (mg-1 kg-1)

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Soil sample | K | Ca | Mg | Fe | Cr | P | Co | Na | S |
| With debris | 5865.0 | 90212.8 | 14213.0 | 21221.1 | 26.8 | 4244.8 | 102.5 | 1129.3 | 6575.3 |
| Without debris | 6672.3 | 83805.3 | 7579.6 | 17887.1 | 45.6 | 8075.0 | 101.5 | 1579.3 | 10735.0 |

Table 3

Biowaste compost chemical analyses and heavy metals normal range in plants, normal range in soils and toxic soils for plants1 with and without nutrition function in plants, Bold text indicates toxic level in substrate (mg-1 kg-1)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Soil sample | Nutrition function in plants | | No nutrition function in plants | | |
| Cu | Zn | Cd | Pb | Al |
| Normal in soils | 30 | 90 | 0.35 | 35 | NA |
| Toxic in soils | 60-125 | 100-400 | 3-8 | 100-140 | NA |
| Normal in plants | **0.4-45.8** | **1-160** | 2 | 3 | 200-1000 |
| With debris | **154.5** | **758** | 1.3 | 63.6 | 8225.7 |
| Without debris | **301.1** | **1468.1** | 2.3 | **128.5** | 6844.3 |

Hajar, E.W.I., Sulaiman, A.Z.B., Sakinah, A.M.M.. 2014. Assessment of Heavy Metals Tolerance in Leaves, Stems and Flowers of Stevia Rebaudiana Plant. Procedia Environmental Sciences, 20: 386-393. https://doi.org/10.1016/j.proenv.2014.03.049.



Figure 3. Determination of plant morphological parameters.

# Results and discussion

Total produced biomass was higher in groups without construction debris, although there was no statistical significance (P=0.05). The highest yield was for the first species composition, which consisted *Festuca* and *Lolium* family species plants, which are medium-height grasses, usually used for hay production or as forage crops. Groups one, two and three, which consisted of plants from *Festuca*, *Trifolium* and *Lolium* families had a higher impact on construction debris in the soil – grown in the substrate with construction debris, these species had a higher decrease in biomass than other species groups

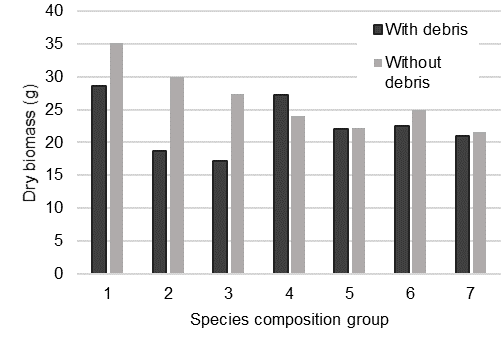
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Figure 4. Total obtained dry biomass depending the species composition group with or without construction debris addition.

As well in the first three groups, root length differs depending on the presence of the construction debris. This may indicate, that the soil properties, which are changes due to the construction debris addition, decrease below and above ground accumulated biomass in these groups. (Figure 5). The root length, therefore the depth of the plant root zone, was longer for groups 5, 6, and 7. Most of these plants are industrial species, grown as forage or food crops. Construction debris increases the root growth for groups 5 and 6, which are bots forage corps with long root systems. There can be see tendency, that construction debris may increase the above and below-ground biomass, for the plant species with deeper root systems, but decreases for plants with shallow root systems.

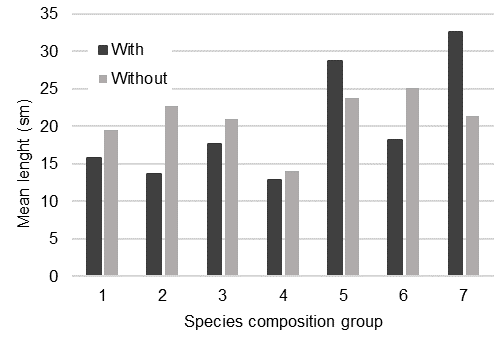


Figure 5. Mean root length depending on species composition group with or without construction debris addition.

The length of the crops in most cases was higher with construction debris addition, however, there were exceptions and results were not statistically significant (Figure 6). The third group, which consisted of *Trifoluim* species, had with shortest plants, between other groups the difference was not so notable.

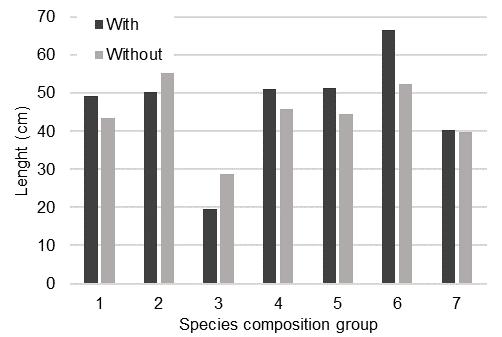


Figure 6. Mean plant above ground length depending on the species composition group with or without construction debris addition

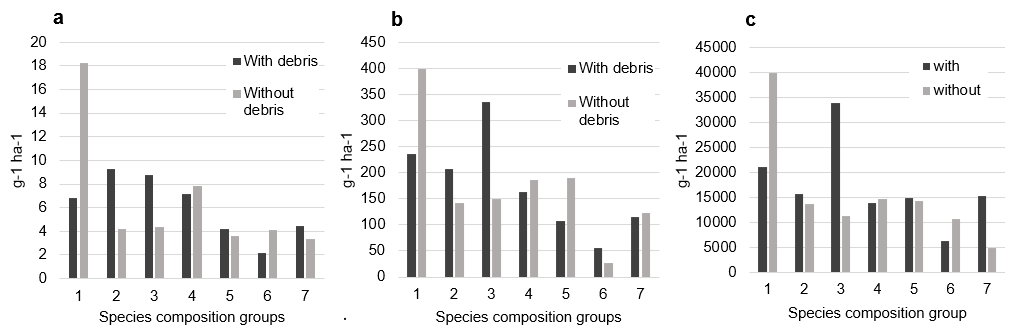
Both the highest Cd and Pb accumulation in the above-ground parts of the plant are observed in species communities 1, 2 and 3 (Table 4). The third plant community has one of the highest total heavy metal contents in the plant in relation to smallest accumulated biomass and vegetation height (Figures 4, 6), therefore dry mass didn’t correlate with metal accumulation. In species communities 4, 6, and 7, which consisted of typical forage and crop plants, Pb and Cd accumulation was lower. Although Zn and Cu are heavy metals that have an important nutrient function in plants, Zn content in all groups without construction debris is above the normal content in plants. Although in most cases with smaller amounts, a substrate with construction debris leads to too high Zn accumulation in the plants. Too high accumulation with Cu occurred only in groups 1 and 3. The highest accumulation of Al occurs in groups 1, 2, and 3. Fast-growing tree species – willow and poplar, are good Zn, Cd and Al accumulators, but Al and Cu accumulation are not higher than normal in the plants.

Table 4.

Heavy metal accumulation in the plants depending on the presence of the construction debris and species composition group (mg-1 kg-1)

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Sample | | Nutrition function in the plants | | | | No nutrition function in the plants | | | | | |
| Cu | | Zn | | Cd | | Pb | | Al | |
| Normal in plants | | 0.4-45.8 | | 1-160 | | 0.2 | | 3 | | 200-1000 | |
| Construction debris (yes/no) | | yes | no | Yes | No | yes | no | yes | no | yes | no |
| After one rotation | 1 | 31.9 | **70.8** | 153 | **304** | 0.2 | **0.4** | **6.3** | **19.7** | **1303** | **3379** |
| 2 | 20.7 | 37.3 | **199** | **291** | 0.2 | **0.3** | **4.6** | **6.7** | **1090** | **1407** |
| 3 | **51.9** | 38.1 | **406** | **266** | **0.3** | **0.3** | **13.5** | **9.5** | **3680** | **2235** |
| 4 | 27.1 | 18.8 | **201** | **209** | **0.3** | 0.2 | **6** | **4.4** | **1580** | 744 |
| 5 | 23.7 | 35.2 | **241** | **300** | 0.2 | 0.1 | **4.4** | **5.9** | 993 | **1127** |
| 6 | 20.5 | 21.4 | **177** | 340 | 0.1 | **0.3** | 1 | 3 | 251 | 257 |
| 7 | 19.7 | 20.8 | 153 | 188 | 0.1 | 0.2 | **3.7** | **4.4** | 736 | 722 |
| Willow | | 19.7 | 15.5 | **1155** | **667** | **3.1** | **1.6** | 1.7 | NA | 48 | 46 |
| Poplar | | 20.9 | 11.2 | **346** | **245** | **2.0** | **1.2** | **6.8** | 1.2 | 321 | 80 |

Total accumulated cadmium is higher in the first four species composition groups, and lower in groups 5, 6 and 7 – plants that are usually used for forage or food crop production (Figure 7). Although, in some groups, there are differences between Cd accumulation depending on construction debris presence, overall there are no statistical differences. Lead accumulation was lower in group 7, which consists of food crops, but the mean value was higher in the first three plant groups.



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Figure 7. Total accumulated amount of heavy metals in plants above ground parts, that have no nutrition function in plants (a- cadmium (Cd), b – lead (Pb), c- aluminum (Al) depending on construction debris presence and species composition groups.

# **Conclusions**

Construction debris's impact on plant growth is mainly determined by the species and its morphology. In the context of biomass, it only increases plant growth for the species with a deep rooting system, but for the species with a shallow rooting system, it could also lead to decreased productivity. Willow and poplar accumulate Cd, Pb and Zn heavy metals more than normal in plants. To create a phytoremediation tree-herbaceous plant system that can accumulate Cu and Al additional herbaceous plant species can be used from groups 1, 2 and 3, which had the highest amount of heavy metals accumulated per mass unit as well as total amount. This research also showed that most forage and food crops had a lower capacity for accumulating heavy metals.