KŪDRAS UN LAUKA AUGSNES KĀ PODU SUBSTRĀTA ĪPAŠĪBU SALĪDZINĀJUMS

COMPARISON OF PEAT PROPERTIES WITH THOSE OF SOIL FROM THE FIELD AS A SUBSTRATE FOR POT TRIALS

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Abstract. *Use of peat as substrate for plant breeding research is common in agricultural research institute like the Institute of Agricultural Resources and Economics (AREI). For extended research topic, conducting of pot trial in conditions similar to the field environment may require use of soil as substrate. This research aims to highlight the difference between physical and chemical characteristics of peat and soil as substrate. Different chemical analyses and physical tests were conducted to three pot trial substrates: sodic gleysol soil; soil mixture (sand and organic manure are mixed with the same soil); and commercialised peat (usually mixed with a scarce proportion of sand according to AREI practice). Results have shown that substrate from peat has different physical property compared to soil from the field regarding soil texture and bulk density. Mixing soil with sand and organic matter had a greater impact on physical property than on chemical characteristics. Commercialised peat is an optimised substrate thanks to incorporated nutrients. Peat presents high content in 12 nutrient parameters out of 14, particularly with Ammonium nitrogen, exchangeable phosphate and potassium and globally, with organic matter and calculated Cation Exchange Capacity. The research has highlighted that effort has been done to make peat soil, well known as inappropriate for growing plant to become the preferred substrate for plant breeding activities. Such effort is also needed to make advancement in use of soil as substrate. Trials should be carried out using different soil-based substrates to evaluate the advantages and disadvantages of their suitability.*
Keywords: *sodic gleysol, commercial peat, physical properties, chemical characteristics, fertility.*

Introduction

Even though only 5% of peat produced in Latvia stay inside the territory, peat remains the major material used as substrate in horticultural and tree seedlings activities (Zelta zeme website, 2021). Unfortunately, as from fossil source, peat is considered as a non-renewable resource (Vincevica-Gaile et al., 2021).

For ecological and economic reasons, effort to find alternative to peat as substrate for planting in pot is currently encouraged worldwide but such initiatives often exclude the use of soil-based material (Schafer and Lerner, 2022). Nonetheless, use of soil-based material as substrate is necessary for some research purposes. The use of peat for breeding activities is for instance suitable to optimize variety performance but it is not recommended to understand processes that are expected on field. For specific agronomical topics, use of soil may be required, even mandatory to get relevant results (Merbach et al., 1999). At the Institute of Agricultural Resources and Economics (AREI), plant breeding research uses peat as substrate to conduct the first phases of the creation of new plant varieties of cereals in order to sustain high varietal characteristics. When extending its research topic to Agroecology, AREI will have to conduct activities where other substrate than peat may be required in controlled conditions, particularly soil that represents the field situation. To do so, lack of knowledge and practice related to the use of soil-based substrate needs to be overcome.

To gain in knowledge and comprehension in the use of soil-based material as substrate for planting in pot, this research aims to highlight the difference between physical and chemical characteristics of peat and soil as substrate. The finding will contribute to reveal the potential advantages of each substrate, and to define the new challenges induced by the use of soil as substrate.

Materials and methods

Three substrates have been prepared for the purpose of this study: two soil-based substrates and one with peat. About one m^3 of sodic gleysol soil was collected, within the first 30 cm deep of a field located at Škeperī, Talsi District, 57°12'58"N, 22°33'08"E. This soil was inventoried by the AREI as a sandy clay one. In contrast to the first substrate that was purely a soil material, the second substrate defined thereafter as soil mixture was set by replacing part of the soil compound with sand and organic matter. Sand was selected among commercial products as having a high rate of particle size close to 2 mm. The

chosen sand has coarser size than that of the sand used by AREI to improve peat substrate structure. As organic matter, cattle manure was taken from a neighbour farmer, due to its proximity. The peat used as substrate was afforded from grocery specialised in Agricultural inputs. The universal substrate (KKS-U) was chosen among available peat products in Latvia as it fits to the growth of any plant thanks to mineral and lime enrichment (Laflora SIA katalogs, 2025). According to the rate of soil in each substrate (Table 1), the studied substrates may be considered as: a full plenty soil (at 100% rate), a half soil (50%) and soilless (0%) substrate.

Table 1

Raw materials proportions displayed in the studied substrates, %

Raw materials	Soil	Soil mixture	Peat
Soil	100	55	–
Peat (commercialized)	–	–	92
Sand	–	30	8
Cattle manure	–	15	–

Two physical properties have been assessed:

- the bulk density was determined with help of the cylinder method (FAO, 2023)
- the particle size of the composition of substrate or granulometric analysis was set by sedimentation (of fine particles), using the pipette method after destruction of the organic matter and by sieving of the coarse particles (French Norm-NF X 31-107) after oven dried at 105° C during 24 hours

Compared to the usual method performed in Latvian laboratory that characterizes soil granulometry with two particles, sand and clay (Kārkliņš, 2008), the pipette method permits the determination of the proportion of silts in addition to sand and clay and proposes a stratification of the texture of each substrate into five categories according to the size of the particles: coarse sand (2000-200 μm), fine sand (200-50 μm), coarse silts (50-20 μm), silts + clay (20-2 μm) and clay (< 2 μm). Due to absence of adequate for the method to characterize fibre composition of peat at the Grain Technology and Agrochemistry Laboratory (AREI), the pipette method was performed either for soil-based or for peat substrate.

Additionally, chemical characteristics of substrates were determined at AREI, following methods and procedures admitted by the Ministry of Agriculture of Latvia (ZM, 2022):

- Soil moisture was determined by gravimetric method (LVS EN ISO 11465:2006);
- Total nitrogen: Kjeldhal method LVS EN ISO 11261:2002L;
- Total carbon: LVS ISO 10694:2006 L;
- pH was established in 1 M KCl suspension (LVS EN ISO 10390:2021);
- Exchangeable phosphorus (P_2O_5) and Exchangeable potassium (K_2O): Egnera-Rīma (DL) method, performed with Atomic Absorption Spectroscopy;
- Sodium, Exchangeable magnesium, Exchangeable sulphur (SO_4-S);

Calcium and ammonium nitrogen analyses, respectively referred 26487-85 and 26489-85 (ГОСТ, 1985a and 1985b) conformingly to the GOST standard of the ancient Soviet Union were supplemented. At last, two parameters were established after calculation:

- C/N ratio that indicates the evolution of organic matter was determined dividing the value of total Carbon (C) by the value of total nitrogen (N) from dry burn method (LVA ISO 10694:2006L)
- Cation exchange capacity (CEC), indicating capacity of the substrate to make nutrient available to plants was determined from the values of major cations from individual chemical analyses and that of the pH value using the formula 1.

$$CEC\ (mEq/100g) = Base\ cations + Acid\ cations \quad (1)$$

where Base cation = (Ca^{2+} + Mg^{2+} + K^{+} + Na^{+}) and Acid cations = 12 (7 – pH value) if pH < 7, Acid cations = 0 if pH > 7 (Culman et al., 2019).

Comparison of means has been deployed, using two sample t test in R programme (version 4.2.3**),** to highlight difference between characteristics of substrates. The p-value was assessed relatively to the respective levels 0.05, 0.01, and 0.001, from low to high significance.

Results and discussion

The sum of particle size proportions for each substrate does not equal 100%, the total rate of the analysed sample mass (Table 2). Apart from water content that remains less than 2.5% for the considered

air dried samples, respectively 2.08%, 2.29% and 0.10% for soil, soil mixture and peat, organic matter completes substrate's weight at 100 g. Thus, peat presents the highest organic matter content (SOM) with at least 25% rate of the whole peat substrate whereas soil based substrates have less than 10% of SOM. Despite a substitution of 15% of soil with cattle manure, the rate of SOM in the soil mixture is 54% of that of the initial soil.

Table 2

Particle size composition of the substrates (% of air-dried substrate sample)

Particles	Coarse sand	Fine sand	Coarse silts	Silts + Clay	Clay
Particle size	2000-200 µm	200-50 µm	50 – 20 µm	20 – 2 µm	< 2 µm
Soil	19.29	31.68	9.52	14.31	15.18
Soil mixture	47.41	20.82	4.50	10.72	9.09
Peat	19.64	34.45	0.33	11.55	8.79

Replacement of 45% of sodic gleysoil with sand and manure homogenizes the bulk density of soil mixture compared to that of the full soil. In contrast, with a bulk density that is twofold higher than that from 0-10 cm depth (p-value = 0.042), the 10-20 cm depth concentrates higher particle compounds in peat substrate (Table 3).

Table 3

Comparison of bulk density (g cm^{-3}) of three substrates, according to soil depth (cm)

Soil depth (cm)	Substrate bulk density		
	soil	soil mixture	peat
0-10	0.95 ± 0.14	1.04 ± 0.02	0.12 ± 0.01
10-20	1.01 ± 0.08	1.04 ± 0.05	0.21 ± 0.02

Results of the chemical analyses of the studied substrates have highlighted that peat present values 35% to 682% higher than those of the soil-based substrates, defining a high level of fertility (available nutrients and capacity to make them assimilated by plants) (Table 4). Compared to that in the sodic gleysol, value of total nitrogen content obtained by the Kjeldahl method is lower in the peat substrate (p-value = 0.019) but higher compared with that of the soil mixture (p-value = 0.002). The value of pH in peat substrate is lower than that of the two-soil based substrates (p-value = 6.944e-13).

Table 4

Chemical properties of the soil, soil mixture and commercialized peat

Parameters	Soil	Soil mixture	Peat
Moisture, %	26.1 ± 0.4	21.0 ± 0.1	66.4 ± 1.3
Exchangeable phosphorus, mg kg^{-1}	76.7 ± 0.5	189.3 ± 1.7	208.5 ±0.6
Exchangeable potassium, mg kg^{-1}	123.0 ± 7.1	202.5 ± 6.4	213.5 ± 7.8
pH KCl	7.1 ± 0.0	7.7 ± 0.0	6.5 ± 0.0
Sodium, mg kg^{-1}	16.0 ± 1.4	10.5 ± 0.7	22.0 ± 1.4
Calcium, mg kg^{-1}	1871.0 ± 8.5	1008.5 ± 14.8	2030.0 ± 22.6
Exchangeable magnesium, mg kg^{-1}	233.2 ±14.1	187.9 ± 4.2	253.0 ± 8.6
Sulfur, mg kg^{-1}	13.3 ± 0.0	6.9 ± 0.1	54.0 ± 0.6
Ammonium nitrogen, mg L^{-1}	3.6 ± 0.0	9.3 ± 0.1	12.8 ± 0.2
Total nitrogen, mg L^{-1}	1.8 ± 0.0	1.4 ± 0.0	1.5 ± 0.0
Total nitrogen, mg L^{-1}, in dry burn	3.4 ± 0.3	1.6 ± 0.0	3.5 ± 0.1
Total carbon, g kg^{-1}	38.7 ± 2.9	28.6 ± 0.8	201.1 ± 24.8
C/N ratio	11.5 ± 1.7	17.8 ± 0.6	57.3 ± 7.6
Cation Exchange Capacity, mEq $100g^{-1}$	11.6 ± 0.1	7.1 ± 0.1	12.8 ± 0.2

Replacement of 15% of soil with OM (cattle manure) has significantly reduced the total carbon in the soil mixture (p-value=5.009e-04). The contents of nutrients that are available to plants such as ammonium nitrogen, phosphate (P_2O_5) and potash (K_2O) are higher in the soil mixture (p-value=8.09e-05, 1.284e-04, and 0.007 respectively) due to the incorporation of cattle manure. In contrast, the total nitrogen (from dry method) is low in soil mixture (p-value=2.711e-05). However, the values of C/N

ratio suggest that the fate of nitrogen would be the same in soil-based substrates. Despite a quasi-similar value of total nitrogen in soil and in peat, more than the double of that of soil mixture, nitrogen would be made available to plant from soil-based substrates than that from peat that is getting to be immobilised as it presents a high C/N ratio.

Substituting 45% of soil by sand and cattle manure has mainly reduced the contents of sodium, calcium, magnesium and sulfur in the soil mixture. Even though no chemical analysis has been conducted on sand and cattle manure, it is obvious that sand did not provide any significant nutrient. As indicated by the technical data sheet, natural sand has been washed, dried, fractionated, and exempted of clay and silts. Particle size inferior to 63 µm was restricted at 3% of the commercialized sand and organic content excluded, limiting addition of eventual organic-based substance. As well, despite the mineral nature of elements that contribute in the calculation of the cation exchange capacity, value of the CEC is the lowest for soil mixture (p-value=2.468e-04, in comparison to soil).

Without any additional material, in contrast to the soil mixture where cattle manure has been incorporated, the sodic gley soil presents high SOM. According to AREI technical register, the field with sodic gleysol has a medium to a low fertility regarding normal value of pH, a slightly higher organic matter content than the average (2.0-2.5), and a medium available phosphate. In comparison, the soil mixture has improved available phosphate content but has decreased the CEC value despite a higher value of pH. Mixture has much more impacted on the physical properties that on the chemical characteristics of the original soil.

Part of the organic matter from peat may have not been destroyed before sedimentation phase of the pipette method, showing the limit of this attempt to determine the particle size distribution of peat. Nonetheless, after sieving throughout 200 or 50 µm of wesh, the remaining organic matter that has not been oxidized in oven may not represent a huge weight of particle as their density is low compared to that of mineral particles.

Use of commercial peat as substrate is ideal for breeding activities due to an ideal range of bulk density value that facilitates drainage (Kārkliņš, 2008) and assimilation of nutrients by plants. However, it is important to emphasize that peat is not only of organic material. Bulk density is tightly related to ash content in peat soil layers (Truba and Oleszczuk, 2014), where ash is exclusively issued from mineral particles. In particular, clay has been incorporated in KKS-U, the chosen commercialized peat (Laflora SIA katalogs, 2025).

According to Klavins et al. (2019), humic substances of a gleysol soil, as well as those of Podzol and Phaozems are not similar to those of peat in opposition to Cambisol and Histosol. This statement strengthens the relevance of the study that highlights the contrast between the characteristics of peat and gleysol soil-based substrate. Nonetheless, doubt concerning the relevance of maintaining the same methods to carry out the physical and chemical analyses of contrasted materials has arisen. Precaution has been taken to rely on the results of analyses that respond to standard accuracy at the laboratory. That is why the SOM values from laboratory analysis have been dropped out due to overestimation for the peat substrate. Thus, SOM has deliberately been deduced as the remaining percentage of substrate minus particle fraction and moisture.

Conclusion

Whereas concern about use of peat currently focuses on its impact on global change, justifying research for an alternative to it as substrate throughout innovative organic raw materials, attention is less attributed to soil to which interest is relevant for research and development in agriculture. This study has confirmed that soil-based substrates cannot compete against commercial peat in terms of fertility. However, the study has also stated that peat, as soilless substrate, is an improved material that cannot represent properties of soil in the field. Therefore, its use is not suitable for specific agronomical or forestry research in (semi-)controlled conditions that depends on soil type but is much more adapted to varietal creation or for breeding high valuable plant species (horticulture). Anyway, before using a soil-based substrate to conduct such an agronomical research, it would be necessary to assess how plants grow and develop with soil in pot during future studies.

Kopsavilkums. *Kūdras kā substrāta izmantošana augu selekcijas pētījumiem siltumnīcā ir izplatīta lauksaimniecības pētniecības institūtos, piemēram, Agroresursu un ekonomikas institūtā (AREI). Paplašinātiem pētījumiem, podu izmēģinājumu veikšanai vidē, kas līdzīgi lauka apstākļiem, var būt*

nepieciešams izmantot tīruma augsni kā substrātu. Šī pētījuma mērķis ir izcelt atšķirību starp kūdru un augsni kā podu substrātiem, salīdzinot to fizikālās un ķīmiskās īpašības podu izmēģinājumos. Tika veiktas dažādas ķīmiskās analīzes un fizikālie testi trim substrātiem: velēnu gleja augsne; augsnes maisījums (izmantojot to pašu augsni, tika pievienotas smiltis un organiskais mēslojums); rūpnieciski apstrādāta kūdra, kurai pievienota neliela daļa smilts (atbilstoši AREI praksei). Rezultāti liecina, ka substrātam, kas izgatavots no uzlabotas komercializētas kūdras, ir atšķirīgas fizikālās īpašības salīdzinājumā ar tīruma augsni – granulometrisko frakciju proporcijas un blīvums. Augsnes sajaukšana ar smiltīm un organiskajiem mēsliem lielākā mērā ietekmē substrāta fizikālās, nevis ķīmiskās īpašības, salīdzinot ar augsni no lauka. Komercializētā kūdra ir optimizēts substrāts, pateicoties iekļautajām barības vielām. Analizējot 14 parametrus, kūdrā 12 no tiem uzrādīja augstas vērtības, īpaši amonija slāpeklis, augiem viegli uzņemamais fosfors un kālijs, kā arī kopējā organiskā viela un aprēķinātā katjonu apmaiņas kapacitāte. Pētījumā gūtie rezultāti apliecina, ka kūdras kā substrāta fizikālās īpašības ir nepieciešams uzlabot, lai tā būtu piemērota laukaugu ilgstošai audzēšanai podos. Šādas pūles ir nepieciešamas arī tādēļ, lai uzlabotu augsnes izmantošanu kā substrātu. Tika secināts, ka ir jāveic izmēģinājumi ar dažādiem augsnes substrātiem, lai izvērtētu to priekšrocības un trūkumus, kā arī to piemērotību podu eksperimentiem.

Key words: *velēnu gleja augsne, komercializēta kūdra, ķīmiskās īpašības, fizikālās īpašības, auglība.*

Acknowledgement. This study has been funded as part of the AREI internal project 50-2024. I would like to thank the personnel of the Research Centre of Stende where the activities were conducted.

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