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Early changes in soil organic carbon following afforestation of former agricultural land

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Abstract: Afforestation of less productive, risky and degraded agricultural land is one of the methods which is recommended for practical agriculture to increase the carbon sequestration. In this study, we have attempted to determine the effect of afforestation of agricultural land (warm, mildly dry climatic region of the Czech Republic) on the soil organic carbon (C_{ox}) concentrations in the mineral soil. Two soil types (Haplic Chernozem and Haplic Cambisol) were afforested. Both an indirect estimation (loss-on-ignition method) as well as chromsulfuric acid mixture oxidation were used to determine the organic carbon content in the soil samples and the methods were compared. In the case of the Haplic Chernozem, the C_{ox} concentration at a depth of 0–10 cm after 1–3 years of afforestation with pedunculate oak or Scots pine significantly decreased ($P < 0.01$ and $P < 0.004$, respectively) with the stand age. Similar to the case of the Haplic Chernozem, the C_{ox} concentration in the Haplic Cambisol also significantly decreased in the variants with Scots pine ($P < 0.003$) or a mixture of forest tree species ($P < 0.006$); no significant ($P > 0.05$) decrease was found in the case of a mixture of forest tree species on the Haplic Chernozem or with Douglas fir on the Haplic Cambisol. Significantly higher ($P < 0.05$) C_{ox} concentrations were typically found in the case of 1-year-old stands compared to 2-year-old or 3-year-old stands. A higher C_{ox} loss than the quantity of residues returned to the soils may be the reason the soil C_{ox} concentration significantly ($P < 0.00001$ and $P < 0.000001$) decreased for the control agricultural plots (Haplic Chernozem and Haplic Cambisol). The carbon stock in the upper 10 cm of the 5-year-old stands was higher on the Haplic Chernozem and lower on the Haplic Cambisol compared to the control agricultural plots.

Keywords: alginite; forest tree species; loss-on-ignition method; wheat

In general, the total area of forest land in the Czech Republic has been increasing. This is partly because of the afforestation of new land, which exceeds the extent of transformation of forest land for other purposes. It is also because of the improvements as to the precision of data from the Land Register (MZe 2015, 2017, 2018). From the beginning of the 1990 s, the post-communist transformation of agriculture in the Czech Republic led to the increased afforestation of non-forest land (Špulák & Kacálek 2011; Vopravil et al. 2015). Subsidies were probably one of the main reasons why 3 753 ha of agricultural land were afforested in 1994–2001 and 1 200 ha in the year 2002 (Poleno et al. 2011; Vopravil et al. 2017).

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The subsidies for afforestation were provided only from national sources until 2003 (MZe 2013). Since 2004, this afforestation has been mainly supported from the European sources, that is, the Horizontal Rural Development Plan of the Czech Republic (2004–2006), and the Rural Development Programme of the Czech Republic (2007–2013 and 2014–2020). The forest land area increased in year-on-year terms by 1842, 2645, 1458 and 1809 ha in the years 2013, 2014, 2016 and 2017, respectively (MZe 2014, 2015, 2017, 2018).

There are many methods which are recommended for practical agriculture to increase the carbon sequestration (e.g., Středa et al. 2008; Williams et al. 2018). Afforestation of less productive, risky and degraded agricultural land is one of these methods. Forests have a high C storage capacity; wood can substitute fossil fuels and wood products can be stored for a long period. For example, 100 m^3 of wood contains 18.5 t C and which requires 68.5 t CO_2 to produce it (Poleno et al. 2011). Smith (2004) stated, in his review, the high potential of European croplands to sequester carbon. Moreover, Chan (2008) stated that many Australian soils have the potential for carbon sequestration. Chen et al. (2020) mentioned that different climatic zones and the age of afforestation represented the dominant factors influencing carbon sequestration.

Post-afforestation changes include the formation of a forest floor layer which may be influenced, for example, by the altitude (Vesterdal et al. 2002; Cukor et al. 2017a). Afforestation may be accompanied by acidification which may be influenced by the forest tree species, redistribution of the soil organic carbon, labile organic carbon fraction, changes in the soil properties (physical, chemical and biological) depending on the soil type (e.g., Ens et al. 2013; Holubík et al. 2014; Lara-Gómez et al. 2020; Nikodemus et al. 2020; Xu et al. 2020; Zhang et al. 2020). The effect of afforestation of agricultural land on the organic carbon in mineral soil may also be altered by the slope gradient (Hou et al. 2020). Following agricultural land afforestation, the characteristics of the plough layer may persist for a long period of time (Vopravil et al. 2014); however, soil properties may change with the age of the stands (Ritter 2007; Holubík et al. 2014; Dłuzewski et al. 2019). Ens et al. (2013), Vopravil et al. (2014) and Rytter and Rytter (2020) found that the afforestation of agricultural land influenced different mineral soil properties (e.g., soil organic matter and its quality, water stable aggregates, saturated hydraulic conductivity and mean weight diameter) 3–10 years after the afforestation; such an effect may vary for different soil depths (Ens et al. 2013; Vopravil et al. 2014; Rytter & Rytter 2020). In the case of 20–60 years after the afforestation, some mineral soil properties (e.g., bulk density and porosity, stability of the soil structure, total soil carbon concentration and labile organic carbon fraction, pH_{KCl}, concentrations of the macronutrients) were influenced (Holubík et al. 2014; Vopravil et al. 2014; Dłuzewski et al. 2019; Nikodemus et al. 2020; Zhang et al. 2020).

In this study, we have attempted to determine the effect of afforestation of agricultural land on the soil organic carbon (C_{ox}) concentrations in a mineral soil. We hypothesised an initial loss of the soil organic carbon at a depth of 0–10 cm after the afforestation because the experimental plots tend to be disturbed. The carbon content in a mineral soil after afforestation of agricultural soils may depend on the forest tree species (e.g., Zhang et al. 2020); however, no significant effect has been observed in different studies (e.g., Vesterdal et al. 2002; Rytter & Rytter 2020). In this study, we investigated the effect of various coniferous and deciduous forest tree species on the C_{ox} concentrations at a depth of 0–10 cm. Furthermore, the application of alginite (an organic rock originating from a fossilised algal biomass) can partially mitigate any possible moisture deficiency and enhance the water uptake in the root area of the seedlings (Gömöryová et al. 2009; Cukor et al. 2017b). Thus, we tested the effect of an alginite application (0.5 and 1.5 kg per planting point) on the carbon stock in the upper 10 cm of the mineral soil, which was assessed 5 years after the afforestation of the agricultural land.

MATERIAL AND METHODS

The used experimental plots were established near the village of Hovorčovice, north of Prague in the Czech Republic (Prague-East District) on a Haplic Chernozem and Haplic Cambisol (IUSS Working Group WRB 2015). This area is characterised by a mean annual air temperature of 8–9 °C and by a mean annual precipitation of 500–600 mm. The afforestation of the agricultural land was performed on two soil types (Haplic Chernozem and Haplic Cambisol). In May 2013, three squares 20 × 20 m were afforested with pedunculate oak (*Quercus robur* L.), Scots pine (*Pinus sylvestris* L.) or a mixture of pedunculate oak, red oak (*Quercus rubra* L.) and

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Norway maple (*Acer platanoides* L.) on the Haplic Chernozem. In the case of the Haplic Cambisol, Douglas fir (*Pseudotsuga menziesii* (Mirb.) Franco), Scots pine and the mentioned mixture (pedunculate oak, red oak and Norway maple) were used. In the case of the mixture, two rows of each of the forest tree species took turns. Except for the above-mentioned variants, the same variants with an application of 0.5 and 1.5 kg of alginite per planting point were established. On each of the soils, the control agricultural plots were established. In the case of the Haplic Cambisol, the cultivation of winter wheat (190 kg N/ha), white mustard (80 kg N/ha), winter wheat (190 kg N/ha) was realised in 2013–2015. In the case of the Haplic Chernozem, winter wheat (190 kg N per ha), white mustard (80 kg N/ha) and creeping red fescue (100 kg N/ha) were cultivated; the collection and transportation of straw were realised. P_2O_5 and $MgSO_4$ were applied at rates of 50 and 100 kg/ha on the control agricultural plots (Haplic Cambisol and Haplic Chernozem).

The C_{ox} concentrations in the mixed soil samples taken during 2014–2016 from a depth of 0–10 cm (three mixed samples per afforested square or control agricultural plot per year) were evaluated in this study. Jensen et al. (2018) reported that current (and historical) studies have often used an indirect estimation (loss-on-ignition method) to determine the organic carbon content in agricultural and forest soils. The loss-on-ignition is converted to soil organic carbon by a fixed conversion factor or by regression analyses (Konen et al. 2002). In this study, the C_{ox} concentration in the samples was estimated through the loss-on-ignition method and the subsequent recalculation (Westman et al. 2006). The use of the loss-on-ignition method is generally accompanied by the over- or underestimation of the soil organic carbon content due to reasons, for example, such as structural water losses from clay minerals or the decomposition of carbonates (e.g., Donkin 1991; Sutherland 1998; Wright et al. 2008; Sun et al. 2010; Hoogsteen et al. 2015, 2018; Jensen et al. 2018). Thus, the C_{ox} concentration was measured according to ISO 14235:1998, and the methods were compared (Table 1). In June 2018, soil samples from each of the variants were taken from a depth of 0–10 cm to determine the C_{ox} concentrations and percent of the coarse fragments (> 2 mm). For the calculation of the C_{ox} stock (t/ha), according to Zhi et al. (2014), the bulk density was also determined. Undisturbed soil samples were taken using a Kopecky cylinder core with a volume of 100 cm^3. After drying at 105 °C to a constant weight, the undisturbed soil samples were weighed. The values of the bulk density were calculated as the dry weight/volume. In the case of all the soils used in our experiment, the soil class according to Novak's classification was a sandy loam (Dumbrovský et al. 2019). The class according to the U.S. Department of Agriculture textural classification (Soil Science Division Staff 2017) was a loam (Haplic Chernozem) or a sandy loam (Haplic Cambisol).

The differences in the values of the C_{ox} were submitted by testing using a one-way analysis of variance (ANOVA) and Tukey's HSD test. The values of the C_{ox} concentration on each of the afforested squares (and the control agricultural land) were also evaluated by linear regression. All the statistical analyses were performed with STATISTICA Cz, Ver. 10 software (StatSoft, Inc., 2011).

RESULTS AND DISCUSSION

The relationship between the C_{ox} concentration measured according to ISO 14235:1998 and that estimated from the loss-on-ignition is shown in Table 1, and it varies for the two soil types (Haplic Chernozem and Haplic Cambisol). For example, Sun et al. (2010) stated that the loss-on-ignition caused a structural water loss in a range 0.56–2.45% when testing different soil samples. The differences observed between the soils in our study likely reflect the differences in the structural water loss and the decomposition of the carbonates (Sutherland 1998; Wright et al. 2008; Sun et al. 2010; Jensen et al. 2018).

The C_{ox} concentration in the Haplic Chernozem at a depth of 0–10 cm after 1–3 years of afforestation of the former agricultural land through pedunculate oak

Table 1. The relationship between the concentration of the soil organic carbon (C_{ox}) measured according to ISO 14235:1998 and the concentration of the C_{ox} estimated from the loss-on-ignition

Soil type	Equations
Haplic Chernozem	C_{ox} (%) = 0.4608 C_{ox} from the loss-on-ignition + 1.0557; R^2 = 0.93
Haplic Cambisol	C_{ox} (%) = 0.1969 C_{ox} from the loss-on-ignition + 1.3359; R^2 = 0.51

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Table 2. The relationship between the soil organic carbon (C_{ox}) concentration and the stand age (1–3 years) on the Haplic Chernozem

Forest tree species or control agriculturally used land	Equations
Pedunculate oak	C_{ox} (%) = 3.58 – 0.43 age; $P < 0.01$, $R^2 = 0.58$
Scots pine	C_{ox} (%) = 3.62 – 0.49 age; $P < 0.004$, $R^2 = 0.67$
Mixture	C_{ox} (%) = 3.32 – 0.35 age; $P < 0.10$, $R^2 = 0.24$
Arable land	C_{ox} (%) = 3.33 – 0.42 age; $P < 0.00001$, $R^2 = 0.71$

or Scots pine significantly decreased ($P < 0.01$ and $P < 0.004$, respectively) with the stand age (Table 2); however, a similar relationship was also observed for the mixture of forest tree species ($P < 0.10$). In the upper 10 cm of the mineral soil, the C_{ox} concentration significantly decreased also ($P < 0.00001$) for the control agricultural plot (Table 2). In the case of afforestation by pedunculate oak or Scots pine, a one-way ANOVA and Tukey's HSD test showed significantly ($P < 0.05$) higher C_{ox} concentrations one year after the afforestation when compared to 2–3 years after the afforestation (Figure 1–2). Moreover, the C_{ox} concentration in the variant with the mixture of forest tree species was significantly ($P < 0.05$) higher one year after the afforestation when compared to the values measured two, but not three years after the afforestation (Figure 3). Similar to the afforestation by the pedunculate oak or Scots pine on the Haplic Chernozem, the one-way ANOVA and Tukey's HSD test showed significantly ($P < 0.05$) higher C_{ox} concentrations for the control agricultural plot one year after the afforestation compared to the concentrations obtained 2–3 years after the afforestation (Figure 4).

In the case of the Haplic Cambisol, the C_{ox} concentration at a depth of 0–10 cm significantly decreased

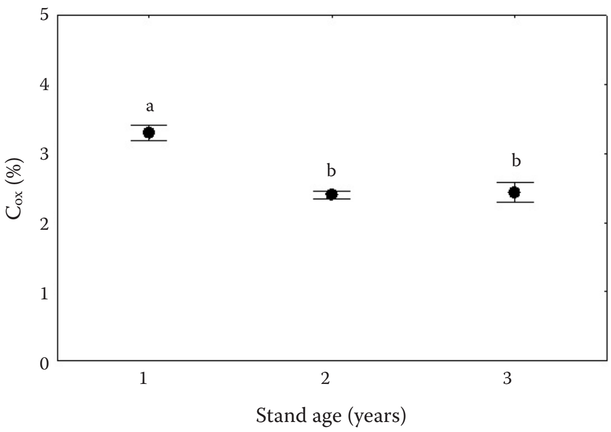

Figure 1. The soil organic carbon (C_{ox}) concentration at a depth of 0–10 cm after 1–3 years of afforestation with the pedunculate oak on the Haplic Chernozem (mean ± standard error); the different indices mark significant ($P < 0.05$) differences

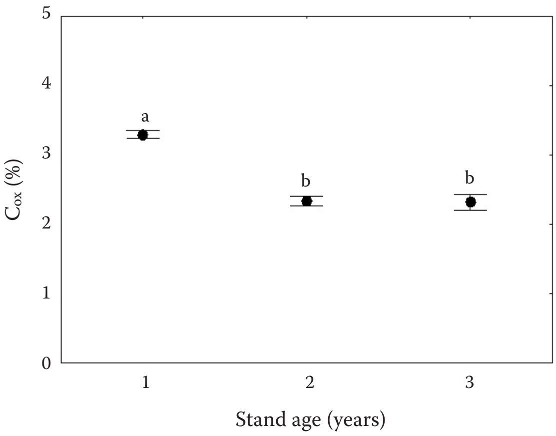

Figure 2. The soil organic carbon (C_{ox}) concentrations at a depth of 0–10 cm after 1–3 years of afforestation with the Scots pine on the Haplic Chernozem (mean ± standard error); the different indices mark significant ($P < 0.05$) differences

Table 3. The relationship between the soil organic carbon (C_{ox}) concentration and the stand age (1–3 years) on the Haplic Cambisol

Forest tree species or control agriculturally used land	Equations
Douglas fir	C_{ox} (%) = 2.41 – 0.25 age; $P < 0.09$, $R^2 = 0.26$
Scots pine	C_{ox} (%) = 2.64 – 0.41 age; $P < 0.003$, $R^2 = 0.71$
Mixture	C_{ox} (%) = 2.61 – 0.45 age; $P < 0.006$, $R^2 = 0.64$
Arable land	C_{ox} (%) = 2.72 – 0.42 age; $P < 0.000001$, $R^2 = 0.61$

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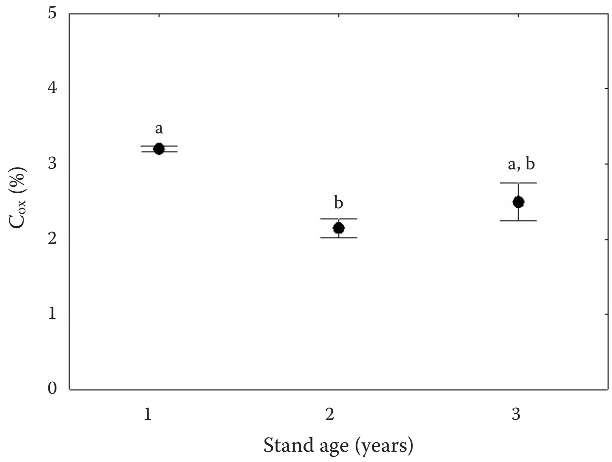

Figure 3. The soil organic carbon (C_{ox}) concentration at a depth of 0–10 cm after 1–3 years of afforestation with the mixture of the forest tree species on the Haplic Chernozem (mean ± standard error); the different indices mark significant ($P < 0.05$) differences

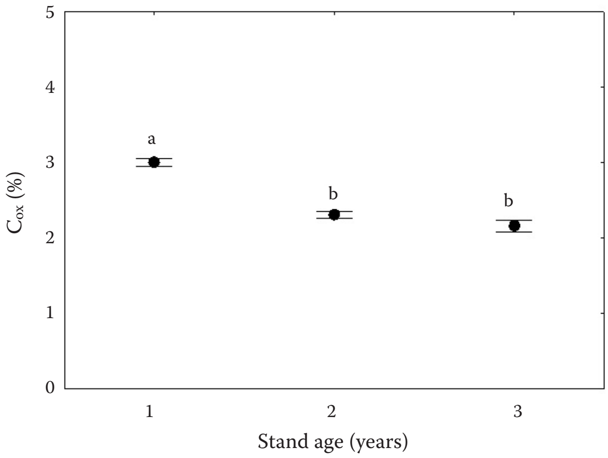

Figure 4. The soil organic carbon (C_{ox}) concentration for the control agricultural plot on the Haplic Chernozem (mean ± standard error); the different indices mark significant ($P < 0.05$) differences

with the stand age in the variants with the Scots pine and the mixture of forest tree species ($P < 0.003$ and $P < 0.006$, respectively, Table 3). The C_{ox} concentration tended to decrease ($P < 0.09$) also in the case of the Douglas fir. Similar to the case of the Haplic Chernozem, the C_{ox} concentration in the Haplic Cambisol also significantly decreased ($P < 0.000001$) for the control agricultural plot (Table 3). For the Haplic Cambisol, the C_{ox} concentrations were significantly higher ($P < 0.05$) after one year when compared to 2–3 years after the afforestation in the case of Scots pine and the mixture of the forest tree species (Figure 6–7). The ANOVA showed no significant differences ($P > 0.05$) between the C_{ox} concentrations of the 1-year-old, 2-year-old and 3-year-old Douglas firs (Figure 5). Similar to the afforestation by the Scots pine or the mixture of the forest tree species, the one-way ANOVA and Tukey's HSD test showed significantly higher ($P < 0.05$) C_{ox} concentrations for the control agricultural plot one year after the af-

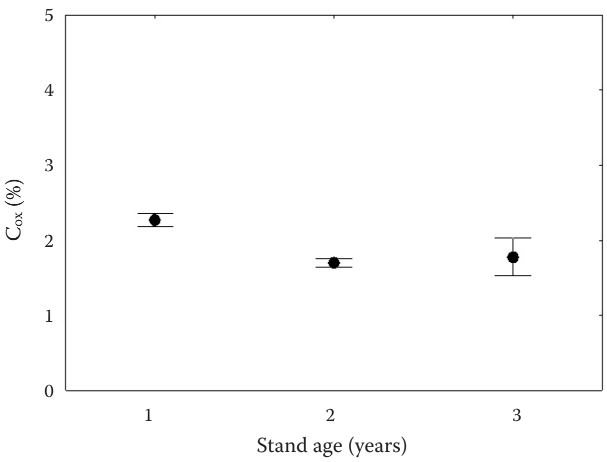

Figure 5. The soil organic carbon (C_{ox}) concentration at a depth of 0–10 cm after 1–3 years of afforestation with the Douglas fir on the Haplic Cambisol (mean ± standard error); no significant ($P > 0.05$) differences between the years were found

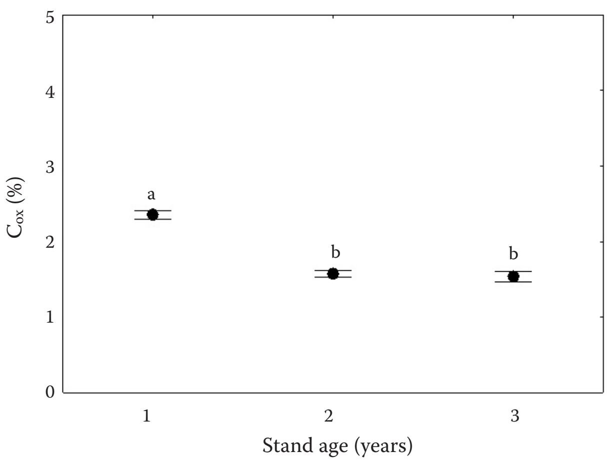

Figure 6. The soil organic carbon (C_{ox}) concentration at a depth of 0–10 cm after 1–3 years of afforestation with the Scots pine on the Haplic Cambisol (mean ± standard error); the different indices mark significant ($P < 0.05$) differences

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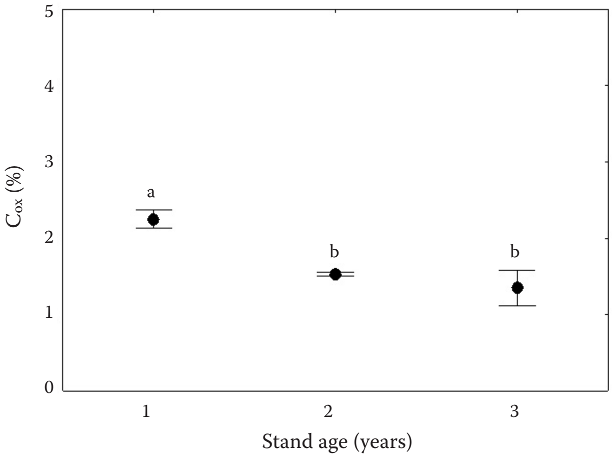

Figure 7. The soil organic carbon (C_{ox}) concentration at a depth of 0–10 cm after 1–3 years of afforestation with the mixture of the forest tree species (mean ± standard error); the different indices mark significant ($P < 0.05$) differences

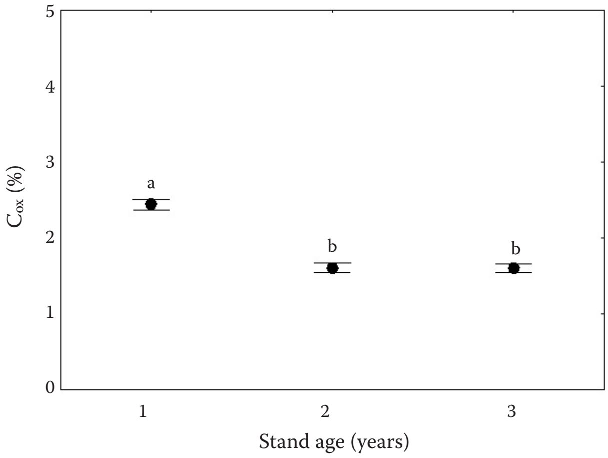

Figure 8. The soil organic carbon (C_{ox}) concentration for the control agricultural plot on the Haplic Cambisol (mean ± standard error); the different indices mark significant ($P < 0.05$) differences

forestation compared to the concentrations obtained 2–3 years after the afforestation (Figure 8).

All the 1-year-old, 2-year-old and 3-year-old variants were compared. In the case of the Haplic Chernozem, the C_{ox} concentrations in the variants with 1-year-old pedunculate oak and Scots pine were significantly different ($P < 0.05$) when compared to the control agricultural plot (Table 4). No significant differences ($P > 0.05$) were obtained in the case of the 2-year-old and 3-year-old variants on the Haplic Chernozem or any variants on the Haplic Cambisol.

In the case of the 5-year-old stands, the carbon stock in the upper 10 cm layer was higher in the afforested variants (16.5–20.9 t/ha) compared to the control agricultural plot (12.3 t/ha, Table 5). The carbon stock was lower in the variants with the alginite (0.5 or 1.5 kg per planting point) compared to the variants without the alginite on the Haplic Chernozem (Table 5). The only exception was the variant with the mixture of the forest tree species plus 1.5 kg of alginite per planting point (Table 5). In the case of the Haplic Cambisol, the carbon stock in the upper 10 cm layer was higher in the control agricultural plot compared to the afforested variants (Table 6). Concerning the use of alginite, the carbon stock was higher in all the variants with the alginite compared to those without the alginite (Table 6).

Thus, our hypothesis on the initial loss of the soil organic carbon at a depth of 0–10 cm was confirmed

Table 4. Significant ($P < 0.05$) differences (marked by different indices) between the variants on the Haplic Chernozem calculated separately for the 1-year-old, 2-year-old and 3-year-old stands

Stand age (years)	Pedunculate oak	Scots pine	Mixture	Arable land
1	a	a	ab	b
2	a	a	a	a
3	a	a	a	a

Table 5. The effect of alginite on carbon stock (t/ha) in the upper 10 cm of the 5-year-old stands on the Haplic Chernozem

Alginite (kg)	Pedunculate oak	Scots pine	Mixture	Arable land
0	20.9	16.5	18.8	12.3
0.5	13.2	15.4	14.8	nd
1.5	18.2	13.5	19.1	nd

nd – not determined

Table 6. The effect of alginite on the carbon stock (t/ha) in the upper 10 cm of the 5-year-old stands on the Haplic Cambisol

Alginite (kg)	Pedunculate oak	Scots pine	Mixture	Arable land
0	5.7	6.5	2.6	9.5
0.5	14.4	6.6	10.2	nd
1.5	19.1	13.8	4.5	nd

nd – not determined

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in this study. Ens et al. (2013) verified that the total soil carbon at a depth of 20 cm decreased three years after the afforestation of sites with different histories (cereal crops, vegetables, pasture, turf grass, managed forests, etc.), but found that this initial loss of carbon after the afforestation is a reversible event associated with the disturbance of the soil and vegetation. Vesterdal et al. (2002) observed significantly increasing concentrations of the total carbon in the upper 5 cm of the mineral soil 1–29 years after the afforestation of agricultural land with Norway spruce or pedunculate oak. However, the total carbon concentration decreased in the 5–15 cm layer, but more so the 15–25 cm layer. Moreover, Hou et al. (2020) stated that the soil organic carbon stock at a depth of 0–20 cm significantly decreased after the afforestation of gentle slopes (a gradient < 10%), and significantly increased after the afforestation of slopes with a gradient > 30%. Rytter and Rytter (2020) found that the soil organic carbon pool at a depth of 0–30 cm increased, decreased, or was unchanged 8–9 years after the afforestation of agricultural land in a boreal and temperate climate. Vopravil et al. (2014) reported a higher soil organic matter content 7–10 years after the afforestation of agricultural land compared to the pastures situated near the afforested sites, and altered the quality of the soil organic matter (ratio of humic to fulvic acids). The improved soil organic matter quality possibly contributed to the improved soil aggregation. Except for the afforested stands, we found that the C_{ox} concentrations decreased for the control and intensively-used agricultural plots fertilised with different doses of nitrogen. The loss of C_{ox} at a depth of 0–10 cm appeared to be higher than the quantity of residue returned to the soil, as reported by many authors (e.g., Prudnikova & Savin 2015; Lamptey et al. 2018).

Furthermore, as reported by Vesterdal et al. (2002) and Rytter and Rytter (2020) for different forest tree species (coniferous and deciduous), and contrary to the results of other studies (e.g., Zhang et al. 2020), we did not observe any significant effects of the used forest tree species on the C_{ox} concentrations at a depth of 0–10 cm. Herein, the lack of significant differences between the used forest tree species may be due to the ground vegetation and litter on the top layer of the mineral soil which was derived from the ground vegetation (Rytter & Rytter 2020). Zhang et al. (2020) also reported that the nitrogen availability, in the case of N_2-fixing forests, could lead to an increased content of organic carbon in the studied mineral soil. Ground vegetation litter inputs may directly influence (increase) the labile soil organic carbon fraction (Xu et al. 2020; Zhang et al. 2020), which is a sensitive indicator of the quality of soil organic matter (Hamkalo & Bedernichek 2014). Xu et al. (2020) reported that the characteristics of the ground vegetation (e.g., biomass) after the afforestation of agricultural land varied with the stand age. Furthermore, the amount of litter tended to increase with the stand age (e.g., Vesterdal et al. 2002; Cukor et al. 2017a). Holubík et al. (2014) also noted no significant effect of the different forest tree species 40–60 years after the afforestation of agricultural land. Moreover, after 30–40 years of agricultural land afforestation, Vopravil et al. (2014) observed the greatest positive effect on the physical soil properties (bulk density, porosity, and water stable aggregates) for Norway spruce, and the least positive effect in the case of Douglas fir.

Significant differences ($P < 0.05$) between the soil types (Haplic Chernozem and Haplic Cambisol) which were calculated in the case of variants with the Scots pine and the mixture of the forest tree species (and the control agricultural land) may be due to the different initial soil properties. For example, Nikodemus et al. (2020) found the effect of the soil type on the total carbon at two depths (0–10 and 11–20 cm) 20–25 years after the natural afforestation of agricultural land with the grey alder [*Alnus incana* (L.) Moench]. Cukor et al. (2017b) reported a rather negative effect of alginite on the mortality of different tree seedlings, and a positive effect on the increase in the seedling height. They concluded that this may be due to slow root growth through the fertiliser.

Gömöryová et al. (2009) obtained close correlations of the total alginite dosage (mixed with the soil) with the gravimetric soil moisture. Furthermore, the authors also observed that the alginite's effects on the soil microbial activities may vary for soils of varying textures. Alginite contains clay minerals and organic matter with high cation-exchange capacities and macronutrients (Cukor et al. 2017b); therefore, its application to the Haplic Cambisol was found to be effective in improving the C_{ox} stock compared to the more fertile Haplic Chernozem.

CONCLUSIONS

In conclusion, the C_{ox} concentration at a depth of 0–10 cm after 1–3 years of afforestation with pedunculate oak or Scots pine significantly decreased ($P < 0.01$ and $P < 0.004$, respectively) with the stand age (Haplic Chernozem); the C_{ox} concentration in the Haplic Cambisol also significantly decreased in the variants with the Scots pine ($P < 0.003$) or the alginate's mixture of the forest tree species ($P < 0.006$). No significant ($P > 0.05$) decrease was found in the case of the mixture of the forest tree species on the Haplic Chernozem or the Douglas fir on the Haplic Cambisol. Significantly higher ($P < 0.05$) C_{ox} concentrations were typically found in the case of the 1-year-old stands compared to the 2-year-old or 3-year-old stands. The lack of significant differences between the used forest tree species may be due to the ground vegetation and litter on the top layer of the mineral soil which was derived from the ground vegetation. Higher C_{ox} loss than the quantity of residue returned to the soils may be the reason the soil C_{ox} concentration significantly ($P < 0.00001$ and $P < 0.000001$) decreased for the control agricultural plots on the Haplic Chernozem and Haplic Cambisol. The carbon stock in the upper 10 cm of 5-year-old stands was higher on the Haplic Chernozem and lower on the Haplic Cambisol compared to the control agricultural plots. In the variants with the alginite (0.5 or 1.5 kg per planting point), the carbon stock in the upper 10 cm decreased on the Haplic Chernozem and increased on the Haplic Cambisol. For the next development, it is necessary to obtain more research findings from sites with different previous use (different types of crops, etc.) and from different climatic regions.

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