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TEMPERATURE EFFECTS ON THE ASH COLOUR OF FOREST LITTER

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Abstract. Research was carried out to identify the influence of temperature (150, 250, 350, 450, 550ºC) on the ash colour of *Acer platanoides* L. leaf litter and *Pinus sylvestris* L. needle litter samples collected from deciduous coniferous mixed forest in Lithuania (54º43‘ N 25º19‘ E) in April 2010. To achieve the objective, a laboratory experiment was conducted to determine ash samples using the Munsell Colour Chart. The analysis of colours has demonstrated that considering all litter samples, an increase in the temperature of litter heating was found to increase ash colour values ($r = 0.92$; $p = 0.01$). All the samples ($n = 50$) of both litter species were divided into categories 2.5Y (5 samples), 7.5YR (10 samples) and 10YR (35 samples). The total black Munsell colour was observed at a temperature of 350ºC for both litter species. Needle ash started turning bright at a temperature of 550ºC while the complete consumption of leaf litter was visible at a temperature of 450ºC. We conclude that the Munsell Colour Chart used for predicting the colour of ash is an informative feature to have the primary classification of ash. It is imperative to analyse the colour of the litter ash of the selected tree species in order to quickly and easily assess and predict their possible impact on the surrounding environment.

Keywords: *Acer platanoides* L., *Pinus sylvestris* L., temperature, colour, litter.

Introduction

Forest fires destroy organic matter, especially litter and debris falling on the forest floor (Odiwe, Muoghalu 2003). The highest soil heating during fire occurs in the uppermost layer of soil (Terefe *et al.* 2008). An increase in soil temperature caused by fire is short-lived, but changes induced in the colour properties by fire are more or less permanent (Terefe *et al.* 2005).

A colour is the most cited attribute used for soil classification and land use decisions made by people around the world (O'Donnell *et al.* 2010). It serves as informative cues for the surrounding environment (Ekici *et al.* 2006; Baltrėnas *et al.* 2007) and is an important primary feature used for the identification, characterization, description and classification of soils (Mattikalli 1997). Soil colour is measured applying different methods; however, the Munsell notation system is the most widely used one for colour naming studies (Buchsbaum, Bloch 2002; Hytonen, Wall 2006; Mouazen *et al.* 2007).

The Munsell collection includes a wide range of lightness and saturation (value and chroma in the Munsell notation) (Buchsbaum, Bloch 2002). Munsell colour measurements consist of three variables: hue, lightness (value) and chroma (HVC) (Rossel *et al.* 2006). The hue notation in the attribute of colour perception is denoted by purple, red, yellow, blue and green (P, R, Y, B and G) and include intermediates such as red-yellow, purple-red, etc. Chroma is the degree of difference from a neutral colour and ranges from 0 (drabbest or dullest) to 8 (most vivid). Value represents lightness that ranges from 0 (black) to 10 (white) (Wells *et al.* 2002; Hytonen, Wall 2006). The colour lightness of ash can indicate the combustion of the organic matter (Goforth *et al.* 2005). According to Dudley (1975), value and chroma were found in the majority of soils to increase ashing. Munsell colour depends on many factors, including light, conditions of the sample and the skills of the person making the match (Singh *et al.* 2004; Baltrėnas, Morkūnienė 2006). The hue of the soil colour depends on the presence of iron oxides that are significantly affected at different temperatures reached during heating (Terefe *et al.* 2008). Generally, the colour of soil is determined by the amount and state of iron and/or organic matter it contains (Singh *et al.* 2004).

The ashes produced by different heating temperatures change their colour. Brightness has been indicated as a result of heating temperature and time (Cakicier *et al.* 2011). According to Ragland and Aerts 1991, wood ashes are brown because of the onset of pyrolysis and shrinkage at a temperature of 250ºC and turn black at a temperature above 300ºC. Moderate intensity fire (300–400ºC) produces black ashes because vegetation is not totally destroyed but high intensity fire (~500ºC) produces light gray or white ashes (Iglesias *et al.* 1997) composed of alkaline oxides (Ca, K, Mg oxides). Ca, K, Mg are the most abundant in white ashes produced from combusted leaf litter (Goforth *et al.* 2005).

The objective of this study was to identify changes in the needles of *Pinus sylvestris* L. and variations in the colour of *Acer platanoides* L. leaf litter exposed to heating at temperatures of 150, 250, 350, 450 and 550ºC under controlled laboratory conditions in order to know the contribution of temperature to dynamic of forest litter properties.

Materials and Methods

The study site is located in a transitional deciduous coniferous mixed forest (Ahti *et al.* 1968) near Vilnius city, Lithuania (54º43‘N 25º19‘E (Fig. 2)). The concerned area belongs to a very sensitive soil group found in Lithuania (Karazija 2008). Soil pH ranges between 5.0 and 5.5. The mean annual temperature is 5.4ºC while the mean temperature in April ranges between 5.6 and 7.1ºC. Mean annual precipitation in April is 40 mm, whereas mean precipitation in April 2010 was 20 mm.

Pinus sylvestris L., *Acer platanoides* L. and smaller proportions of *Populus tremula* L. and *Picea abies* L were dominated in the site. The samples (3 kg) of *Pinus sylvestris* L. needle litter and *Acer platanoides* L. leaf litter were collected within the area of approximately 15 m² during the spring in April 2010.

The collected litter was separated from the materials of other species (mosses, twigs, etc.), cleaned with deionized water and later dried at room temperature (~18ºC) for 24 hours. Sample batches of needle (n = 25) and leaf litter (n = 25) were placed in porcelain crucibles heated in a muffle furnace at temperatures of 150, 250, 350, 450 and 550ºC for 2 hours. In order to obtain homogenous samples, ash after heating was pulverized using Frich Pulverizate 23 to make the samples homogenous (Gray, Dighton 2006; Úbeda *et al.* 2009). The colour of the homogenized ash samples was determined using the Munsell Colour Book. The sample of the page in the Munsell Colour Book is presented in Figure 1. The measurement of colours was repeated twice (Mouazen *et al.* 2007) and done by the same person under the same lightning conditions (Bodi *et al.* 2011).

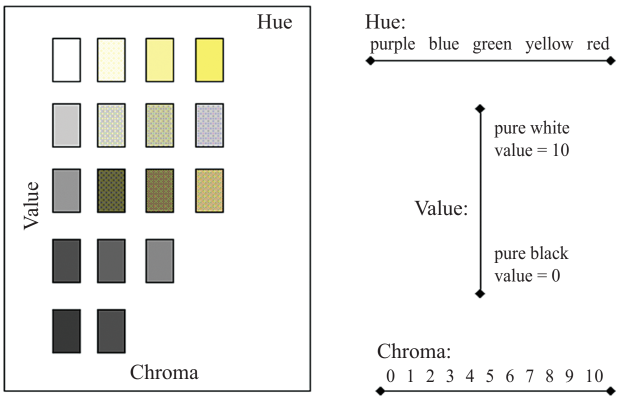


Fig. 1. Page sample in the Munsell Colour Book

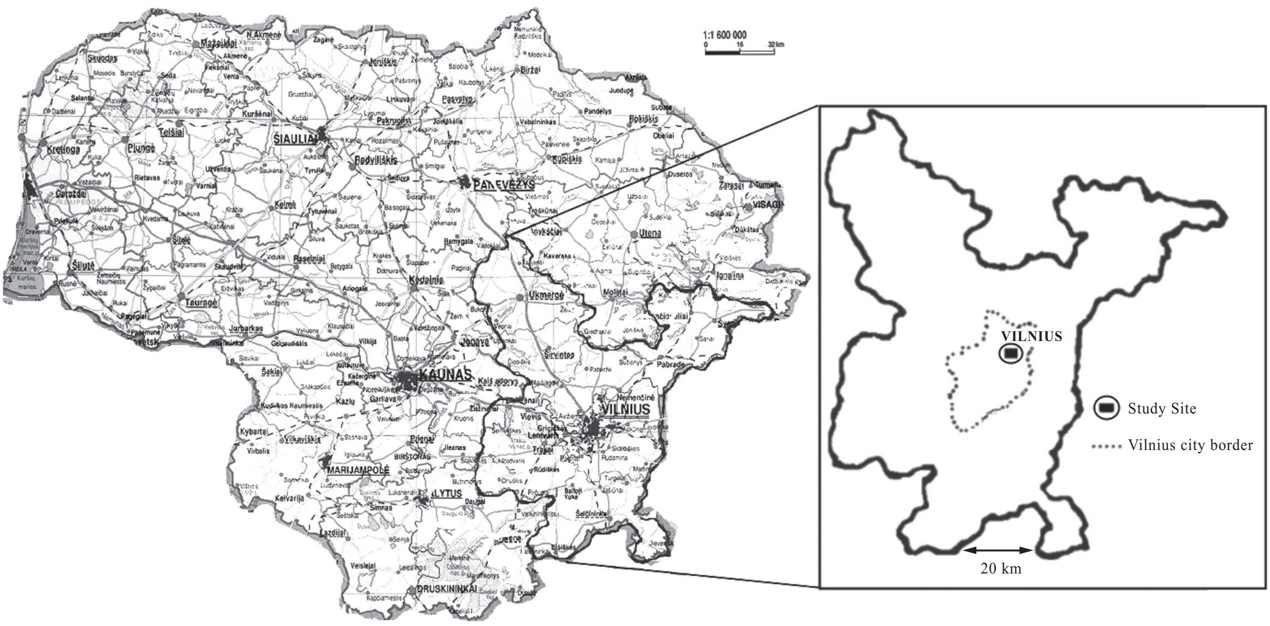


Fig. 2. A map of the study site showing its location within Lithuania

Results and Discussion

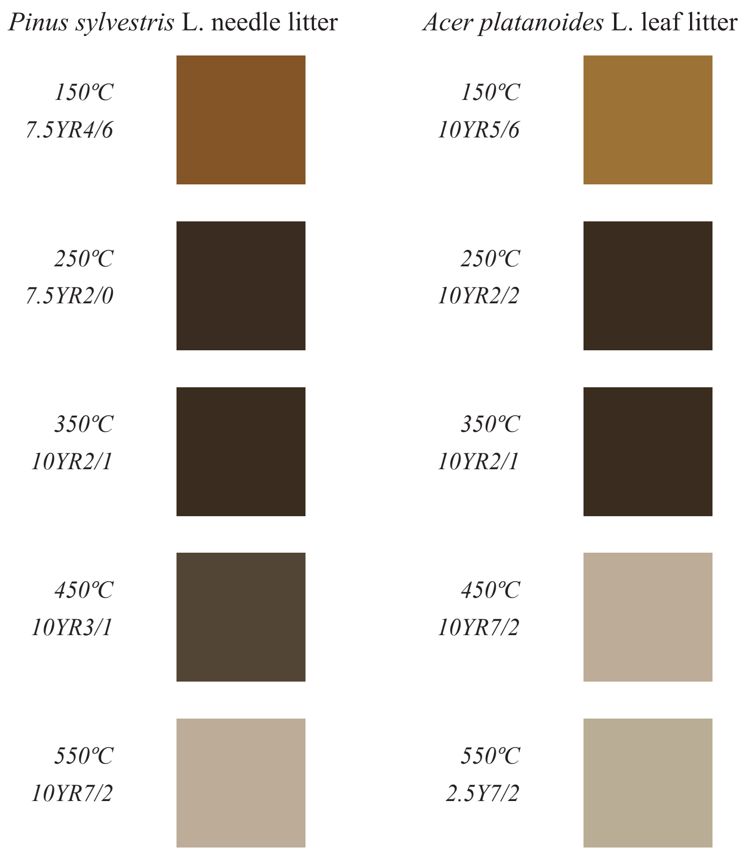
Ash colour can be used as an indicator of fire severity, and depending on the consumption of the organic matter, can range from producing black to producing white ash (complete ashing) (Neary *et al*. 1999; Bodi *et al.* 2011). The colour lightness of the chart and ash combustion residues is a qualitative parameter describing the conditions of post-fire and has a strong correlation with the completeness of combustion, fire duration and intensity (Roy *et al.* 2009). Table 1 presents the results of our study developed on the basis of Munsell Colour Charts.

It can be observed that each temperature created a certain colour range of ash. The determined colour parameters showed that ash colour changed along with temperature gradient in litter samples. Ash samples were found to belong to three hue groups – 2.5Y (5 samples), 7.5YR (10 samples) and 10YR (35 samples). These groups can be classified into colour classes, including brown, brownish black, black, dull yellow orange for *Pinus sylvestris* L needle litter and yellowish, brownish black, black, dull yellow orange, grayish yellow for *Acer platanoides* L. leaf litter (Table 1).

Table 1. Colour parameters with temperature gradient in *Pinus sylvestris* L. needle litter and *Acer platanoides* L. leaf litter (n = 5)

Temperature (ºC)	Colour*
Pinus sylvestris L. needle litter	
150	7.5YR4/6
250	7.5YR2/0
350	10YR2/1
450	10YR3/1
550	10YR7/2
Acer platanoides L. leaf litter	
150	10YR5/6
250	10YR2/2
350	10YR2/1
450	10YR7/2
550	2.5Y7/2

* Colour according to Munsell (Chroma Value)



Heating at a temperature of 150ºC caused the loss of water content from the leaves and needles (Úbeda *et al.* 2009). Litter ashes heated to temperatures from 150 to 250ºC had brown (*Pinus sylvestris* L.) or yellowish (*Acer platanoides* L.) colour which could be caused by iron oxides depending on the oxidation site of iron. The oxidation of iron minerals occur at a temperature lower than 300ºC (Úbeda *et al.* 2009).

According to Raclavska *et al.* (2009), iron (oxidation state 3+) can be brown, red or yellow. Furthermore, Yufen *et al.* (2005), Terefe *et al.* (2008) have proposed that the colour of ash is controlled by iron oxides with a distinct grade of hydration and the content of unburned carbon (Raclavska *et al.* 2009; Zaeni *et al.* 2010). Also, biological components are most susceptible to heating and altered at temperatures between 100ºC and 150ºC (Terefe *et al.* 2008).

According to Adriano and Weber (2001), ash is generally considered to contain Al, Ca, K, Fe and Na as predominant elements. The growth of heat intensity increases organic matter combustion as well as nutrient availability (Badia, Marti 2003). Superficially, this may suggest that fire at a temperature varying from 300 to 400ºC produces black ash because vegetation is not totally destroyed under such thermal conditions (Iglesias *et al.* 1997) and is indicated by its higher organic C content compared to white ash (Goforth *et al.* 2005).

Nutrient losses during and immediately after burning depend on the interaction of fuel consumption, the severity of fire, microclimate, vegetation composition, structure, fuel moisture content and fuel compactness (Wanthongchai *et al.* 2008). Variations in colour parameters showed a total black Munsell colour at a temperature of 350ºC for both litter species (Fig. 3).

This can be attributed to the presence of incompletely burnt materials as Pino (Pino *et al.* 2008) observed. Moreover, the substantial consumption of organic matter starts in the range of temperatures from 200 to 250ºC and is completed at approximately 460ºC (Certini 2005).

The complete consumption of the organic matter of needle litter ash was visible at a temperature of 550ºC while leaf litter ash started turning bright at a temperature of 450ºC. According to Iglesias *et al.* (1997), there is a total combustion of organic components producing white ash when fire temperature exceeds 500ºC. Chroma value increased with a growth in temperature and reached the maximum value at a range of temperatures between 450 and 550ºC for *Acer platanoides* L. leaf litter and at a temperature of 550ºC for *Pinus silvestris* L. needle litter. Along with an increase in temperature from 150ºC to 550ºC, the colour intensity of both ash samples rose significantly and caused ash to turn from brown/yellowish to dull yellow orange/grayish yellow.

The correlation between temperature and the chroma of the Munsell colour chart is r = 0.92 (p = 0.01) for both kinds of litter. This suggests that ash colour used as a parameter for classifying ash strongly correlates with burn severity.

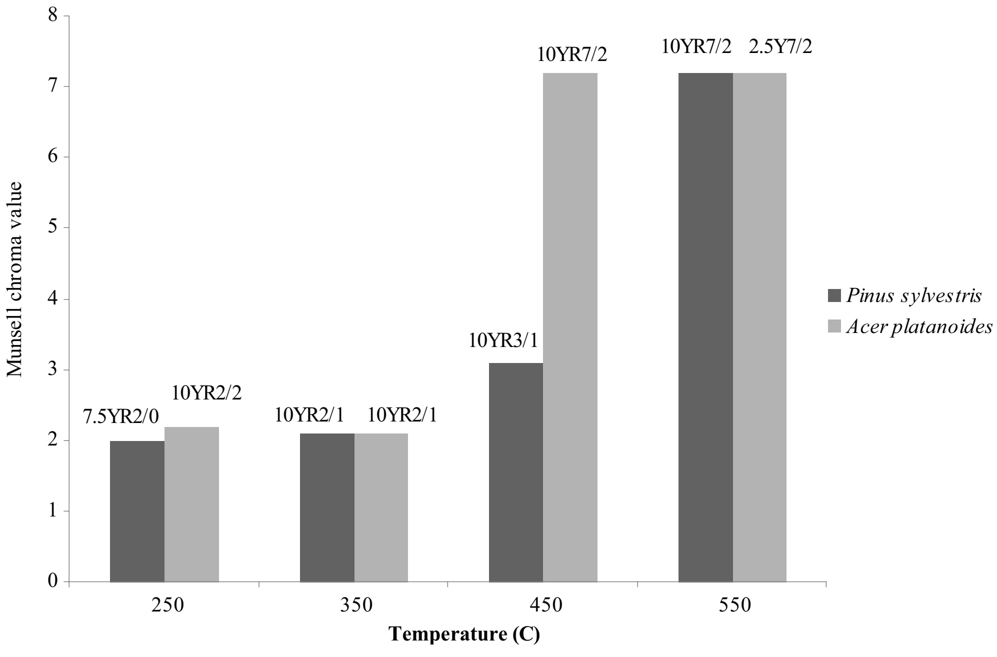


Fig. 3. Munsell chroma values with a temperature gradient in *Pinus sylvestris* L. needle litter (n = 5) and in *Acer platanoides* L. leaf litter (n = 5)

Conclusions

1. The Munsell Colour Chart is a useful tool for classifying ash heated at different temperatures and those we can find in soil after fire for giving primary information in the specific colour space. Information about colours can be used as a preliminary indicator for determining an implicit range of fire temperature which would then aid and improve the accuracy of measures taken to mitigate or prevent further environmental damage.
2. The samples heated up to the temperatures from 150 to 250ºC had brown (*Pinus sylvestris* L.) and yellowish (*Acer platanoides* L.) colour which could be caused by iron oxides accompanied by the loss of water content in needles and leaves.
3. The samples heated up to a temperature of 350ºC showed the total black Munsell colour for both litter species. It means that the organic matter was not completely burnt.
4. The samples of *Acer platanoides* L. leaf litter heated up to a temperature of 450ºC started turning bright (10YR7/2) while the samples of *Pinus sylvestris* L. needle litter had a bright colour (dull yellow orange colour) after heating to a temperature of 550ºC.
5. The analysis of ash colours using the Munsell Colour Chart showed that the colour values of *Pinus sylvestris* L. needle litter and *Acer platanoides* L. leaf litter increased with a growth in heating temperature ($r = 0.92$; $p = 0.01$).

Acknowledgement

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TEMPERATŪROS ĮTAKA MIŠKO PAKLOTĖS PELENŲ SPALVAI

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Santrauka

Tyrimas atliktas siekiant nustatyti temperatūros įtaką (150, 250, 350, 450, 550 ºC) paprastosios pušies spyglių ir paprastojo klevo lapų, surinktų iš lapuočių ir spygliuočių mišraus miško Lietuvoje (54° 43 „N 25° 19 ,E) 2010-ųjų balandį, pelenų spalvai. Laboratorijoje *Munsell* spalvų sistema buvo naudojama, norint nustatyti pelenų spalvos reikšmes. Tyrimas parodė, kad didinant degimo temperatūrą visų pelenų spalvų vertės atitinkamai didėjo ($r = 0{,}92$, $p = 0{,}01$). Pagal spalvų skalę visus mėginius (50) galima suskirstyti į kategorijas: 2.5Y (5 mėginiai), 7.5YR (10 mėginių) ir 10YR (35 mėginiai). Juoda spalva buvo stebima abiejų rūšių pelenuose, kurie buvo deginami 350 ºC temperatūroje. Spyglių pelenai tapo šviesūs esant 550 ºC temperatūrai, o šviesėjantys lapų pelenai pastebėti 450 ºC temperatūroje. Galime teigti, kad *Munsell* spalvų sistemos naudojimas pelenų spalvai nustatyti yra informatyvus pirminės pelenų klasifikacijos rodiklis.

Reikšminiai žodžiai: paprastoji pušis, paprastasis klevas, temperatūra, spalva, paklotė.