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EFFECT OF SOIL PREPARATION METHOD ON SOIL TEMPERATURE

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The success of the forest regeneration with planting is determined by many factors and one of them is soil preparation. Chosen soil preparation method impacts different environmental aspects and one of them is soil temperature and that is one of main abiotic factors determining the growth of roots. Development of the root system is a key prerequisite for growth of newly planted trees. The aim of this research was to assess the impact of the soil preparation method on the surface (5 and 20 cm) temperature of the soil. The study was done in 8 young stand sites with different soil preparation methods, soil preparation design (orientation relative to cardinal points) and different forest types in central and north-western part of Latvia. Soil temperature measurements were taken at 5 cm and 20 cm depths in both sides of furrows and in spot mounds at every study site with hand held thermometer, in few young stands unprepared soil temperature was also measured. Mean values and standard error were calculated and the statistical significance was determined by: the Shapiro-Wilk normality test, the Kruskal-Wallis Test and pairwise Wilcoxon test with a 95% confidence level. Our results show that soil preparation positively impact soil temperature compared to unprepared soil and soil temperature in spot mounds was significantly higher than in furrows during clear and hot (27-32°C) day at both depth and in overcast weather with moderate air temperature (20-23°C) in depth of 20 cm.

Keywords: *forestry, spot mounding, disc trenching,*

INTRODUCTION

Nowadays, one of the main societal challenges is to adapt to climate change in all areas, including forestry, particularly as forests play an enormous role in global biogeochemical cycles (Kolström et al. 2011). The impact of climate change varies significantly at regional level. Closer to the equator, the climate is getting much warmer and drier, while the temperature in the European boreneoral zone will rise slightly, but periods of abnormally high temperatures will occur more often (Wilmking, 2004). Overall, the productivity of the northern forests will increase (Menzel, Fabian 1999), but water deficits could rise during the spring and summer periods (Lindner et al., 2010).

In Latvia, forest land occupies approximately 52% of the State territory, of which approximately half is owned by the State and is managed by Joint Stock Company "Latvia's State Forests". Around one third of the forest regeneration is done artificially by planting tree seedlings on pre-prepared soil (State Forest Service 2018). Forest regeneration by planting is widely used practice in forest management, that started in the late 19th century, (Sutton, 1993) and promptly foresters concluded that for successful planting results there is need for soil preparation (Kundziņš,1939). Since first acknowledgements planting and soil preparation methods have been widely improving and developing. Soil preparation is used to increase the survival potential of the trees and to improve their growth rate (Mjöfors et al., 2017), because it provides planted trees with favourable growth conditions in boreal forests (Löf et al. 2012). Appropriate soil preparation method in combination with nutrients necessary for stand developmental also has positive effect to GHG emission decreasing – carbon capturing in fast growing trees (Klavina et al 2016; Petaja et al. 2018).

These days, disc trenching is the most commonly used soil preparation method in the boreal forests (Henneb et al., 2015), but the greatest lack of disc trenching is that it is not suitable in wet forest areas where furrows usually are flooded, in such environmental conditions it is more appropriate to create spot mounds (Kankaanhuhta et al., 2010; Dzerina, et al., 2016; Dumins, Lazdina 2018). Soil temperature and water availability are among the main factors determining the distribution pattern and growth of the roots, and it is one of the most important conditions for plant growth and survival (Grossnickle, 2005). Also soil preparation method has impact on root system development and orientation (Celma et al., 2019). For example, in a harsh environment, as in the north of Scandinavia, soil temperature is one of the main abiotic factors determining the growth of trees (Nilsson et al., 2010) These factors can be affected differently by chosen soil preparation method. Positive effects of changes in soil temperature caused by spot mounding and disc trenching may take up to 4-5 seasons (Sutton, 1993; Nilsson et al., 2010). When using disc trenching as a soil preparation method, it is very important to plan how furrows will be placed against the cardinal points, as it will determine sunlight, along with soil temperature (Burton et al, 2000). Higher soil temperatures contribute to most chemical processes, provide more favourable conditions for micro-organisms and stimulate root growth unless temperatures exceed critical values (Lundmark–Thelin, Johansson, 1997; Mellander et al., 2004) For example, there are studies that root growth follows a positive linear correlation with the soil temperature during the spring – autumn vegetation period (Vaapavuori et al., 1992). Scientists have identified the optimal soil temperature for widely used conifers such as Scots pine and Norway spruce, it is 20 to 25°C, but temperatures above 35°C have a strongly negative impact on root growth. In this temperature range, the roots stop growing and do not sprout new ones, so the trees ultimately die (Lyr, Garbe, 1995). The limit of low temperatures for these species, in which root growth nearly stops, is 4 to 8°C (Alvarez-Uria, Körner, 2007).

The objective of this study was to assess the impact of different soil preparation methods on the surface (5 and 20 cm) temperature of the soil in different weather conditions and furrow orientation.

MATERIAL AND METHODS

Study sites

The study was done at eight young stand sites which were reforested in the spring of 2017 and 2018. Five of them are located at the north-western part of Latvia (Dundaga parish): 14-1 (57.547595, 22.537580), 14-2 (57.546463, 22.540651), 28-1 (57.560695, 22.563560), 17-14 (57.477699, 22.604212), 29-2 (57.476095, 22.602713) and three at the central part of Latvia (Ķekava and Jelgava parish): KS (56.710578, 24.227303), DMS (56.771624, 24.189055), P (56.721703, 23.938456) (coordinates are given in the decimal degrees format) (Figure 1).

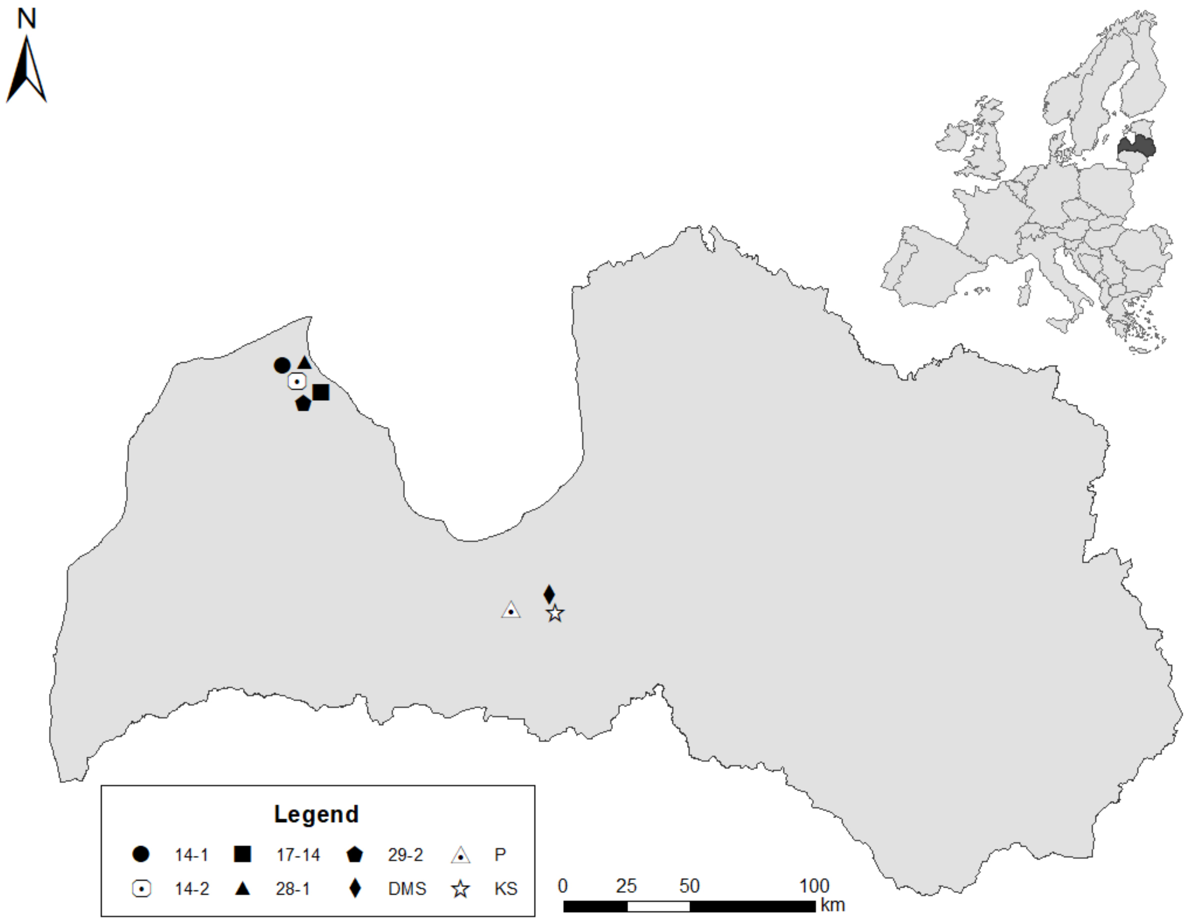

Figure 1. Study site locations.

Three of five study sites in Dundaga parish were reforested in the spring of 2017, but soil prepared about half year earlier, respectively in the fall of 2016. These sites are 14-1 and 14-2 (*Hylocomniosa*) on mineral soil with natural water regime and 28-1 (*Vacciniosa mel.*) with peat layer not more than 20 cm and young stand is drained. Other two sites (17-14 and 29-2) in Dundaga parish also are drained, but peat layer is deeper than 20 cm (*Myrtillosa turf. mel.*). Study sites 17-14 and 29-2 are reforested in the spring of 2018 and soil were prepared about few weeks earlier. Similar differences are with three study sites at central part of Latvia. Study sites DMS and KS were reforested in 2018 and soil were prepared about half year earlier. Study site DMS (*Myrtilloso-sphagnosa*) is on mineral soil with natural water regime, but KS (*Myrtillosa turf. mel.*) is drained and with peat layer deeper than 20 cm. Study site P were reforested in the year 2017, soil was prepared in the fall of 2016, young stand is drained (*Myrtillosa mel.*), but peat layer is not more than 20 cm (Zālītis, 2006; Berķis, 2013).

Placement of furrows

Depending on the location of furrows in each site relative to the cardinal points, the resulting amount of sun radiation and soil temperature in seedling plant position (on the hinge) is derived. If furrows are located parallel to the north-south cardinal points (the hinge is either west or east side) then both sides of furrow receive maximum solar radiation mid-day, in the morning east sided hinge is shadowed and west sided sunlit, but in the evening opposite – west side hinge is shadowed, but east side hinge is sunlit. If furrows are located perpendicular to the north-south cardinal points (the hinge is either north or south side), then both furrows receive maximum solar radiation in morning and evening hours, but in the mid-day period (when solar radiation reaches its highest point) southern hinge is in shadow and northern hinge is sunlit, which results in different soil temperatures in each furrow. Furrows in study sites were not designed taking into account their locations relative to the cardinal points. In study sites 14-1, 14-2 and KS furrows are located parallel to the north-south, in 28-1 parallel to the west-east, in 17-14 and DMS parallel to the northwest-southeast and 29-2 and P parallel to the northeast-southwest cardinal points (Figure 2).

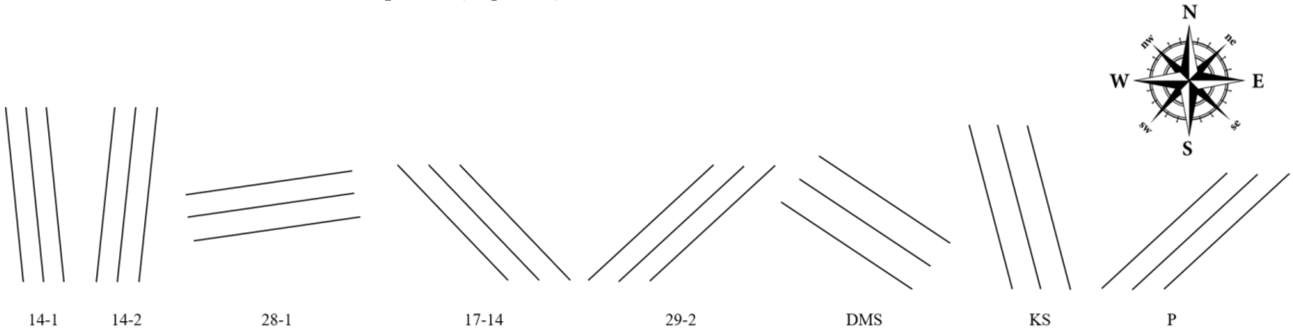

Figure 2. Schematic illustration of furrows placement across study sites.

Sampling design

Soil temperature were measured in the July of 2018 with handheld soil thermometer. Every young stand contains furrows (made with disc trench) and mounds (made with excavator), at the study sites 14-1, 14-2, 28-1, 17-14 and P unprepared soil is also left. Soil temperature were measured simultaneously (by two people) in furrows and mounds for main data comparison, unprepared soil was measured straight afterwards. At each site in every furrow two sample plots were made, same number of sample plots were evenly placed across mounds, but in unprepared soil measurements were taken in 8 sample plots. Outside temperature (air) was measured as well. Inside each sample plot soil temperature were measured in two depths: 5 cm (topsoil) and 20 cm (in the root zone of young trees), in furrows each sample plot contains of two measurements in each side of furrow (Figure 3). During measurements at study site P and all locations at Dundaga parish, outside temperature was from 28 to 32°C, the days were sunny with rare clouds, however during measurements at study sites DMS and KS outside temperature was 23 and 21°C and both days were overcast.

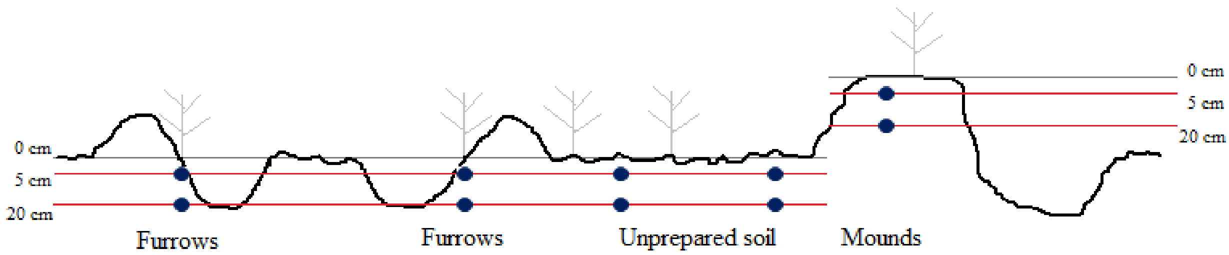

Figure 3. Schematic illustration of soil temperature measurement locations across different soil preparation methods.

Statistics

The data was analysed by the R program for Statistical Computing, Core Team (2017) version 3.4.3. For normality assumption was used the Shapiro-Wilk normality test. Because data was not distributed normally the Wilcoxon Signed-Rank Test was used to compare temperature differences at 5 cm and 20 cm depth. To determine if soil preparation technique had significant impact on soil temperature the Kruskal-Wallis Test was applied. If there was a significant impact, then pairwise Wilcoxon test was applied to determine between which soil preparation methods the temperature significantly differs. All tests were done with a 95% confidence level. Standard error was also calculated for mean values.

RESULTS

In all research sites (regardless of soil preparation methods applied) mean and single measured temperature at depth of 5 cm was significantly higher than in 20 cm depth ($p<0.05$). The highest soil temperature 44°C at 5 cm depth was measured in site 17-14 where soil was prepared in mounds (air temperature 29°C), the lowest in furrows in site DMS 17°C (air temperature 23°C). The highest temperature 36°C at 20 cm depth was also recorded in spot mound in site 14-1 and the lowest temperature 9 °C in south-west hinge in site 17-14 (air temperature 29°C). There is positive correlation between temperature at 5 cm and 20 cm depth (Figure 4).

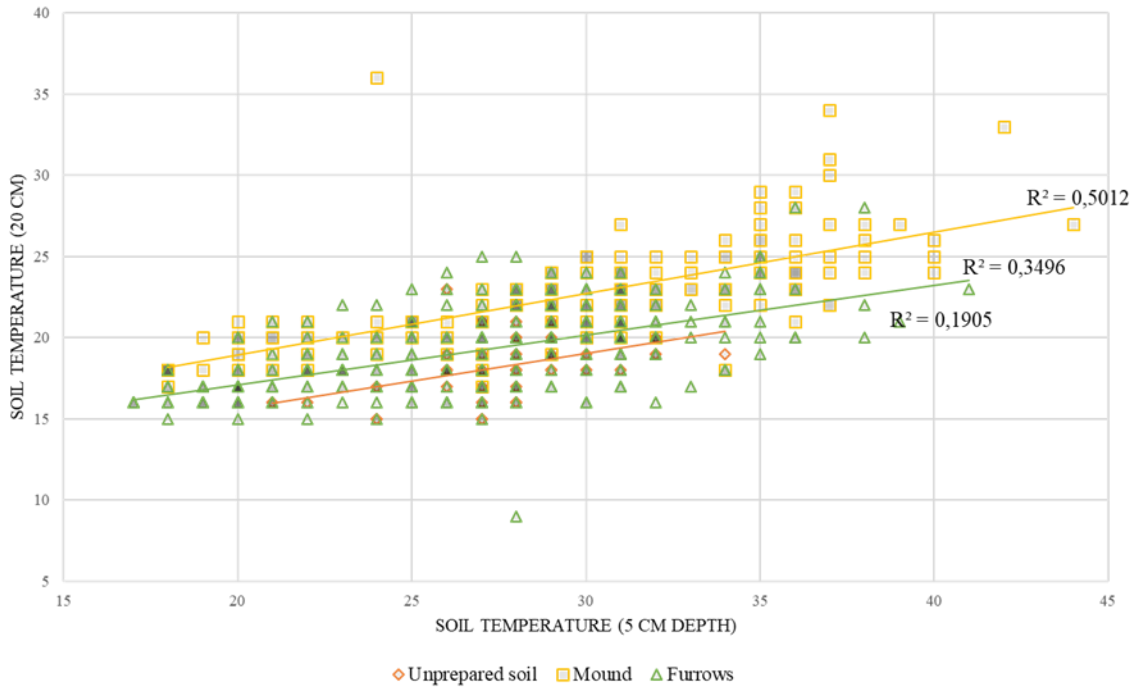

Figure 4. Correlation between soil temperature at 5 cm and 20 cm depth.

The mean soil temperature during hot and sunny day (air temperature around 30°C) is higher in spot mound than furrows, with one exception in experimental stand 28.1 where highest temperature at 5 cm depth was recorded at furrows in north hinge. When it is overcast and air temperature is from 20-23°C, then in 5 cm depth there is no significant difference, but at 20 cm depth in mounds temperature is significantly higher. Average mean temperature at both depths in spot mounds were significantly higher ($p<0.05$) compared to unprepared soil and also in most of the cases soil temperature in furrows was significantly higher than in unprepared soil. In southern hinge was lower temperature compared to northern hinge in sunny weather and in eastern hinge was lower than western hinge at depth of 5 cm. At the depth of 20 cm the significant differences were not found. When the sky was overcast and the air temperature was lower (20-23°C) there were not significant difference related to furrow orientation to cardinal points (Table 1).

DISCUSSION AND CONCLUSIONS

Our research results showed similarities to previous studies – soil preparation positively increase soil temperature (Örlander et al., 1998, Hansson et al., 2018) during hot days. For instance, mean difference reached up to 8°C in 5 cm and 20 cm depth between soil prepared in spot mounds and unprepared soil. Previously researchers have suggested that soil temperature at depth of 20 cm in mounds is higher than in furrows (Örlander et al. 1998) and our results show similar pattern. Soil temperature in south-facing microsites is higher than north facing. Mounding may improve seedling growth conditions including soil temperature (Sutton 1993), but reaching certain point (for Scots pine and Norway spruce >35°C) temperature have a strongly negative impact on root growth (Lyr, Garbe, 1995). Only at site 17-14 in spot mounds at depth of 5 cm temperature exceed this limit (Table 1). At individual measurements soil temperature exceeded this limit at 5 cm in both soil preparation methods in different sites, but at 20 cm depth only spot mounds temperature reached critical value (Figure 4). The optimal temperature for root growth is 20 to 25°C (Lyr, Garbe, 1995) and that was achieved with soil perpetration in most of the study sites at root growth depth zone 20 cm (Table 1).

And on the basis of the conducted research conclusions are:

1. Soil preparation positively increase soil temperature at 5 cm and 20 cm depth;
2. Soil in spot mounds was significantly higher than in furrows and average temperature is more suitable for optimal tree root growth;
3. At conditions of long-term heat period there is possibility that soil temperature reaches critical value for root growth in spot mound (>35°C);
4. Furrow orientation to cardinal points impact soil temperature at upper layer, but at 20 cm depth it equals.

Table 1. Mean soil temperature at 5 cm and 20 cm depth. Values within column with the same letter are not significantly different P<0.05 (pairwise Wilcoxon test) in one study site.

Year of soil preparation	Site	Soil preparation	Mean temperature °C at 5 cm depth ± SE	Mean temperature °C at 20 cm depth ± SE	Air temperature °C
2018	17–14	Mound	36 ± 0.7 a	27 ± 0.8 a	29
		SW hinge	29 ± 0.6 c	19 ± 0.4 c	
		NE hinge	32 ± 0.7 b	20 ± 0.5 c	
		Unprepared	28 ± 0.6 c	19 ± 0.3 c	
	29–2	Mound	31 ± 0.4 a	23 ± 0.5 a	30
		NW hinge	29 ± 0.3 b	22 ± 0.4 b	
		SE hinge	27 ± 0.5 c	23 ± 0.4 a	
2017	28–1	Mound	28 ± 0.5 a	21 ± 0.3 a	27
		N hinge	29 ± 0.6 a	21 ± 0.4 a	
		S hinge	26 ± 0.4 b	20 ± 0.4 a	
		Unprepared	25 ± 0.7 b	17 ± 0.6 b	
	14–1	Mound	34 ± 0.5 a	24 ± 0.6 a	32
		W hinge	32 ± 0.5 ab	23 ± 0.5 a	
		E hinge	30 ± 0.4 b	23 ± 0.3 a	
		Unprepared	30 ± 0.4 b	20 ± 0.3 b	
	14–2	Mound	33 ± 1 a	23 ± 0.6 a	31
		W hinge	28 ± 0.9 b	18 ± 0.8 b	
		E hinge	24 ± 0.8 c	17 ± 0.3 bc	
		Unprepared	27 ± 0.7 b	16 ± 0.6 c	
	P	Mound	29 ± 0.7 a	23 ± 0.3 a	31
		NW hinge	30 ± 0.4 a	21 ± 0.3 b	
		SE hinge	31 ± 0.4 a	22 ± 0.2 b	
		Unprepared	27 ± 0.4 b	18 ± 0.3 c	
2018	DMS	Mound	23 ± 0.9 a	20 ± 0.4 a	23
		SW hinge	21 ± 0.7 a	18 ± 0.4 b	
		NE hinge	20 ± 0.5 a	18 ± 0.3 b	
	KS	Mound	20 ± 0.3 a	19 ± 0.2 a	21
		W hinge	20 ± 0.4 a	17 ± 0.1 b	
		E hinge	21 ± 0.4 a	17 ± 0.2 b	

This was a pilot study before long lasting full-scale study. In spring of 2019 in the same forest sites in the same soil depth (5 cm and 20 cm) have been installed 50 temperature sensors. These sensors measure temperature simultaneously once in every 30 minutes' and data collection will continue to end of 2020. That will give possibility to get a more accurate point of view how chosen soil preparation method impact temperature of the soil and the orientation importance of furrows to cardinal points.

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