Temperature regime of the arable layer of sod-podzolic soil under different tillage systems and crops

S V Zhelezova
Department of Agriculture and Field Research Methods, Faculty of Agronomy and Biotechnology, Russian State Agrarian University – Moscow Timiryazev Agricultural Academy, 127550, Timiryazevskaya st., 49, Moscow, Russian Federation
E-mail: soferrum@gmail.com

Abstract. In the field experiment there was studied the seasonal temperature regime of the arable layer of sod-podzolic soil under different soil treatment. It was shown that soil treatment (conventional plowing and No-till technology) did not have a significant effect on the topsoil temperature regime. Seasonal and daily temperature variations in topsoil depended on the location of the soil temperature measurement point, on the distance from the windbreak forest belts and on the crop coverage of the soil.

1. Introduction
Soil temperature is one of the key factors for biotic and abiotic processes in soils. It significantly influences on seed germination, winter survival and total adaptation of plants [1], especially of winter crops. Seasonal regime of soil temperature depends on weather conditions, soil moisture, vegetation cover and the snow cover in the autumn-winter period. Survival of winter crops seeding strongly depends on winter temperature and snow conditions. So-called “black frost” damage and long period of soil freezing are the common reasons of the winter crop seedling losses. It is an important task to study the period and depth of soil freezing depending on various conditions. Soil spatial heterogeneity, relief, arable soil treatment and vegetation cover – all these factors affect the soil temperature regime. Such observations are important for precision agriculture because spatial heterogeneity of crops strongly correlated with soil moisture and temperature regimes in-situ. Cultivation technology and soil treatment affect winter crops survival.

The soil conservation No-till technology becomes more and more popular in the world, but in Russia No-till technology is at the starting point of its development. The main advantages of direct sowing and No-till treatments are the soil conservation and saving of energy. Simultaneously, No-till technology has significant disadvantages, especially at the first years of development and setting [2]. The survival of cereal crops at the early stage depends on the weather and topsoil conditions. The method of soil tillage determines some important agrophysical properties of the arable layer, so, the problem of comprehensive comparison study of the topsoil condition under different treatment is quite relevant.

This study is the part of the complex long-term field experiment of the Center of precision agriculture at Russian State Agrarian University – Moscow Timiryazev Agricultural Academy [3]. The main aim of this study was to estimate seasonal temperature regimes of the topsoil under No-till and Plowing soil treatment.
2. Material and methods

2.1. Experimental Site and temperature measure point position

Research of the topsoil temperature regime was carried out during two vegetation seasons 2009/2010 and 2010/2011 at the Field Experimental Station of Russian State Agrarian University – Moscow Timiryazev Agricultural Academy, Moscow, Russia (N 55,8369˚; E 37,5636˚). Climate in Moscow region is a humid continental, according Köppen climate classification climate code is Dfb [4]. The average annual temperature is about 6.6˚C. The average annual precipitation, including snow, is near 700 mm, and annual rainfall varies from 300 to 450 mm. The soil of experimental field is Sod-Podzolic, or Retisols by FAO soil classification [5], middle loamy.

There was studied the seasonal temperature regime of the topsoil layer (0–20 cm) under different soil treatment with soil cover of winter wheat crop and under influence of windbreak tree stripes.

Two technologies of soil treatment (tillage or no-tillage) are compared in the experiment. Plowing treatment (Plow) is a classical traditional processing of conventional tillage. It includes post-harvest disk plowing to break the stubble, autumn conventional plowing, and pre-sowing cultivation of the soil. Alternative treatment is No-till technology (NT). Stripes under two compared technologies are situated constantly at the stationary plots and are repeated in time permanently from year to year (figure 1, stripes NT, stripes Plow).

![Figure 1](image_url)

**Figure 1.** Field experiment design: constant plots under different technologies (NT – No-till treatment; Plow – Conventional tillage treatment) and locations of soil temperature measurement points (■ – in season 2009/2010; x – in season 2010/2011).

Both vegetation seasons the dynamics of soil temperature under winter wheat crop planted under two kinds of soil treatment was compared (figure 1). Also, at the first season of monitoring there were compared points under fallow without crop (figure 1, blue squire markers, points 7) and under tree shadow of windbreak tree stripe (figure 1, blue squire markers, points 8). The second season
experimental temperature measurement points were located not only under different soil treatment, but also in different distance from windbreak Larch Avenue (figure 1, crisscross yellow markers, 1–8).

2.2. Measurement of the temperature of the arable layer of soil

The seasonal dynamics of the temperature of the arable layer of soil has been studied in detail using i-button technology (www.i-button.com). At each temperature measurement point there were used three button positions at the topsoil on the different depth: 2 cm, 10 cm and 20 cm. Measurements were recorded automatically three times a day: at 6 am, at 2 pm, and at 10 pm. These time point measurements were chosen to record the temperature at the coldest time of the day (near sunrise), at the hottest time of the day (apparent noon) and in the evening after sunset. The air temperature and precipitation were also measured every day.

All results were processed using cluster analysis and time series analysis. Both vegetation seasons there were calculated and drawn Chrono-isotherms of soil temperature during autumn-winter and of spring-summer parts of the seasons. Such calculations allowed us to compare the temperature regimes at different survey points on the field.

3. Results and discussion

3.1. Weather conditions and topsoil temperature

The vegetation seasons of 2009/2010 and 2010/2011 were inclement for winter wheat crop. There were two frost winters and two extremely hot summers. The duration of the soil freezing period did not depend on the soil tillage treatment, but was strongly correlated with the point location and plant cover over the soil. In the winter 2009/2010 the shortest freezing period was recorded at the point under windbreak tree stripes (figure 2, left, p.8), and the longest – under fallow without crop cover (figure 2, left side, p.7). In the second winter soil freezing time period also did not depend on the soil tillage treatment, but depended on the point location and the distance from the Larch Avenue (figure 2, right side).

Figure 2. Curves of temperature (upper diagrams) and chrono-isotherms of soil temperature in the different survey points (p.1 – p.8) during autumn-winter part of two vegetation seasons: left side – 2009/2010, right side – 2010/2011.
3.2. The influence of point location on the temperature regimes

Larch Avenue as a windbreak barrier creates a favorable microclimate at the southern border of the field. The point 1 (see figure 1, crisscross markers) is situated more closely to big trees of the Avenue – approximately 37 m to the north from the closest tree line. Relief of experimental field is smooth with slight slope (less than 1.5˚) North-East exposition (figure 3, (a)). Also, the point 1 is situated at the top of smooth hill, and other point are situated down the slope to the North (figure 1; figure 3, (a)).

In the season 2010/2011 three point positions on the field had the maximum sum of the effective temperatures (SET). There were points 1, 2 and 8 (figure 3, (c)). These places are favorable for crops development. Comparison SET at the different points with yield maps of this field confirms the existence of zones of different productivity associated with the accumulation of heat. More productive zone on the field is situated around points 1–2 and 8. The plant growth conditions are the best around the point 1 because of Larch Avenue influence and smoothing weather extremums. For example, in the hottest day of summer 2011, the 1st of July, the maximum air temperature was +30˚C, and the temperature on the topsoil at the point 1 at 2 p.m. has risen to +38˚C, and at the point 8 the topsoil temperature was +44˚C (figure 3, (b)).

![Figure 3](image)

**Figure 3.** Influence of point position on summer soil temperature regime:
(a) – point position in the relief of field; (b) maximum soil temperature value on the hottest day the 1st of July 2011; (c) the seasonal sum of effective temperature (> +10˚C) in soil in different points.

Two seasons of topsoil temperature monitoring confirm positive influence of windbreak tree stripes to the soil temperature regime, the development and productivity of winter wheat.

There were no significant differences between topsoil temperature regimes under two methods of soil treatment. Specific soil and micro-relief conditions in-situ affect soil temperature much more significantly, than soil tillage system. For example, it can be demonstrated with the cluster analysis of
soil temperature data for two parts of the season 2009/2010 (figure 4). Points under No-till and Plowing are close to each other, and Windbreak and Black fallow points are outstanding (figure 4, (a)).

![Figure 4. Dendrograms of cluster analysis of winter (a) and summer (b) soil temperatures at the season 2009/2010.](image)

4. Conclusions
The study of the soddy-podzolic soil temperature regime under winter wheat crop on the experimental field during two full annual cycles revealed the presence of zones with certain features of the temperature regime. The connection was found out between the temperature regimes and field sub-zones of different crop productivity at different distances from the Larch Avenue.

References
[1] Körner C 2016 Plant adaptation to cold climates *J. F1000Research* 5 (F1000 Faculty Rev) 2769
[2] Pittelkow C, Linquist B, Lundy M, Liang X, Groenigen K, Lee J, Gestel N, Six J, Venterea R and Kessel C 2015 When does no-till yield more? A global meta-analysis *J. Field Crop Res.* 183 156–68
[3] Belenkov A, Zhelezova S, Berezovsky E and Mazirov M 2012 Precision agriculture methods in a field experiment of Russian Timiryazev state Agricultural University *J. Izv. Timiryazev Acad.* 7 94–101
[4] Beck H, Zimmermann N, Vicar T, Vergopolan N, Berg A and Wood E 2018 Present and future Köppen-Geiger climate classification maps at 1-km resolution *J. Sci. Data* 5 180–14
[5] World reference base for soil resources 2014. *International soil classification system for naming soils and creating legends for soil maps*. http://www.fao.org/3/i3794en/i3794en.pdf