Formation of Soil Thermal Regime under Sea-Buckthorn Plantations

S.V. Makarychev

Abstract

The results of the study of diurnal, seasonal and annual hydrothermal regimes of the genetic horizons of leached chernozem soil in sea-buckthorn plantations are presented. The temperature profile and the temperature field of the soil strata for several years of observations are discussed. The effect of environmental factors on the thermophysical state of the chernozems of the Altai Priobye (the Ob River area) in the conditions of a fruit garden is shown.

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The most important indicator of soil thermophysical state is soil temperature. The rate of water and nutrients uptake by a plant as well as water solubility of salts, oxygen and carbon dioxide relate to soil temperature. It is known that the distinctive feature of the behavior of all thermal balance components is a pronounced diurnal variation. The meteorological factor renders the greatest effect on the frequency of the variation of thermal balance and its components. The soil genesis, crop being grown, agronomic practices, and the geographic location of the observation site render weaker effect on thermal regime formation.

An important integrated index which best describes the temperature regime in a soil profile may be the total of daily temperatures at different depths of soil strata. The results of such observations are presented in Fig. 1. It follows that in 2006 the soil profile was characterized by high total temperatures up to August, and in 2007, gradually increasing through the growing season, the total temperature reached the maximum values on 23.July and remained high until the second decade of September. The total soil temperatures at different depths are largely related to the weather conditions of the study period. For example, June of 2006 was warmer than the long-term annual average norm, and in 2007 the warmest month was July, which affected the soil temperature values.

In evaluating the heat supply of sea-buckthorn planting options at different observation times it is necessary to consider the weather conditions not only on the day of measurement, but also in the preceding period. That, as mentioned above, enables to identify the major factor which determines the temperature in the soil profile. In rainy or cloudy weather there were practically no differences in total temperatures between the options: on 13.June, 01.July and 15.August, 2006, in the mentioned weather type, the differences ranged from one to three degrees. In 2007 the regular patterns remained: on 08.May, 30.June, 11.July and 31.July, the total temperature in sea-buckthorn planting layout option 4.0×2.0 m was higher than in the denser option by 1-5° C, and on 09.August, even lower by one degree. In clear sunny weather, planting layouts rendered a very significant effect on soil temperature. In 2006, in the control planting layout, the total temperature in the soil profile was higher than in denser planting option on 21.June 21 by 13°C, on 30.July by 10°C, on 29.August by 26°C, and on 29.September by 13°C.

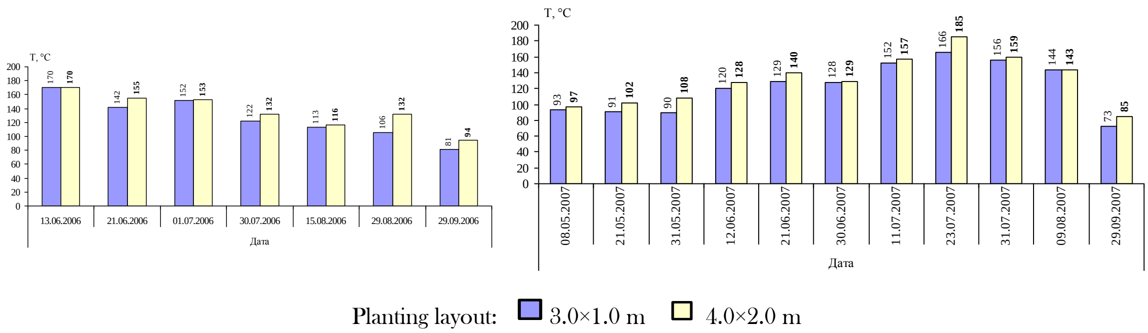


Fig. 1. Soil total temperature at 1p.m. in the strata of 0-100 cm in the rows of sea-buckthorn plantings

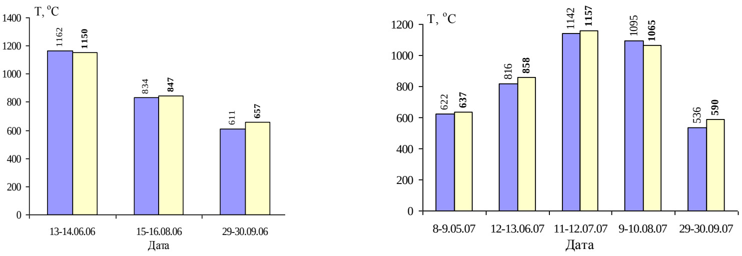
The maximum temperature values of leached chernozem soil are inseparably associated with soil heating by solar radiation. For example, in 2006 the highest temperature of the soil surface was on 13.June (up to 42.5°C) by air temperature of 29.3°C, and in 2007 it reached as high as 46.2°C (at Tair = 31.1°C).

In addition to evaluating the effect of sea-buckthorn planting layouts on soil temperature during the intense heating of daylight hours, the data on the diurnal temperature variation of chernozem soil is equally important. If on the soil surface in similar weather conditions measurement dates of 2006-2007 significant differences in temperature were not recorded, then at 20 cm depth the classic planting layouts were more heated. It should be emphasized that was observed in solar stable weather when sea-buckthorn plants, shading the soil surface during the daylight hours, reduce the heat flux, and at night prevent the soil from heat radiation.

A more complete picture of sea buckthorn planting layouts effects on soil heat balance is provided by the total temperature in the soil profile within 24 hours. Our observations have shown that in cloudy rainy weather, when cooling process prevailed over heating, the best heat-shielding action was revealed by denser planting layouts. More closed crowns in 3.0×1.0 m layout contributed to additional conservation of 12-30°C per day, depending on the intensity of soil cooling process.

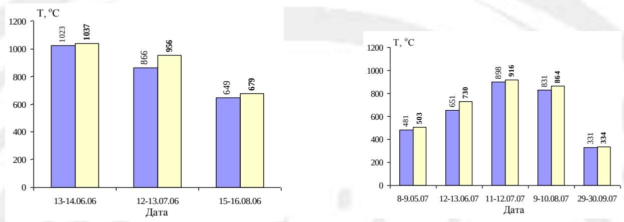
Yet in partly cloudy variable weather the traditional planting layouts were better heated up. That was observed on 15-16.August, 2006, on 08-09.May, 2007, and on 11-12.July, 2007. However, the differences between the layout options were within the range of 13-15°C. And finally, in a relatively settled clear weather, in sea-buckthorn rows of 4.0×2.0 m planting layout, the total soil temperature exceeded that of the denser planting option by 46°C on 29-30. September, 2006; the difference on 12-13.June, 2007, amounted to 42°C, and on 29-30.September, 2007, to 54°C.

Sea-buckthorn planting with wide row spacing in the control variant received by far more heat than denser layouts. Moreover, even during cooling spells the total daily temperatures of the soil chernozem in 4.0×2.0 m planting layout were higher, apparently due to better soil heating of daylight hours by diffused solar radiation (Fig. 2-3). The most significant differences between the variants of the experiment were recorded in sunny weather, and reached 90°C on 12-13.July, 2006.



Planting layout: 3.0×1.0 m 4.0×2.0 m

Fig. 2. Soil total temperature in the strata of 0-100 cm in the rows of sea-buckthorn plantings



Planting layout: 3.0×1.0 m 4.0×2.0 m

Fig. 3. Soil total temperature in the strata of 0-20 cm under sea-buckthorn plantings in row-spacings

Thus, leached chernozem soil under the sea-buckthorn plants in 4.0×2.0 m planting layout was heated up more intensively, but the physical evaporation from the soil surface in that case was also intensified, and that obviously hindered moisture conservation and conservative moisture uptake by the plants in rainfed conditions, particularly at the second phase of the growing season. Denser sea-buckthorn plantings reduced diurnal soil temperature variations and contributed to the formation of steadier thermal background.

Figure 4 shows the temperature profile of chernozem under sea-buckthorn plants in the rows of 3.0×1.0 m planting layout in the period from June, 2006, to May, 2008. It follows that the thermo-chrono-isopleth curve 20°C extended to the depth of 30 cm in 2006 and 42 cm in 2007. As mentioned above, spaced planting layout received more heat and, therefore, it was heated up better. The temperature profiles of the compared variants were similar in whole, except for the penetration depth of the isopleths above 20°C. If in 2006 the differences in the planting layouts amounted to 4 cm only, then in 2007 - to 18 cm.

It should be emphasized that the heat-up depth of chernozem soil depended significantly on the weather conditions. The largest fluctuation amplitudes during the growing season are representative of the humus-accumulative horizon, and of the horizon transitional to illuvial. It is noteworthy that the soil heat-up to the biologically favorable temperatures above 15°C throughout one meter deep chernozem profile occurred from late June - early July to mid-August; and that at the top of the maximum plant roots concentration profile lasted longer (up to three months). To evaluate the heat supply of soil the sum and the duration of effective temperatures is often used. For example, in 2007 the period of effective temperatures was about 5 months, and throughout all soil horizons due to heat transmission inertia. The state of relative balance in chernozem soil profile with insignificant temperature gradients followed the heat-up period. That was most clearly expressed in 2006 for six weeks (from the third decade of August to 05.October the temperature ranged from 10°C to 15°C). Further cooling of the chernozem soil proceeded gradually and depended largely on the time of steady snow cover formation. The obtained data agree well with previous studies of the temperature regime of leached chernozem under various garden crops.

Figure 5 shows the temperature field of chernozem in 2006-2008. In the soil upper layers the temperature variation is most closely associated with the change of meteorological factors. That is confirmed by a number of maximum values pronounced in 2007. The soil temperature fluctuations are represented by parabolic curves, and in the upper soil layers they are of greater slope angle; with the depth the parabolic branches become noticeably lower sloping. It can be also clearly seen in the Figure that the periods of relative stabilization of the temperature field occurred after the formation of sufficiently thick snow cover. Following the spring warming caused by thawing, the temperature field undergoes "perturbation" that ends with soil re-freezing. The closest location of the thermo-chrono-isopleth curves correspond to the "perturbation" periods. In winter, due to the thermal insulating effect of snow cover the subsurface temperature gradients were minimal.

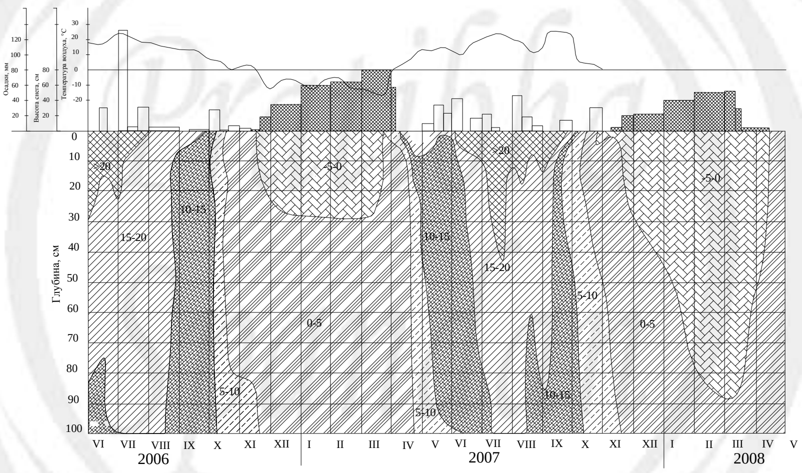


Fig. 4. Temperature profile of leached chernozem under sea-buckthorn plants in 2006-2008.

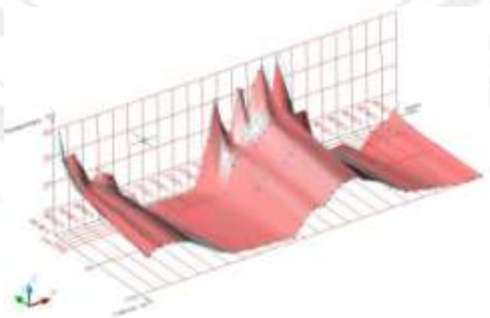


Fig. 5. Temperature field of leached chernozem under sea-buckthorn plants in 2006-2008.

Thus, in a steady sunny weather at the end of the growing season the soil under dense planting layouts accumulated more heat, and during the periods of cooling in summer it was cooled to a lesser extent.