Influence of tillage methods on carbon dioxide emissions in spring wheat crops

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Abstract. The agriculture intensification is associated with an increase in anthropogenic load on arable soils. Tillage leads to disruption of the natural process of soil formation in connection with which the soil biota activity changes and the carbon cycle is disrupted. The purpose of the study is to establish the effects of the tillage method on the carbon dioxide emission in spring wheat crops. The emission of carbon dioxide during the growing season of spring wheat varies significantly depending on the soil processing method and temperature. At the beginning of spring wheat development, the daily emission of carbon dioxide during the dump and subsurface tillage method does not exceed 36.0 and 36.2 CO₂ kg/ha using zero technology provides a reduction in production CO₂ production to 27.8 kg/ha*day. With an increase in soil temperature by July 24, the daily emission increases on a dump and subsurface background to 105.5 and 106.0 CO₂ kg/ha*day, on a zero background to 95.4 CO₂ kg/ha*day. In the future, it decreases. The total carbon losses during the dump and subsurface tillage methods are 2829 and 2793 kg/ha, the use of zero tillage technology reduces carbon losses in grain agrocenosis by 18%.

1 Introduction

The intensification of agriculture is associated with an increase in the intensity of soil tillages, the use of fertilizers and chemicals [1]. Tillage has a significant impact on all biochemical processes in the soil. This is due to the fact that mechanized processing has a direct impact on the soil agrophysical properties, namely moisture reserves, aeration, temperature, density of the arable layer, etc. All this together indirectly affects not the intensity of soil biota development, which participates in the carbon cycle, as well as the processes of organic matter mineralization and humification [2,3]. Researchers are currently still discussing the selection of an optimal system of basic tillage in various soil-climatic zones, aimed at obtaining a positive carbon balance in soils [4]. Some researchers note in their works that traditional dump tillage for their climatic zone shows a better effect in organic carbon sequestration, in comparison with No-Till technology [5,6]. Nevertheless, other scientists note that the transition to zero tillage technology leads to the restoration of the natural process of soil formation and, as a consequence, the carbon accumulation in the arable layer [7,8]. Another group of researchers notes the greatest positive effect in reducing the harmful effects of carbon dioxide emissions with a non-waste
and minimal tillage method [9]. Based on this, there is currently no clear understanding of the impact of tillage methods on carbon dioxide emissions in the agrocenoses of Western Siberia. In this regard, it is necessary to conduct research on the effect of tillage methods on carbon dioxide emission in crops, to fulfill the adopted concept of "4 permille". The purpose of the study is to establish the effects of tillage methods on carbon dioxide emissions in spring wheat crops.

2 Materials and Methods

The research was carried out on the experimental field of the State Agrarian University of the Northern Trans-Urals on the territory of the forest-steppe zone of the Tyumen region in grain crop rotation. On the dump variant, plowing was carried out (PN-8-35) to a depth of 20-22 cm; on the subsurface variant, loosening was carried out (PChN-2,3) to a depth of 20-22 cm; on the zero variant, the main tillage was not carried out. In the spring, on physically fermented soil, they harrowed with medium harrows in two tracks. In the future, pre-sowing cultivation (KPS-4) to a depth of 6-8 cm was carried out on the dump and subsurface versions. In the future, they sowed (SPM-5,4) on the zero variant, direct sowing was carried out with SKP-2,1 seeders. Nitrogen fertilizers were applied in all variants with sowing at a dose of 70 kg/ha in the active substance. The seeding rate of spring wheat is 6.0 million germinating seeds per hectare. The experiment was laid down in a four-fold repetition, the plots are fixed. To account for carbon dioxide emissions, cultivated plants were cut from a 0.25 m² plot. In their place, sealed vessels with a valve of a fixed volume and area were installed, buried in the ground by 2 cm to prevent losses of CO₂. At the end of the day, the carbon dioxide content was measured by the AZ77535 infrared gas analyzer through a sealed valve in a four-fold repetition. In the future, the background value of carbon dioxide in the air was measured, which was subtracted from the values obtained. The recalculation method was used to determine the value of carbon dioxide emissions per hectare per day. Statistical data processing was carried according to Dospekhov using Microsoft Excel software.

3 Results and Discussions

Carbon dioxide emissions in the variant with the traditional tillage method (dump tillage) on May 11 amounted to 108 CO₂ kg/ha*day, the transition to a subsurface tillage method did not significantly affect this indicator. With zero tillage technology in this time period, the production of CO₂ was 83 CO₂ kg/ha*day, which is 24% lower than with traditional tillage (the smallest significant difference (LSD₀₅) is 2,9 CO₂ kg/ha*day). A significant decrease in carbon dioxide emissions when abandoning basic tillage is explained by the lower soil temperature during this period, which, due to the mulching layer of straw of grain crops, warms up longer (Fig.1).
By May 25, the intensity of CO₂ production increases almost twice in all the studied variants. On the dump background, carbon dioxide emissions amounted to 71.2 CO₂ kg/ha·day, the use of sub-surface loosening did not affect this indicator, the deviations were in the range of measurement error. With zero tillage technology, this indicator is 53.4 CO₂ kg/ha·day, which is lower than with traditional tillage by at least 25%. By this period, the temperature of the arable layer on all the studied variants was almost the same. Consequently, during this period of time, the production of carbon dioxide was more influenced by the density of the arable layer addition, which, as researchers note with zero tillage, is significantly higher, thereby it reduces aeration and the intensity of biological processes taking place in the soil [10,11].

The intensity of soil respiration on June 10 was 6-20% higher than previous measurements. On the dump background, the emission of carbon dioxide was 76.7 CO₂ kg/ha·day, on the subsurface - 76.0 CO₂ kg/ha·day. The use of zero tillage technology ensured a reduction in CO₂ emissions to 17% relative to the dump tillage method.

With an increase in soil temperature, there is a significant increase in carbon dioxide emissions in spring wheat crops in all the studied variants. By July 24, the production of carbon dioxide per day was maximum and amounted to 105.5 and 106.0 CO₂ kg/ha·day on a dump and subsurface background. With zero tillage technology, these values did not exceed 95.4 CO₂ kg/ha·day.

In the future, the production of carbon dioxide due to a decrease in soil temperature begins to decrease by August 24, the values of CO₂ emissions on all dump background decreased to 47.4 CO₂ kg/ha·day, on subsurface and zero to 43.5 and 33.6 CO₂ kg/ha·day, respectively. In the future, by October 17, the rate of carbon dioxide emission reaches its marked minimum and reaches 10.3 and 9.8 CO₂ kg/ha·day on a dump and subsurface background. On the variant with zero tillage up to 7.5 CO₂ kg/ha·day.

Thus, the intensity of CO₂ emissions on the dump and subsurface background is almost the same throughout the growing season of spring wheat. This is due to the fact that the temperature of the soil, the density of addition on these variants is almost the same throughout the growing season. When loosening is not carried out, part of the plant residues gets into the lower layers of the soil, which makes it possible for the soil microflora to work throughout the treated layer. A significant decrease in the production of carbon dioxide on a zero background is due to the fact that aeration in the soil layer of 10-30 cm decreases here, thereby reducing the carbon dioxide emission [12,13].
In total, for the period from May 1 to May 11, 396 CO₂ kg/ha was released from the soil under the dump tillage (Fig.2), no significant differences were noted relative to the traditional tillage against subsurface background. With the No-till technology, the amount of CO₂ produced was 23% lower than the dump background, which corresponded to 203 kg/ha of pure carbon (Fig.3).

In the future, over the time interval of May 11-25, the amount of released CO₂ increased 2.5 times. The dump and subsurface background did not differ significantly in the production of carbon dioxide, which was 997-1008 CO₂ kg/ha, which corresponded to 321-334 kg/ha of carbon. At zero tillage during this time interval, carbon losses were 17% lower relative to dump treatment and amounted to 278 kg/ha. A similar pattern is noted in other works where zero tillage reduces carbon dioxide emissions. Nevertheless, the authors note that the effectiveness of this method largely depends on the soil and climatic zone [14,15].
From May 25 to July 10, the total amount of carbon lost increased to 1,227 CO₂ kg/ha, which is equivalent to 334 kg/ha of carbon. On the dump background, there were no significant differences with the subsurface background. When using zero tillage, 1021 CO₂ kg/ha was released during this period of time, which corresponds to 278 kg/ha of carbon.

In the future, from June 10 to June 24, the total carbon loss on the dump and subsurface background did not differ significantly from the previous values and amounted to 348-353 kg/ha. While in the variant with No-till technology, the total amount of CO₂ production for this period was 1216 CO₂ kg/ha, which is 18% higher than the previous values. This may be due to the fact that due to the smaller volume of plant biomass, the intensity of soil warming is influenced not only by the ambient temperature but also by solar radiation. As a result, by this time interval, the soil under spring wheat crops increases on a zero background, which had a positive effect on the activity of soil biota and respiration intensity.

In the range from July 24 to July 6, the total emission of CO₂ increased significantly to 1,654 and 1,684 CO₂kg/ha on a dump and subsurface background, which is 29-30% higher than the previous values. When using zero technology, the total amount of carbon dioxide released was 1,489 CO₂ kg/ha, which is 10% lower than with traditional tillage.

In the future, the amount of carbon lost over time intervals decreased significantly in the period from July 10 to July 24 to 402 - 404 kg/ha on a dump and subsurface background. On a zero background, up to 363 kg/ha, which is 10% lower than dump tillage.

With a decrease in air and soil temperature, the total flow of carbon dioxide begins to decrease significantly due to a decrease in the activity of soil biota, as well as the intensity of root system respiration. By the period from August 24 to September 4, the total CO₂ emission was at the level of spring values and reached 445 and 420 CO₂ kg/ha on a dump and subsurface background and 279 CO₂ kg/ha with zero tillage technology. The minimum amount of carbon lost was observed in the coldest period of time from October 4 to October 23 – 53 kg/ha on a dump background, 51 kg/ha on a subsurface background, and 39 kg/ha with zero tillage technology.

The total flows of carbon dioxide during the growing season of spring wheat during the transition from dump to subsurface tillage do not change. This is due to the fact that during these tillages, plant residues enter the treated soil layer, the density of addition and aeration improve, which leads to an increase in the mineralization process. The use of energy-saving No-till technology has significantly reduced carbon losses in the grain agroecosystem. Firstly, due to the lowered soil temperature at the beginning of spring wheat development due to the mulching layer. Secondly, due to the lack of tillage, aeration decreases and the process of organic matter mineralization slows down. Thirdly, the absence of plant residues in the lower soil layers reduces their microbiological activity.

The total carbon dioxide emission during the growing season was 10402 CO₂ kg/ha, which corresponds to the loss of carbon from the soil in the amount of 2829 kg/ha during dump tillage. With subsurface tillage, these values did not differ significantly from traditional dump tillage - 10269 CO₂ kg/ha or 2793 kg/ha of carbon. The use of No-till technology ensured a reduction in CO₂ emissions over the studied time interval by 18% relative to the dump and subsurface backgrounds, where the total carbon loss was 2308 kg/ha (Fig.4).
4 Conclusions

1. Carbon dioxide emissions at the beginning of spring wheat development during dump and subsurface tillage are 36.0 and 36.2 CO₂ kg/ha *day, whereas with No-Till technology these values do not exceed 27.8 CO₂ kg/ha*day. With increasing soil temperature, carbon dioxide emissions rise to their maximum. On July 24, on a dump and subsurface background, the emission is 105.5 and 106.0 CO₂ kg/ha* day, with zero processing technology, a maximum of 95.4 CO₂ kg/ha*day is released. In the future, with a decrease in soil temperature, the daily production of carbon dioxide decreases.

2. The total release of carbon dioxide during dump tillage during the growing season is 10402 CO₂ kg/ha, which corresponds to a loss of 2829 kg/ha of carbon. The use of subsurface loosening is accompanied by the same alienation of carbon as with dump tillage. The use of No-till technology provides a significant reduction in total carbon dioxide emissions to 8485 CO₂ kg/ha, which corresponds to a loss of 2308 kg/ha of carbon.

Acknowledgement


References


