BIO Web of Conferences **139**, 13001 (2024) https://doi.org/10.1051/bioconf/202413913001
AgriScience2024

Production of carbon dioxide in crops of various seedings and fallows in the conditions of the forest-steppe zone of Western Siberia

Evgeniy Demin*

Northern Trans-Urals State Agrarian University, 625003, Respubliki, 7, Tyumen, Russia

Abstract. Currently, the global climate measurement is taking place in the world, which is directly related to the intensity of greenhouse gas emissions. The contribution of the agro-industrial complex industry to global emissions is a significant share, which is more than half. At the same time, the introduction of agriculture leads to a violation of the natural process of soil formation, a change in phytocenosis and an increase in carbon dioxide emissions. Due to the different mass of the root system, different types of cultivated plants make a diverse contribution to the formation of CO_2 emissions from the soil surface. The purpose of the study is to evaluate the effect of cultivated crops and fallows on the intensity of carbon dioxide emissions in the Trans-Urals. In fields free from cultivation of crops, 6,753 kg/ha of carbon dioxide is released during the growing season. The cultivation of grain crops increases the total emissions by almost 2026 kg/ha. Cultivation of row crops at 4,979 kg/ha, which is 74% higher than the fallow field values. In alfalfa crops, 14023 kg/ha is allocated during the growing season, which is 108% higher than in the fallow field.

1 Introduction

Global climate change is leading to significant changes in all sectors of production, in particular, the food security of the population. The primary cause of climate change is considered to be the high concentration of greenhouse gases in the atmosphere [1]. The most active of them is carbon dioxide, its share in the radiation exposure of all long-lived greenhouse gases is about 66% [2]. Approximately half of all carbon dioxide emissions into the atmosphere are accounted for by the agro-industrial complex of the economy [3,4]. According to some researchers, soil types, types of land use, and agrotechnical techniques have a significant impact on emissions in ecosystems [5]. The use of soil in agricultural turnover leads to the fact that the natural composition is disrupted. Processing leads to a violation of the distribution of plant residues in the soil horizon, as well as to the measurement of biological activity, agrophysical properties, which together affects the naturally formed factors of soil formation. This can lead to a change in the flow of climatically active gases, decomposition of plant residues, humification of organic matter,

* Corresponding author: gambitn2013@yandex.ru

etc. [6-9]. All factors together have a direct impact on the intensity of carbon dioxide production in the surface of agroecosystems [10]. This is due to the fact that the root system is involved in the process of soil gas exchange, as well as due to the symbiotic microflora of legumes.

Previous studies indicate that the rate of carbon dioxide production correlates with the root system mas, both within one species and in different types of cultivated plants, fallows, as well as varieties and hybrids. This may be due to a number of reasons. The first is the root system, namely its volume and mass, which, as some studies show, affects the processes of gas exchange in agroecosystems as a result of respiration [11], the second reason is the activity of soil biota, in particular nodule bacteria in legumes, which participate in the process of soil gas exchange [12]. In this regard, to present a picture of the global model of carbon dioxide emissions in agrocenoses, it is necessary to assess the contribution of various types of crops to carbon dioxide emissions.

The purpose of the study is to evaluate the influence of cultivated crops and fallows on the intensity of carbon dioxide emissions in the Trans-Urals.

2 Materials and Methods

Studies on the effect of carbon dioxide production rate in the cultivation of various types of crops and fallows were conducted on leached chernozem in 2023. The agricultural technology in the experiment was traditional for the northern forest-steppe zone, while fertilizers were not used in the experiment. The crops studied included spring wheat, corn, second-year alfalfa, and dead fallow. Emission measurements were carried out during the growing season (May-October), every 10-16 days by the chamber method using an infrared gas analyzer, the research methodology is published in more detail in the previously conducted work [3].

3 Results and Discussion

The production of carbon dioxide in seedings of various crops may differ significantly throughout the year, as well as depending on weather conditions, temperature, humidity, and soil type [13]. In dead fallow, due to the absence of plants, carbon dioxide emissions occur due to the process of organic matter mineralization and respiration of soil microbiota [14].

In early May, the CO_2 emission rate in dead fallow was 34.0 kg/ha (Fig. 1). By May 25, this indicator increased by 20%, relative to the initial values at LSD_{05} = 4.9 kg of CO_2/ha per day. The following measurements, which were carried out in the month of June, were similar to the values obtained at the end of May. It was only by July 10 that an increase in the rate of carbon dioxide emission in dead fallow began to be noted, where values relative to previous measurements increased to 79.9 kg CO_2/ha per day, which was the maximum in this studied variant. Subsequently, starting in August, there was a change in the CO_2 production rate downwards. By August 9, carbon dioxide emissions had dropped almost twice, relative to the values obtained in July, and dropped further during the study to 8.1 kg/ha. The first reason for the variation in the emission rate is the change in soil temperature, which has a direct effect on the activity of soil aerobic microorganisms that participate in the respiration process. The second reason may be that the activity of microorganisms in the soil depends on the nitrogen content in the soil, and the maximum nitrogen accumulation activity of the current nitrification occurs in the month of July [15].

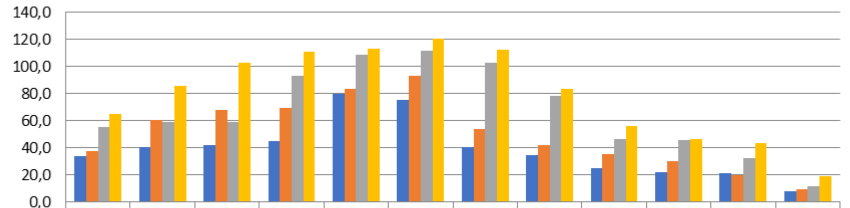
In spring wheat seedings at the beginning of May, the release of carbon dioxide from the soil is 37.4 kg CO_2/ha per day, which did not differ significantly from the values obtained on dead fallow. This is due to the fact that during this period of time, the root system of spring wheat is at the initial stage of development and practically does not participate in the process of soil gas exchange. By May 25, the intensity of gaseous carbon losses increases by more than two times relative to the initial values. Relative to the dead fallow, the values obtained during this period are twice as high as in the dead fallow at the same time. Subsequently, by June 10, carbon dioxide emissions increased by 12% relative to previous values and were 60% higher than in fallow. On June 24, the loss of carbon dioxide from the soil under spring wheat crops did not differ significantly from previous measurements. By the end of the first decade of July, the gaseous carbon losses rate intensity increased by 20% relative to previous measurements. The highest rate of carbon dioxide production in spring wheat crops occurred in the third decade of July and was 19% higher than in dead fallow during the same period. As well as in dead fallow, after July 25, there was a gradual decrease in daily carbon dioxide losses per unit area, in August the values dropped to 53.8-41.9 kg/ha, in September to 35.1- 30.3 kg/ha, in October to 20.1-9.3 kg/ha. At the same time, with dead fallow from October, the differences cease to be noted until the end of the growing season. This is due to the fact that after harvesting spring wheat, the root system of the plant ceases to participate in soil respiration.

In corn crops at the beginning of development, the emission intensity was higher than in spring wheat crops and dead fallow by 18.3 and 21.7 kg/ha, respectively. This may be due to the fact that corn was sown later than spring wheat, and cultivation and sowing increased soil aeration, which led to increased biological activity of the soil, and as a result respiration. This theory is further explained by the fact that until June 10, there were no significant differences in the rate of carbon dioxide production in corn crops. Due to the biological characteristics of corn, namely due to the poorly developing root system at the beginning of the growing season. Therefore, on June 10, the emission rate of spring wheat, which was in the active growth phase, was 13% higher than in corn crops. At the end of June, during the period of active growth and root mass gain in corn, the intensity of the carbon dioxide emission rate changes. During the day, corn emission begins to be higher than that of spring wheat by 23.3 kg/ha and in the remaining study period it is higher than that of spring wheat. By the end of July, there was an increase in CO_2 emissions to 112.0 kg/ha, which is the maximum marked value for this crop. In the future, there is a decrease in the rate of carbon dioxide emissions in corn crops by 8% from the maximum values by the end of the first decade of August. Despite this, the rate of CO_2 emission remains almost twice as high as in spring wheat crops. At the end of August, there is a significant decrease in gaseous carbon sequestration in corn crops, where the rate of CO_2 production decreased by 24% compared to the previous period. Nevertheless, it was also significantly higher than in spring wheat crops. Subsequently, the rate of carbon dioxide emission continued to decrease, reaching a minimum of 11.8 kg/ha in mid-October. At the same time, almost to the end of the observations, it was noted that in corn crops the emission intensity is significantly higher than in spring wheat. It was only by October 17, when the soil temperature dropped below 7°C, that significant differences in emission intensity between crops ceased to be observed. The increased CO_2 emissions in the second half of the corn growing season relative to spring wheat is due to the fact that corn root system during this time period significantly exceeds grain crops in weight and, as a result, has a stronger effect on soil gas exchange [16].

In alfalfa crops of the second year of use, the intensity of carbon dioxide emissions was higher than in sowings of cereals and row crops during the entire research period. This may be due to the fact that the root system of perennial grasses of the second year of use has already been formed and is fully involved in soil gas exchange [17].

Starting in May and almost until the end of October, the emission of carbon dioxide from the soil surface under alfalfa is 1.5-2 times higher than that of spring wheat. At the same time, the general dynamics during the growing season in terms of the rate of gaseous carbon losses is similar to other studied crops. By the end of July, the CO_2 emission rate increases to 121.0 kg/ha and then begins to drop to 19.0 kg/ha.

In this regard, it can be assumed that the overall dynamics of emissions during the growing season of cultivated plants may be related to the hydrothermal coefficient, namely the soil temperature. While the type of cultivated plant affects the amount of carbon sequestered in a specific period of time, which is confirmed by the data obtained.



	11.05	25.05	10.06	24.06	10.07	24.07	9.08	24.08	5.09	19.09	4.10	17.10
Dead fallow	34,0	40,8	42,2	45,3	79,9	75,2	40,3	34,5	24,9	22,3	21,3	8,1
Spring wheat	37,4	60,7	67,7	69,8	83,7	93,2	53,8	41,9	35,1	30,3	20,1	9,3
Corn	55,7	58,8	59,0	93,1	108,7	112,0	103,2	78,5	46,3	46,0	32,7	11,8
Alfalfa	64,9	85,8	102,6	111,1	113,4	121,0	112,3	83,7	56,4	46,8	43,7	19,0

Fig. 1. Carbon dioxide emissions from the cultivation of various types of crops and fallows, kg of CO_2/ha per day (LSD05 =4.9 kg of CO_2/ha).

In total, from May to October, carbon dioxide emissions reached 6,753 kg/ha at the site without cultivated plants (Fig. 2). The cultivation of spring wheat increased the rate of gaseous carbon losses ib the form of CO_2 to 8779 kg/ha, which indicates that the share of the contribution of spring wheat root system to the total emission is 30%.

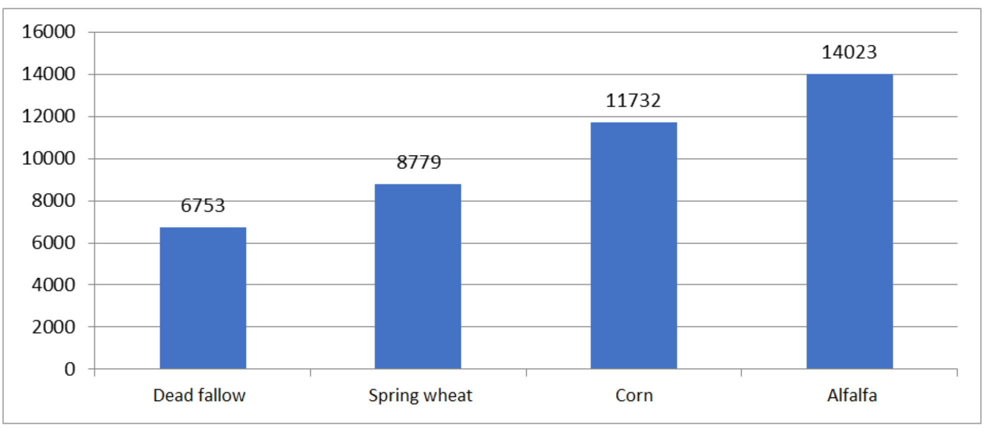


Fig. 2. Total carbon dioxide emissions during the growing season, kg/ha.

In corn crops, the contribution of the root system to emissions during the growing season was 74%, and in alfalfa crops 108%.

4 Conclusions

The intensity of carbon dioxide emissions in agrocenoses significantly depends on the type of cultivated crops and fallows. During the growing season, the intensity of carbon dioxide production from the soil surface in all studied variants increased from May to July due to soil warming. In the future, the intensity of CO_2 emissions begins to gradually decrease by mid-October. In the fallow field, the emission values during the growing season varied in the range of 8.1-79.9 kg/ha during the day. In spring wheat, these values were 1.1-1.6 times higher, in corn - 1.4-2.6 times. On a site without cultivated plants, carbon dioxide emissions reached 6,753 kg/ha during the growing season. The cultivation of spring wheat increased the rate of gaseous carbon losses ib the form of CO_2 to 8779 kg/ha, which indicates that the share of the contribution of spring wheat root system to the total emission is 30%. The share of the root system of corn and alfalfa in the total emission was 74% and 108%.

Acknowledgments

Research completed with grant support Russian Science Foundation № 23-76-10005, https://rscf.ru/en/project/23-76-10005/

References

1. Yu.A. Israel, A.A. Romanovskaya, Meteorology and Hydrology, **5,** 5-15 (2008).
2. International Energy Agency (IEA). Global Energy Review: CO2 Emissions in 2021; IEA: Paris, 2022. https://www.iea.org/reports/ global-energy-review-co2-emissions-in-2021-2.
3. E. Demin, S. Miller, K. Likhanov, BIO Web of Conferences, **82,** 06006 (2024) DOI 10.1051/bioconf/20248206006
4. R.I. Safin, A. R. Valiev, V. A. Kolesar, Bulletin of the Kazan State Agrarian University, **16(3(63)),** 7-13 (2021). DOI 10.12737/2073-0462-2021-7-13.
5. Yu.A. Fedorov, V.V. Sukhorukov, R.G. Trubnik, Anthropogenic transformation of the natural environment, **7(1),** 6-34 (2021). DOI 10.17072/2410-8553-2021-1-6-34.
6. D.I. Eremin, E.A. Demin, IOP Conference Series: Earth and Environmental Science, **1043(1),** 012016 (2022). DOI 10.1088/1755-1315/1043/1/012016.
7. V.M. Garmashov, I.M. Kornilov, N.A. Nuzhnaya, et al, Bulletin of the Kursk State Agricultural Academy, **7,** 39-44 (2018).
8. E. Demin, IOP Conference Series: Earth and Environmental Science, **1043(1),** 012027 (2022) DOI 10.1088/1755-1315/1043/1/012027
9. K. Paustian, J. Six, E.T. Elliott, H. Hunt, *Management options for reducing CO_2 emissions from agricultural soils*, Biogeochemistry **48(1)** 147-163 (2000). 10.1023/A:1006271331703
10. L.P. Polyakova, Economics, Labor, Management in Agriculture, **6(100),** 43-56 (2023). DOI 10.33938/236-43
11. O.E. Sukhoveeva, Proceedings of the Russian Academy of Sciences. Geographical series, **2,** 74-85 (2018). DOI 10.7868/S2587556618020073.
12. T.I. Chernov, M.V. Semenov, Soil Science, **12,** 1506-1522 (2021) DOI 10.31857/S0032180X21120029.
13. M.A. Ponomarev, V.N. Surovtsev, Environmental protection and nature management, **3,** 49-52 (2023).
14. A.A. Zavalin, A.S. Karashaeva, H.A. Husainov, Agrochemical Bulletin, **1,** 19-23 (2024) DOI 10.24412/1029-2551-2024-1-004.
15. E. Demin, D. Eremina, *Balance model of humus state of arable chernozems of the Western Siberia*, International Scientific and Practical Conference on Development of

the Agro-Industrial Complex in the Context of Robotization and Digitalization of Production in Russia and Abroad (2021) DOI: 10.1088/1755-1315/949/1/012084

16. Yu.A. Kuzychenko, R.S. Stukalov, R.G. Gadjiumarov, Bulletin of Nizhnevolzhsk Agrarian University Complex: Science and higher professional education, **1(57),** 74-81 (2020) DOI 10.32786/2071-9485-2020-01-07.
17. D.M. Pankov, *The intensity of development of the root system of perennial legumes and their role in growing on an artificial substrate in the conditions of the forest-steppe of the Altai Territory,* **2,** 14-22 (2024)