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Hemp *(cannabis sativa l.)* Is an effective carbon-depositing crop

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Abstract. The article presents the results of a quantitative assessment of carbon deposition by sowing hemp *(Cannabis sativa L.)*. Field studies were conducted in Khabibrakhmanov Peasant Farm Enterprise (Republic of Bashkortostan), the carbon content in plant biomass was determined by the CN 802 analyzer. It was found that cannabis crops form 7.87 t/ha aboveground biomass at the end of the growing season, including stems – 6.40 t/ha (81.3% of the aboveground mass), inflorescences – 0.77 t/ha (9.8% of the aboveground mass), seeds - 0.70 t/ha (8.9% of the aboveground mass), and roots - 1.02 t/ha. Of the total biomass, 8.19 t/ha is preserved. Sowing captures a relatively large amount of carbon dioxide from the atmosphere (14.78 t/ha) and, accordingly, carbon (4.03 t/ha). The effectiveness of cannabis in terms of decarbonization mainly consists in the conservation of a significant amount of accumulated carbon (91%) for a long time into long-term products and into the soil. The cultivation of hemp in carbon farms is recommended to reduce the carbon footprint and sell carbon units.

1 Introduction

One of the most important problems of mankind in the last decade is global climate change due to an increase in greenhouse gases in the air. An increase in the concentration of greenhouse gases delays the infrared spectrum of solar radiation near the planet surface, as a result of which it heats up [1]. Today, the world community is taking measures to prevent climate warming. Thus, back in 2005, the European Union launched a scheme for trading quotas for CO_2 emissions. In 2015, within the framework of the Paris Agreement, quotas were replaced by a new approach to forming states' own policies to combat greenhouse gases, setting an unprecedented goal – to reduce carbon emissions to almost zero by 2050. According to the Decree of the President of the Russian Federation dated 11/14/2020 No. 666 "On reducing greenhouse gas emissions", it follows that by 2030 it is planned to reduce emissions by 30% compared with 1990. Russia, as a participant in global efforts to counter climate change, plans to achieve carbon neutrality by 2060. This was stated by President V.V. Putin during the virtual G20 summit on November 22, 2023.

One of the directions of combating climate change is the use of a biological method of capturing carbon from the atmosphere and its "conservation" in the soil with the help of plants and soil biota, in contrast to expensive physico-chemical (the use of various types of filters

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and adsorbents) and geological (pumping carbon into the deep layers of the earth). Most researchers see forest plantations [2, 3], swamps [4] and steppe ecosystems [5] as a means of depositing carbon from the atmosphere. Crop production, in particular, field crops, occupies an important place in carbon deposition [6]. There is fragmentary data on the expediency of cultivating leguminous perennial grasses due to the greater intake of their post-harvest and root mass into the soil [7]. Rapeseed is particularly good at absorbing carbon from the atmosphere and storing it underground, because its roots go deeper than many other crops [8]. There is an indication that flax, hemp and miscanthus are promising carbon-negative crops [9]. It is believed that hemp is one of the fastest growing plants in the world and can grow up to 4 meters tall in 100 days. Hemp is twice efficient as trees at absorbing and retaining carbon: 1 hectare (2.5 acres) of hemp absorbs from 8 to 22 tons of CO_2 per year, more than any forest area [10]. In Italy, hemp is considered as an environmentally friendly crop capable of mitigating climate change and desertification [11].

At the same time, there is practically no scientific information in the Russian Federation on quantitative indicators of carbon deposition by hemp. The quality and use of hemp in the food, textile, pharmaceutical, and construction sectors of the country's economy have been studied in sufficient detail. It has been established that products made from hemp are environmentally safe and easily decomposed by microorganisms [12]

Hemp seeds are used for the production of oil, and are also eaten in hulled, crushed, or sprouted form. They contain minerals (K, P, S, Mg, Fe, Ca, Zn, etc.), vitamins PP, B1, B2, B3, B6, C, E, beta-carotene, essential fatty acids Omega-3 and Omega-6 in an optimally balanced ratio for humans (1:3). Cosmetic preparations based on hemp oil are hypoallergenic, have a high penetrating ability, have regenerating, moisturizing, toning properties, restores the hydrolipidic balance of the skin, maintaining its elasticity and smoothness, protects the skin from harmful ultraviolet radiation. In many countries of the world, hemp is grown for medical (pharmacological) purposes, as a source of the most valuable pharmacological raw material – cannabidiol [12, 13].

The fiber obtained from the stem does not rot, and is considered an almost indispensable raw material for the production of slings, ropes, twines, steel cable cores and various technical fabrics for use in aggressive environments, such as seawater. Fiber is also a major component of yarns and fabrics for the production of home textiles and clothing. Hemp cellulose is used for the production of paper and packaging materials, and it is also used in the textile, chemical, and perfumery and cosmetics industries. With the addition of synthetic substances to hemp fiber, bioplastics are obtained, which are then used to manufacture consumer electronics housings. In the global automotive industry, bio-composite hemp products are becoming increasingly popular for the production of body parts, seat fillers and other elements [14].

In the world, the popularity of using brome in construction in combination with lime or cement (Hempcrete), which give the natural material a high degree of strength, is increasing. Insulation materials and composite materials made of hemp are widely used due to their high functionality, durability and shape preservation [15]. Thus, in Ufa, at the USSTU Konoplast LLC, they mastered the development of new composite materials based on technical hemp.

Considering the demand for hemp products, its acreage in the country is expanding and in 2022 amounted to 13.8 thousand hectares. According to the experts of Smart Consult, in the medium term, the hemp seed production volume in Russia by 2025 may amount to 7.6 thousand tons [16].

In this regard, the purpose of the study was to quantify the potential of hemp cultivation in carbon deposition and conservation.

2 Materials and Methods

The object of the study was the dual-use hemp variety Rodnik (*Cannabis sativa L. ssp. Sativa)*. Field observations, morphological analysis of plants, laboratory analysis of soil and plant biomass were carried out. Field research was carried out in the Khabibrakhmanov Peasant Farm Enterprise, whose territory is located in the pre-Ural steppe of the Republic of Bashkortostan. The climate of this zone is sharply continental. The sum of positive temperatures during the growing season is 2570°C and for a ten-degree period is 2250°C. The duration of the frost-free period is 201-203 days. During the growing season, 300 mm of precipitation falls, the hydrothermal coefficient is 0.96. The soil of the experimental field is characterized by a neutral reaction. The content of organic matter in the soil is typical for leached chernozem, the content of macronutrients (phosphorus, potassium, sulfur) is quite high. The availability of manganese in the soil is medium (48.84 mg/kg), highly provided with boron (2.31 mg/kg) and molybdenum (0.08 mg/kg).

We considered the density of plants, determined the phenological phases of plants – according to the methodology of the State Variety Testing, plant height – by measuring with a measuring ruler, leaf area – by portion method, photosynthetic potential and net photosynthesis productivity - according to A. A. Nichiporovich [17]. Determination of the aboveground mass of plants – by weighing the mass of plants from 1 m^2 in nine places of the site, the underground mass (roots) of plants – by the Stankov method [18]. Agrochemical analysis of the soil was carried out according to the relevant GOST standards. The carbon content in the biomass of plants was determined by the CN 802 analyzer.

3 Results and Discussion

One of the positive parameters of hemp plants in terms of carbon deposition is a relatively long vegetation period and the formation of a large biomass. In 2023, the duration of vegetation of plants was 103 days, which is significantly more than this indicator of spring grain crops. Before harvesting (September), the density of standing plants was 138 pcs/m^2 and the height of plants was 135 cm.

Hemp sowing reached the maximum photosynthesis area by the flowering phase (36.7 thousand m2/ha), although due to relatively arid and hot weather, the photosynthesis area was formed slowly and relatively lower than typical for this crop. The photosynthetic potential changed similarly to the area of the photosynthetic apparatus of the phytocenosis. The net productivity of photosynthesis in the flowering phase was 6.03 g/m2 day.

The aboveground biomass of hemp crops at the end of the growing season was 7.87 t/ha, including the mass of stems – 6.40 t/ha (81.3% of the aboveground mass), inflorescences – 0.77 t/ha (9.8% of the aboveground mass) and seeds - 0.70 t/ha (8.9% of the aboveground mass) (table). In Serbia (Institute of Field and Vegetable Crops), the yield of hemp stems of the Carmagnola variety averaged 13.23 t/ha [19]. In our studies, the relatively low biomass of hemp plants is due to arid climatic conditions.

Hemp has a taproot system that penetrates up to one and a half meters deep. The bulk of the hemp roots was in a layer of 30 cm and it amounted to 1.02 t/ha or 13.0% of the above-ground mass. 8.89 tons of biomass was formed per hectare of sowing.

Table 1. Indicators of carbon deposition and conservation by sowing hemp.

Plant organ of hemp	Weight, t/ha	C content, %	C deposit, t/ha
Stem	6,40 (72%)	44,60	2,85 (70,7%)
including:			
hemp stock	5.63	44,60	2,51

Inflorescence	0,77 (8,6%)	44,58	0,34 (8,4%)
Seeds	0,70 (7,9%)	54,14	0,37 (9,2%)
Total aboveground mass	7.87	–	3,56
Roots	1,02 (11,5%)	45,87	0,47
Total conservation	8.19	–	3,66 (11,7%)
including:			
stems in long-term use products	5.63	44,60	2,51
stems (stubble) and inflorescences in the soil	1.54	44,60	0,68
roots in the soil	1.02	45,87	0,47
Total	8.89	–	4,03

According to the results of laboratory analysis, the carbon content in the stems was 44.6%. The stems deposited the main amount of carbon 2.85 t/ha, which is 70.7% of the total amount of carbon in the biomass (Figure). In the inflorescences, the carbon content was 44.38% and, per hectare, the mass of inflorescences was 0.34 tons, or 8.4% of the total amount absorbed by sowing. Laboratory analysis has shown that the carbon content in seeds is significantly higher (54.14%) than in the stem, inflorescence and root. The seed yield of 7.0 t/ha contained 0.37 t/ha of carbon or 9.2% of the total amount absorbed by sowing. In general, 1 hectare of hemp crop deposited 4.03 tons of carbon, including in the aboveground mass of 3.56 tons and roots of 0.47 tons (11.7% of the total amount absorbed by sowing).

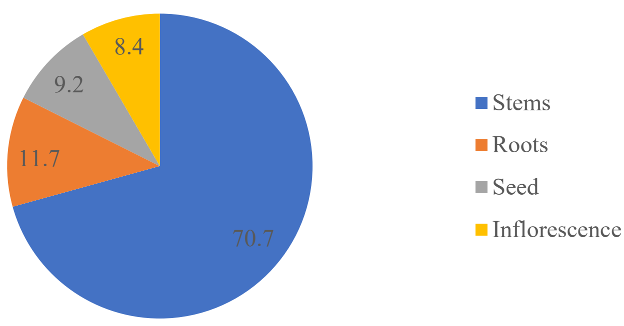

Fig. 1. The share of vegetative organs of cannabis plants in carbon storage.

The advantage of hemp in terms of reducing carbon dioxide in the atmosphere is not so much in the formation of a large biomass, there are plants with higher biomass, but in the conservation of a significant volume of its products. The information above was given: various products from hemp stems have long-term use and they remove carbon from the cycle for a long time, for example, tow and hempcrete up to 50-80 years. For dual use (for seeds and hemp stock) 80% of the aboveground hemp biomass is removed from the field, and the rest of the aboveground mass in the form of stubble and crushed inflorescences and the upper part of the stem remains in the field. According to our calculations, when the hemp stock yield 5.63 t/ha, carbon is removed from 1 hectare of sowing of 2.51 t from the field and it is preserved in processing products for a long time.

The roots, crushed inflorescences and part of the stems (stubble) are embedded in the soil after harvesting the seeds. The weight of these hemp parts was 2.56 t/ha. The carbon content in the roots is 45.87%, stems – 44.60% and inflorescences – 44.58%. As a result, carbon is stored in the soil of 1.15 t/ha.

Hemp seeds are processed into edible oil and the cake is used as animal feed. Therefore, carbon in seeds is usually not preserved for a long time.

In general, hemp crops deposit carbon per year of 4.03 t/ha or 14.78 t/ha of CO_2, 91% (3.66 t/ha) of carbon preserved for a long time. Compared with the annual accumulation of carbon in the phytomass of forests in the Republic of Bashkortostan (on average 3.8 t/ha) [3] hemp cultivation is more effective for carbon deposition.

In Khabibrakhmanov Peasant Farm Enterprise, hemp has been cultivated on an area of 620 hectares in recent years. The farm has established the production of fiber from hemp stock, as well as brome is sold to consumers. In general, 2498 tons of carbon or 9160 tons of CO2 are absorbed by hemp crops in this farm, 2269 tons of carbon are preserved in the form of fiber and brome, transformed into soil carbon.

4 Conclusions

Hemp crops capture a relatively large amount of carbon dioxide (14.78 t/ha) and, accordingly, carbon (4.03 t/ha) from the atmosphere. The effectiveness of cannabis in terms of decarbonization mainly consists in the conservation of a significant amount of accumulated carbon (91%) for a long time into long-term products and into the soil. It is advisable to cultivate hemp in carbon farms to reduce the carbon footprint and sell carbon units.

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