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Influence of Hemp Residues on Soil Chemical Parameters and Spring Wheat Productivity

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Abstract: The utilization of hemp residues, obtained after the harvest of hemp flowers, is a potential soil amendment in crop cultivation that might enhance soil health, nutrient availability, and crop productivity. However, more research is required to choose the best agricultural practice for optimizing hemp residue degradations. This study aimed to determine the integrated effects of hemp residues in different soil tillage systems on spring wheat yield. The results of the two-year experiment show that under favorable climatic conditions and soil moisture contents, the highest spring wheat grain yield (6.0 t ha^{-1}) is achieved in plots where hemp residues are plowed in autumn. Similar results are obtained in dry weather conditions, but the yield is lower by more than half—2.3 t ha^{-1}. The influence of residues increases the C content in the soil. The findings advance our understanding of integrated agricultural practices through the utilization of hemp residues for promoting resilient and sustainable crop production systems.

Keywords: hemp residues; soil; spring wheat; yield

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1. Introduction

Improving agricultural crop productivity and soil chemical composition by introducing crop residues is one of the sustainable farming practices encouraged in recent times [1]. Crop residue consists of plant biomass left in the field after harvesting valuable parts such as the stems, leaves, and seeds [2]. About 5 billion metric tons of crop residues are produced annually worldwide [1]. Despite this large amount, only a small fraction is used for animal feed, biorefinery production, or household fuel, and it requires labor-intensive collection and transport processes.

Residue incorporation is an optimal farm management strategy that not only preserves soil health in the long term, but also improves the grain yield, nutrient absorption, and resistance to pests. Crop residues contain nutrients essential for soil fertility and sustainability [1,3]. Their incorporation enriches soil nutrient profiles, improves soil material, conserves water, increases soil porosity [4], and promotes soil carbon sequestration [3]. During decomposition, residues break down through the action of soil microbes, releasing macro- and micronutrients into the soil [5]. The retention of crop residues increased the stability of the agricultural environment as well as the availability of nutrients [6]. Crop residue decomposition is influenced by soil microbial populations, soil conditions (temperature, moisture, and porosity), residue type and quality, residue placement, the degree of soil contact, tillage, and the cropping method [3,7,8].

Hemp fiber is a replaceable product for food, pharmaceuticals, textiles, and construction materials. Moreover, it is likely to contribute to carbon sequestration in the soil and, simultaneously, reduce greenhouse gas emissions [9]. Fiber hemp loosens and softens the soil, and the fallen leaves form a mulch that preserves soil materials and bacteria. After harvesting, the root system quickly disappears. If fiber hemp is applied in the field, up to two-thirds of the organic matter might be returned to the soil. Farmers mostly use crop straw to return vital nutrients to the soil. There are many experiments about straw's influence on the soil's chemical properties, crop yield, and straw decomposition. Hemp residues have a longer decomposition time compared to other crops' straw [10]. The practice of returning hemp residues to the soil after hemp flower harvest is still not widespread. Furthermore, scientists have only conducted a few experiments to determine the influence of hemp residues on the soil's chemical properties and crop yields. Fiber hemp plants reduce the population of nematodes and pathogenic fungi in the soil, and they can be used without pesticides, herbicides, or fungicides [11]. The introduction of fiber hemp in crop rotation has been suggested to improve healing processes [12]. However, knowledge about the decomposition of fiber hemp stems in the soil and its impact on soil quality and crop productivity is needed.

One of the most essential actions that reliably influence the soil structure is tillage, which affects the dynamics of crop residue decomposition in the soil ecosystem and increases fertilizers' efficiency [13]. Common tillage practices include residue incorporation, resulting in increased residue decomposition in the rhizosphere. Increasing soil porosity in the deeper soil layers by incorporating residues promotes the proliferation of the root system, which directly improves crop productivity [14]. In addition, this practice enhances the plant's physiological growth status, nutrient uptake, photosynthetic capacity, and yield [15]. In recent times, hemp has primarily been cultivated for its seeds and flowers rather than for its fibers, so there is a need to make use of the stems, which are often left as residues. A comprehensive look into the literature showed very few studies about hemp residues' influence on the crop yield and soil quality, though immediate responses of cyst nematode, soil-borne pathogens, and soybean yield to one-season hemp disturbance in continuous soybean were reported [16]. Common wheat (*Triticum aestivum* L.) was selected for research as it is one of the most important groups of crops in the world [17]. Wheat is one of the main sources of food for humans and animals. Therefore, scientists are constantly improving wheat varieties [18,19] and cultivation technologies and monitoring their adaptation to increasingly warmer climates [20] to preserve a stable and high-quality harvest. Still, scientists note that climate change is causing crop yields to decline, especially in areas with insufficient rainfall [21]. Therefore, it is necessary to find ways to preserve the wheat crop in the context of climate change; one of the ways is integrating crop residues. Hence, this study aimed to analyze the influence of hemp residues on the soil and its attendant effect on spring wheat yield.

2. Materials and Methods

2.1. Experimental Design and Treatments

The experiment was carried out in the experimental fields of the Lithuania Research Centre for Agriculture and Forestry (55°40′ N, 23°87′ E) for two growing seasons (2022 and 2023). The soil of the experimental fields was sandy loam (Endogleyic Epistagnic Endocalcaric Cambisol (*Loamic, Aric*, and *Drainic*)). The texture of the soil was 58.8% sand, 37.8% silt, and 3.9% clay. The spring wheat (*Triticum aestivum*) cultivar "Collada" (Einbeck, Germany) was selected for the experiment. The sowing rate was 210 kg·ha^{-1} (spring wheat). Seeds were sown on 22 April 2022 and 5 May 2023, respectively. The cultivation period was from April to August for two (2) years.

A year before spring wheat cultivation (2021 and 2022), hemp "*Cannabis sativa* L. cultivar Felina 32" was cultivated. Hemp flowers were harvested, and the rest of the biomass—8 t·ha^{-1}—was chopped. Hemp residues were returned to the soil by different tillage methods and at different times of the year (Table 1).

Table 1. The treatments used in the experiment.

Nomenclature	Treatments
1	Control (without hemp residues)
2	Hemp residues are plowed in autumn
3	Hemp residues are plowed in spring
4	Hemp residues left in the field with no tillage

The field experiment was established in a complete randomized design with 4 treatments in three replicates, and each one was tested for two years. Each treatment plot was 30 m^2 in size (3 m × 10 m). In treatment 2 (Table 1), after the harvest of flowers, hemp residues were immediately chopped and incorporated into the soil with a stubble scraper (8–10 cm deep), and after 2–3 weeks, the plots were plowed deeply (20–25 cm) with a semi-screw plow. For treatment 3, everything was the same as in treatment 2, but the residues were deeply plowed in the spring. For treatment 4, hemp residues were chopped and left on the soil in autumn. Before sowing, the soil was treated with a stubble scraper (6–8 cm deep) and sown with a universal disc seeder.

Spring wheat was fertilized with 210 kg ha^{-1} of ammonium nitrate once per cultivating season at the plant stem elongation stage.

Meteorological conditions showing the average air temperatures during the growing season (May–July) of 2022–2023 are presented in Figure 1. The average temperature was between 15.4 °C and 17.7 °C, while the long-term average was 16.75 °C. The total precipitation recorded in 2023 was lower compared to that in the first year of the experiment (53.2 mm) in the May–July period. In 2023, it was an extremely dry period during the experiment with an average precipitation of 9.6 mm (Lithuanian Hydrometeorological Service-Dotnuva data under the Ministry of Environment data, http://www.meteo.lt/, accessed on 22 February 2024)

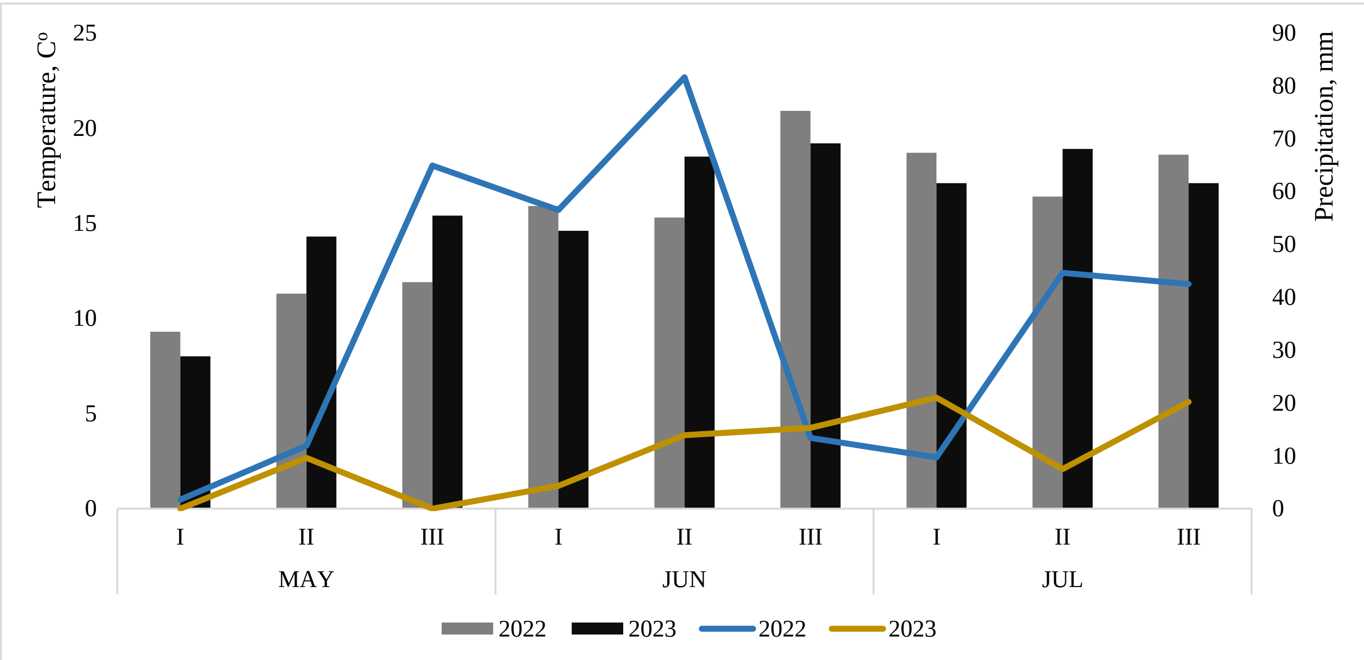

Figure 1. The meteorological conditions during the experimental period (the bars present the temperature data, and the lines—for temperatures I, II, and III—represent the years).

2.2. Analyses of Soil Chemical Properties

The carbon and nitrogen contents were measured using the CNS Elemental combustion system equipment (Netherlands). An amount of 10 mg of the samples was weighed in the alov capsule, and then the capsule was folded and placed in the equipment. The agrochemical properties measured from the soil layer were mobile P_2O_5 (130 ± 10 mg·kg^{-1}), determined using the Olsen method (A-L) in the extract (spectrophotometer) at a wavelength of 880 nm; mobile K_2O (150 ± 10 mg·kg^{-1}), determined using JENWAY PFP7 (A-L) in the extract (flame photometer) with the Egner–Riehm–Domingo method [22]; and organic carbon, determined using ISO 10694:1995 [23] with dry-fired standard coal analyzer Liquid TOC II. The soil was heated to +900 °C in a synthetic air flow, and an infrared detection method was used to measure the amount of carbon dioxide produced. Soil samples were collected before and after the end of the growing season in 2022 (after four months), before sowing in the year 2023, and after the year 2023 harvest (4 months) from the start of the experiment.

2.3. Photosynthetic Performance Measurements

The chlorophyll index was measured periodically at 20, 44, 60, and 78 days after sowing with a SPAD-502 chlorophyll meter (Minolta, Ramsey, NJ, USA). The SPAD device was used to measure the absorbance of chlorophyll in the blue (400–500 nm) and red (600–700 nm) wavelength ranges. Five plants were randomly selected in each plot, and the youngest fully expanded leaf was measured.

The maximum quantum efficiency of PSII photochemistry (Fv/Fm) was measured using a multi-function pulse-modulated handheld chlorophyll fluorometer (model OS-30p; manufacturer: Opti-Sciences, Inc., Hudson, NH, USA). Photosynthetic quantum efficiency was directly read after 20 min of dark adaptation on the chlorophyll fluorometer [24]. The actinic light intensity was 1000 µmol m^{-2} s^{-1}.

2.4. Statistical Analyses

The observed data were statistically processed using R Studio 4.3.2 software. Tukey's HSD test was applied to determine significant differences between means at an alpha level of 0.05. Lowercase letters that differ denote significant differences at $p < 0.05$.

3. Results

3.1. Spring Wheat Grain Yield

The variation in the spring wheat grain yield in different treatments is presented in Figure 2. The highest spring wheat yield of 6 t·ha^{-1} was determined in the control treatment and after the deep plow in autumn 2022. A significantly lower wheat grain yield was found in treatments where hemp residues were plowed in spring and hemp residues were left on the soil surface. This may have been influenced by the selective incorporation of hemp residues in early spring or by leaving them on the soil. The hemp residues did not have enough time to start the decomposition process. Because of this, the hemp residues started to compete with the plants for nutrients and nitrogen for the decomposition process, and the yields were lower.

Almost the same results were obtained in 2023, but due to the very dry conditions, the yield was more than twice as low as the one obtained in 2022. In 2023, the highest yield of 2.4 t·ha^{-1} was determined in the treatment involving hemp residues plowed in autumn, and a similar result to the control treatment was obtained. Further results show that in the treatment where hemp residues were left on the soil surface with no tillage, the yield was estimated at 0 t/ha, as only a few plants germinated. This was due to the extreme climatic conditions recorded in 2023 (Figure 1).

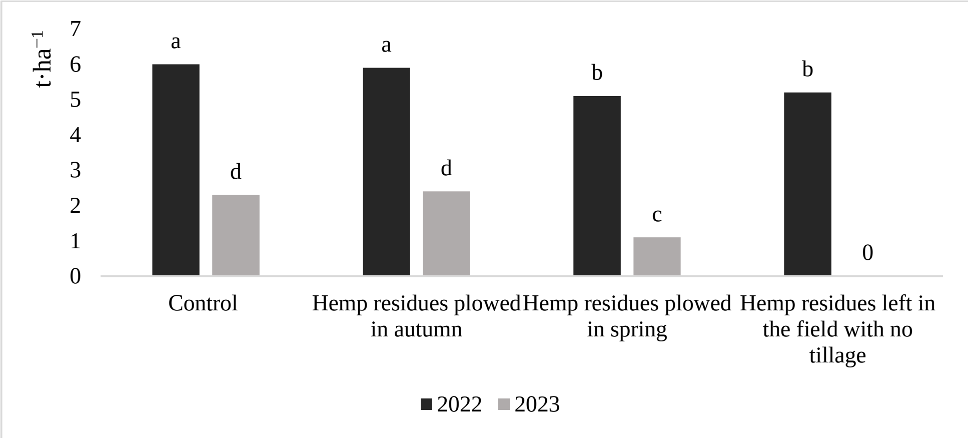

Figure 2. Spring wheat grain yield. Data are presented as means ± standard error; different letters correspond to significant differences ($p < 0.05$) between means according to Tukey's HSD test.

3.2. Spring Wheat Chlorophyll Index and Photosynthetic Quantum Efficiency

The chlorophyll index is directly proportional to the amount of chlorophyll in the leaves, an essential indicator for photosynthesis. The higher the chlorophyll in the leaves, the better the photosynthesis. As expected, during the experimental year of 2022, the results show that after 20 days of sowing, the highest nitrogen concentration was in the treatment where hemp residues were plowed in the soil in spring. This was due to the residues being incorporated in spring and not yet having had the time to absorb nitrogen for their decomposition process. A total of 44 days after sowing, the amount of nitrogen was already lower in the treatment where hemp residues were incorporated in early spring compared to the other treatments. However, statistically reliable results were obtained after 20 days only when comparing the hemp residues incorporated in early spring. No more statistically reliable results were obtained in any measurement period (Figure 3).

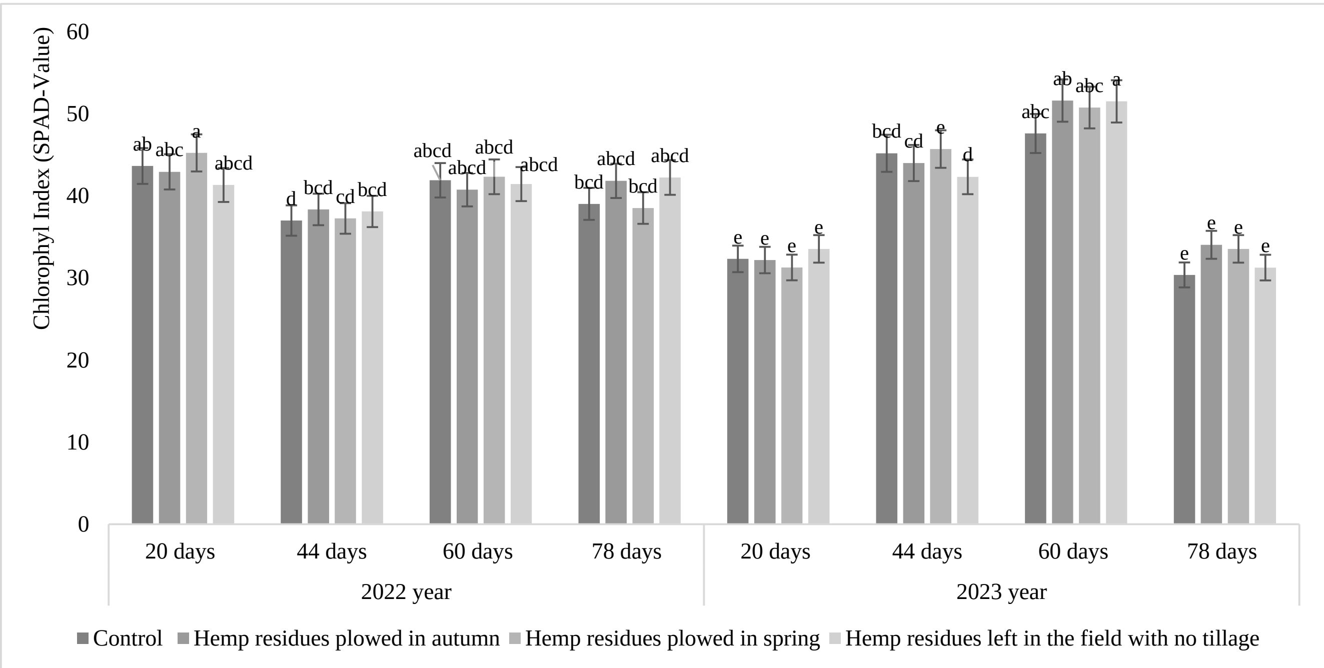

Figure 3. Chlorophyll index measurements were taken in a leaf of spring wheat during the experiment. The data are presented as the means ± standard error; different letters correspond to significant differences ($p < 0.05$) between the means according to Tukey's HSD test.

Furthermore, the results for 2023 show no significant difference between all of the treatments after 20, 60, and 78 days after sowing. Significant differences were observed between the hemp residues plowed in spring and the hemp residues left in the field and no tillage treatments 44 days after sowing. Additionally, it was observed that treatment 3 was statistically significant compared to all of the treatments during 44 days of observation (Figure 4).

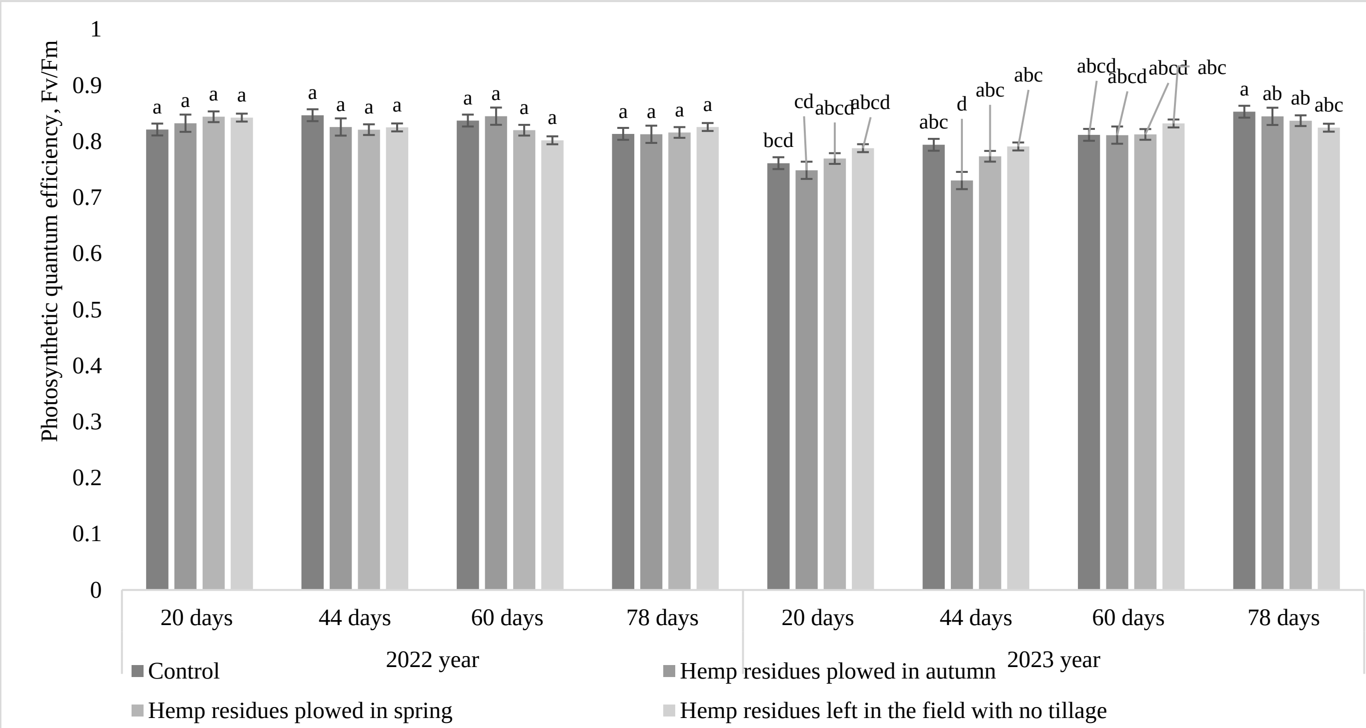

Figure 4. The effects of different tillage methods and hemp residues on the photosynthetic quantum efficiency of spring wheat. The data are presented as the means ± standard error; different letters correspond to significant differences ($p < 0.05$) between the means according to Tukey's HSD test.

A fluorescence analysis is essential as it helps show the plants' stress levels. The results show a typical high stress level in the plants. This must have resulted from the harsh meteorological conditions in 2022, which were characterized by high temperatures, although precipitation was normal.

The 2023 photosynthetic quantum efficiency results show statistically significant differences in all of the measurements. A total of 44 days after sowing, the treatment where the hemp residues were incorporated into the soil in autumn was the most distinguished with the lowest amount of photosynthetic quantum efficiency, and this result had significant differences ($p < 0.05$) compared to the other treatments. However, when comparing the observation periods, significant differences were found between the measurements taken 44 days after sowing and 78 days after sowing ($p < 0.05$). As expected, these results were influenced by an extremely dry season.

3.3. The Soil Chemical Parameters before and after the Experiment

The influence of the soil mobile phosphorus (P_2O_5), mobile potassium (K_2O), and organic carbon (OC) contents before and after the experiment is presented in Tables 2 and 3. The Table 2 results show that mobile P_2O_5 significantly decreased in the control and in the treatment where the hemp residues were plowed in autumn. However, in the treatment where hemp residues were plowed in spring, the mobile P_2O_5 content significantly increased. The mobile K_2O content decreased in all treatments after the experiment, with significant differences only being observed in the control. The organic carbon content did not have any significant differences before and after the experiment.

Table 2. The mobile P_2O_5, K_2O, and organic carbon contents in the soil in the 2021–2022 season.

	P_2O_5 before Exp.	P_2O_5 after Exp.	K_2O before Exp.	K_2O after Exp.	OC before Exp.	OC after Exp.
Control	82.6667d	65.6667b	163b	145.333a	0.9125a	0.77a
Hemp residues plowed in autumn	96.333c	87.333ab	182ab	151.66667a	0.975a	0.7333a
Hemp residues plowed in spring	106b	111.6667a	196.25a	157a	1.0175a	0.82333a
Hemp residues left in the field with no tillage	116a	117.66667a	194a	86.3333a	0.915a	0.91333a

Different letters in the column indicate significant differences at $p < 0.05$. Before exp.—before the experiment; after exp.—after the experiment; P_2O_5—phosphorus oxide; K_2O—potassium oxide; OC—organic carbon.

Table 3. The mobile P_2O_5, K_2O, and organic carbon contents in the soil in the 2022–2023 season.

	P_2O_5 before Exp.	P_2O_5 after Exp.	K_2O before Exp.	K_2O after Exp.	OC before Exp.	OC after Exp.
Control	107.6667a	78b	97.75a	86.333a	1.5175a	1.42a
Hemp residues plowed in autumn	97.6667a	94ab	101.5a	98a	1.62a	1.55a
Hemp residues plowed in spring	82a	84.6667a	98.25a	87.333a	1.575a	1.39a
Hemp residues left in the field with no tillage	89.3333a	89.6667a	102.5a	109.3333a	1.6875a	1.48333a

Different letters in the column indicate significant differences at $p < 0.05$. Before exp.—before the experiment; after exp.—after the experiment.

In 2023, significant differences in the mobile P_2O_5 content were found only in the control ($p < 005$). However, the mobile P_2O_5 content decreased by almost two times. Nonetheless, the mobile K_2O and organic carbon contents had no significant differences between the treatments before and after the experiment (Table 3).

3.4. The Soil Nitrogen and Carbon Contents before and after the Experiment

The nitrogen and carbon contents are among the most important aspects of soil health and wheat yield during the vegetation season. In this study, hemp residues were expected to improve the soil C and N availability. However, the results show that for 2022, the nitrogen content decreased after the treatments where hemp residues were plowed in spring and hemp residues were left in the field with no tillage. There were significant differences in the N content after the experiment between the treatments where hemp residues were plowed in autumn, hemp residues were plowed in spring, and hemp residues were left in the field with no tillage. Additionally, the lowest nitrogen content (0.21%) after the experiment was observed in the treatment where hemp residues were plowed in spring, which was statistically significant compared to the other treatments.

Similar results were observed in the carbon content after the experiment. Notably, the carbon content increased in the treatment where the hemp residues were left in the field with no tillage, showing a 44% carbon content increase after the experiment. The carbon content after the experiment increased in the soil for both years. In 2022, the highest carbon increase was observed in the treatment where hemp residues were left in the field with no tillage, while the lowest carbon content (1.60%) was found in the treatment where hemp residues were plowed in spring after the experiment (Table 4). Additionally, the carbon content in the treatment where hemp residues were left in the field with no tillage was significantly different from that of the other treatments after the experiment (Table 4).

Table 4. Nitrogen and carbon contents in soil in 2021–2022 season.

	N Content before Experiment, %	N Content after Experiment, %	C Content before Experiment, %	C Content after Experiment, %
Control	0.23c	0.23c	0.95d	1.79b
Hemp residues plowed in autumn	0.21c	0.24c	0.89d	1.65c
Hemp residues plowed in spring	0.22c	0.21b	0.95d	1.60c
Hemp residues left in field with no tillage	0.24c	0.23a	0.98d	2.18a

Different letters in the column indicate significant differences at $p < 0.05$. Before exp.—before the experiment; after exp—after the experiment; N—nitrogen; C—carbon.

Similarly, considering 2023, the nitrogen content was the highest after the experiment in the treatment where "hemp residues are left in the field and with no tillage" and was significantly different ($p < 0.05$) compared to the other treatments (Table 5). The same trend was observed in the carbon content in 2023, with the treatment where hemp residues were left in the field with no tillage resulting in a significantly higher carbon content after the experiment than the other treatments. However, no significant difference in the carbon content was found between the treatment where hemp residues were plowed in autumn and in the control before and after the experiment (Table 5).

Table 5. The nitrogen and carbon contents in the soil in the 2022–2023 season.

	N Content before Exp., %	N Content after Exp., %	C Content before Exp., %	C Content after Exp., %
Control	0.13b	0.16b	0.95c	0.93c
Hemp residues are plowed in autumn	0.13b	0.14b	0.89c	1.01c
Hemp residues are plowed in spring	0.14b	0.15b	0.95c	1.5b
Hemp residues left in the field with no tillage	0.14b	0.23a	0.97c	2.75a

Different letters in the column indicate significant differences at $p < 0.05$. Before exp.—before the experiment; after exp.—after the experiment; N—nitrogen; C—carbon.

4. Discussion

It is well known that the nitrogen content and straw residue incorporation affect the water and nutrient use efficiency, crop yield, and nutrient loss [25]. The present study indicates that tillage and hemp residues influenced the spring wheat yield. Additionally, climatic conditions influenced the spring wheat yield during the growing season. Returning fiber hemp residues to the soil can increase the grain yield. This may result from a higher chlorophyll content, leading to more photosynthetic accumulation, which was also reported by other researchers [26,27]. The grain yield is a key indicator of cereal productivity, influenced by soil quality, climatic conditions, and nutrient uptake [28–31]. Wang et al. [32] determined that the return of hay to the soil together with 150–225 kg·ha^{-1} of nitrogen fertilizers can ensure an improved grain yield, specifically 6480–6660 kg ha^{-1}, which is a yield similar to what was obtained in this study in 2022. Interestingly, the crop yields were halved in 2023 due to low precipitation and high temperatures. Therefore, it must be noted that returning plant residues to the soil, such as straw or hemp residues, can increase yields, but not in drought years. If the supply of nitrogen fertilizers is not increased promptly and efficiently, the yields will be adversely affected [25].

4.1. Chlorophyll and Photosynthetic Quantum Efficiency Contents

Chlorophyll is the primary growth pigment of plants, which contributes to photosynthesis. Stressful conditions negatively affect chlorophyll in plant leaves and can drastically reduce its content [33]. We noticed that in 2022, the highest chlorophyll index was determined 20 days after sowing, and the treatments where hemp residues were applied in early spring stood out the most. Later, during the growing season, the chlorophyll index remained similar. Still, the highest index was obtained either in the control or the treatment where hemp residues were inserted in the soil in autumn (Figure 4). This is because the mineralization of hemp residues requires nitrogen. After the plants were fertilized with nitrogen, the residues from the fall had already begun to mineralize, providing more nitrogen for the plants' uptake. The same results were obtained in a similar study by Li et al. [25,34] when they used mulch to grow wheat. However, in 2023, contrasting results were obtained when the lowest chlorophyll index was determined 20 days later. This season was particularly dry, with the results indicating that the chlorophyll index fluctuated significantly when the plants were under abiotic stress. All of this was due to drought and a low water content. Li et al. [25,34] emphasized the significance of this concerning the major influence of water quantity on the chlorophyll index in the leaves.

Another significant indicator is the maximum quantum efficiency of PSII photochemistry (Fv/Fm), which is usually used to determine the efficiency of the photosynthesis apparatus [35]. It is an effective tool for detecting changes in the performance of the photosynthetic apparatus that can be caused by environmental stress [33], nutrient changes, and soil compaction [36]. Little is still known about the influence of different tillage practices on photosynthetic quantum efficiency crops. Some studies have shown that tillage promoted photosynthesis by increasing the Fv/Fm ratio in maize [37] and winter wheat [38] compared to no tillage. Hussain et al. showed that the photosynthetic quantum efficiency did not differ significantly between tillage systems [36]. This study also found that tillage and hemp residues did not significantly affect the Fv/Fm ratio.

4.2. Tillage Effect on Crop Yield and Soil

The effect of different tillage systems on crop yield has been widely studied, but not all studies use plant residues in combination with tillage [39–43]. Some studies have found positive effects of direct tillage on the grain yield, yield components, and quality parameters [43–45]. Brennan et al. found that with minimum tillage, high crop residue returns can increase crop productivity by improving the soil structure and fertility [40]. However, the results of this study were inconsistent with those of Macak et al. [46] and Janusauskaite et al. [33], who reported that the simplification of tillage had a negative effect on plant productivity. The results of our study show that the grain yield significantly decreased when no-tillage farming was applied.

4.3. The Residue's Influence on the Nitrogen and Carbon Contents in the Soil

This study's results show that the nitrogen content did not differ significantly but increased after the experiment. Returning hemp residues to the soil can effectively boost soil organic carbon, enhance nitrogen immobilization and mineralization turnover, and increase nitrogen availability. The same results were obtained by other scientists who added straw to the soil [44]. The soil carbon also increased after incorporating hemp residues into the soil. Although different residue application times resulted in various amounts of carbon, an increase was observed in all cases. The carbon content of hemp residue might explain the increased carbon content, which it releases to the soil during decomposition. Chen and Wang found the same results with straw beautification [45,46].

5. Conclusions

The results show that hemp residues incorporated into the soil or left on the soil surface positively impact the spring wheat yield. The selected time of insertion and no-tillage farming were major factors involved in the positive impact noticed. Climatic conditions are also an important consideration that impacted the results in these studies. Crop yields can be meager in seasons with dry growing conditions and when hemp residues are left on the soil surface in no-tillage farming. Additionally, the results show that the safest and best yield was obtained by incorporating hemp residues in autumn before the plants started seeding. The residues begin the decomposition process in the soil and thus take up less nitrogen from the soil, thus resulting in a higher yield than when the residues are applied early or left on the soil surface. Hemp residue also increases soil carbon. However, the amount of nitrogen decreases due to the decomposition of residues; hence, additional nitrogen fertilization is required to preserve the maximum yield.

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References

1. Shinde, R.; Shahi, D.K.; Mahapatra, P.; Singh, C.S.; Naik, S.K.; Thombare, N.; Singh, A.K. Management of crop residues with special reference to the on-farm utilization methods: A review. *Ind. Crops Prod.* **2022**, *181*, 114772. [CrossRef]
2. Krishna, V.V.; Mkondiwa, M. Economics of Crop Residue Management. *Annu. Rev. Resour. Econ.* **2023**, *15*, 19–39. [CrossRef]
3. Xu, Y.; Ding, F.; Gao, X.; Wang, Y.; Li, M.; Wang, J. Mineralization of plant residues and native soil carbon as affected by soil fertility and residue type. *J. Soils Sediments* **2019**, *19*, 1407–1415. [CrossRef]
4. Fu, B.; Chen, L.; Huang, H.; Qu, P.; Wei, Z. Impacts of crop residues on soil health: A review. *Environ. Pollut. Bioavailab.* **2021**, *33*, 164–173. [CrossRef]
5. Fazal, A.; Khan, A.; Anjum, A.; Khan, S.; Khan, A.A.; Akbar, H. Wheat production and partial nitrogen budget in response to herbicide and nitrogen application. *J. Plant Nutr.* **2022**, *45*, 1253–1263. [CrossRef]
6. Khan, A. Phenology, Crop Stand and Biomass of Wheat in Response to Farmyard Manure and Soil Amendments. *Sarhad J. Agric.* **2020**, *36*, 777–788. [CrossRef]
7. Tian, P.; Lian, H.; Wang, Z.; Jiang, Y.; Li, C.; Sui, P.; Qi, H. Effects of deep and shallow tillage with straw incorporation on soil organic carbon, total nitrogen and enzyme activities in Northeast China. *Sustainability* **2020**, *12*, 8679. [CrossRef]
8. Raza, T.; Qadir, M.F.; Khan, K.S.; Eash, N.S.; Yousuf, M.; Chatterjee, S.; Manzoor, R.; Ur Rehman, S.; Oetting, J.N. Unrevealing the potential of microbes in decomposition of organic matter and release of carbon in the ecosystem. *J. Environ. Manag.* **2023**, *344*, 118529. [CrossRef]
9. Godeau, C.; Morin-Crini, N.; Staelens, J.N.; Martel, B.; Rocchi, S.; Chanet, G.; Fourmentin, M.; Crini, G. Adsorption of a triazole antifungal agent, difenoconazole, on soils from a cereal farm: Protective effect of hemp felt. *Environ. Technol. Innov.* **2021**, *22*, 101394. [CrossRef]
10. Stulpinaite, U.; Tilvikiene, V.; Doyeni, M.O. Decomposition of Hemp Residues in Soil as Facilitated by Different Nitrogen Sources. *Agriculture* **2024**, *14*, 508. [CrossRef]
11. Fleming, M.P.; Clarke, R.C. Physical evidence for the antiquity of *Cannabis sativa* L. *J. Int. Hemp Assoc.* **2015**, *5*, 80–95.
12. Adesina, I.; Bhowmik, A.; Sharma, H.; Shahbazi, A. A review on the current state of knowledge of growing conditions, agronomic soil health practices and utilities of hemp in the United States. *Agriculture* **2020**, *10*, 129. [CrossRef]
13. Khan, H.; Khan, A.; Khan, S.; Anjum, A.; Akbar, H.; Muhammad, D. Maize productivity and nutrient status in response to crop residue mineralization with beneficial microbes under various tillage practices. *Soil Tillage Res.* **2024**, *239*, 106057. [CrossRef]
14. Zhao, H.; Qin, J.; Gao, T.; Zhang, M.; Sun, H.; Zhu, S.; Xu, C.; Ning, T. Immediate and long-term effects of tillage practices with crop residue on soil water and organic carbon storage changes under a wheat-maize cropping system. *Soil Tillage Res.* **2022**, *218*, 105309. [CrossRef]
15. Gu, Y.; Liu, Y.; Li, J.; Cao, M.; Wang, Z.; Li, J.; Meng, D.; Cao, P.; Duan, S.; Zhang, M.; et al. Mechanism of Intermittent Deep Tillage and Different Depths Improving Crop Growth From the Perspective of Rhizosphere Soil Nutrients, Root System Architectures, Bacterial Communities, and Functional Profiles. *Front. Microbiol.* **2022**, *12*, 759374. [CrossRef]
16. Zhang, Q.Y.; Li, Z.L.; Han, B.J.; Zhou, K.Q.; Zhang, X.Y.; Hashemi, M.; Liu, X.B. Immediate responses of cyst nematode, soil-borne pathogens and soybean yield to one-season crop disturbance after continuous soybean in northeast china. *Int. J. Plant Prod.* **2013**, *7*, 341–353.
17. Shiferaw, B.; Smale, M.; Braun, H.J.; Duveiller, E.; Reynolds, M.; Muricho, G. Crops that feed the world 10. Past successes and future challenges to the role played by wheat in global food security. *Food Secur.* **2013**, *5*, 291–317. [CrossRef]
18. Yang, C.; Fraga, H.; van Ieperen, W.; Trindade, H.; Santos, J.A. Effects of climate change and adaptation options on winter wheat yield under rainfed Mediterranean conditions in southern Portugal. *Clim. Chang.* **2019**, *154*, 159–178. [CrossRef]
19. Omics, I.; Jeyasri, R.; Muthuramalingam, P.; Satish, L.; Pandian, S.K. An Overview of Abiotic Stress in Cereal Crops: Negative impacts, regulation, biotechnology and integrated omics. *Plants* **2021**, *10*, 1472. [CrossRef]
20. Jarecki, W. Response of Winter Wheat to Delayed Sowing and Varied Nitrogen Fertilization. *Agriculture* **2024**, *14*, 121. [CrossRef]

21. Neupane, D.; Adhikari, P.; Bhattarai, D.; Rana, B.; Ahmed, Z.; Sharma, U.; Adhikari, D. Does Climate Change Affect the Yield of the Top Three Cereals and Food Security in the World? *Earth* **2022**, *3*, 45–71. [CrossRef]
22. Buneviciene, K.; Drapanauskaite, D.; Mazeika, R.; Tilvikiene, V.; Baltrusaitis, J. Granulated biofuel ash as a sustainable source of plant nutrients. *Waste Manag. Res.* **2021**, *39*, 806–817. [CrossRef]
23. Mrak, T.; Grašič, B.; Prislan, P. Soil contamination with potentially toxic elements and root herbivory: Effects on root surface area and stem secondary xylem of young common beech (*Fagus sylvatica* L.). *Acta Physiol. Plant* **2023**, *45*, 1–8. [CrossRef]
24. Janusauskaite, D. The Allelopathic Activity of Aqueous Extracts of Helianthus annuus L., Grown in Boreal Conditions, on Germination, Devel-opment, and Physiological Indices of *Pisum sativum* L. *Plants* **2023**, *12*, 1920. [CrossRef] [PubMed]
25. Li, H.; Liu, R.; Peng, Y.; Wang, X.; Zhou, C.; Wang, J.; Wang, L. Straw Residual Retention on Wheat Photosynthetic Characteristics, Utilization of Water and Nitrogen, and Reactive Nitrogen Losses. *Agronomy* **2023**, *13*, 2988. [CrossRef]
26. Six, J.; Elliott, E.T.; Paustian, K. Soil macroaggregate turnover and microaggregate formation: A mechanism for C sequestration under no-tillage agriculture. *Soil Biol. Biochem.* **2000**, *32*, 2099–2103. [CrossRef]
27. Das, S.; Richards, B.K.; Hanley, K.L.; Krounbi, L.; Walter, M.F.; Walter, M.T.; Steenhuis, T.S.; Lehmann, J. Lower mineralizability of soil carbon with higher legacy soil moisture. *Soil Biol. Biochem.* **2019**, *130*, 94–104. [CrossRef]
28. Wu, G.; Ling, J.; Liu, Z.X.; Xu, Y.P.; Chen, X.M.; Wen, Y.; Zhou, S.L. Soil warming and straw return impacts on winter wheat phenology, photosynthesis, root growth, and grain yield in the North China Plain. *Field Crops Res.* **2022**, *283*, 108545. [CrossRef]
29. Srivastava, R.K.; Panda, R.K.; Chakraborty, A.; Halder, D. Enhancing grain yield, biomass and nitrogen use efficiency of maize by varying sowing dates and nitrogen rate under rainfed and irrigated conditions. *Field Crops Res.* **2018**, *221*, 339–349. [CrossRef]
30. Li, N.; Zhou, C.; Sun, X.; Jing, J.; Tian, X.; Wang, L. Effects of ridge tillage and mulching on water availability, grain yield, and water use efficiency in rain-fed winter wheat under different rainfall and nitrogen conditions. *Soil Tillage Res.* **2018**, *179*, 86–95. [CrossRef]
31. Otteson, B.N.; Mergoum, M.; Ransom, J.K. Seeding rate and nitrogen management effects on spring wheat yield and yield components. *Agron. J.* **2007**, *99*, 1615–1621. [CrossRef]
32. Wang, X.; Jia, Z.; Liang, L. Effect of straw incorporation on the temporal variations of water characteristics, water-use efficiency and maize biomass production in semi-arid China. *Soil Tillage Res.* **2015**, *153*, 36–41. [CrossRef]
33. Janusauskaite, D.; Kadziene, G. Influence of Different Intensities of Tillage on Physiological Characteristics and Productivity of Crop-Rotation Plants. *Plants* **2022**, *11*, 3107. [CrossRef]
34. Li, S.X.; Wang, Z.H.; Li, S.Q.; Gao, Y.J. Effect of nitrogen fertilization under plastic mulched and non-plastic mulched conditions on water use by maize plants in dryland areas of China. *Agric. Water Manag.* **2015**, *162*, 15–32. [CrossRef]
35. Kulig, B.; Lepiarczyk, A.; Oleksy, A.; Kołodziejczyk, M. The effect of tillage system and forecrop on the yield and values of LAI and SPAD indices of spring wheat. *Eur. J. Agron.* **2010**, *33*, 43–51. [CrossRef]
36. Hussain, S.; Ulhassan, Z.; Brestic, M.; Zivcak, M.; Zhou, W.; Allakhverdiev, S.I.; Yang, X.; Safdar, M.E.; Yang, W.; Liu, W. Photosynthesis research under climate change. *Photosynth. Res.* **2021**, *150*, 5–19. [CrossRef] [PubMed]
37. Liu, K.; Wiatrak, P. Corn production response to tillage and nitrogen application in dry-land environment. *Soil Tillage Res.* **2012**, *124*, 138–143. [CrossRef]
38. Del Pozo, A.; Yáñez, A.; Matus, I.A.; Tapia, G.; Castillo, D.; Sanchz-Jardón, L.; Araus, J.L. Physiological traits associated with wheat yield potential and performance under water-stress in a mediterranean environment. *Front. Plant Sci.* **2016**, *7*, 987. [CrossRef] [PubMed]
39. Feiziene, D.; Feiza, V.; Karklins, A.; Versuliene, A.; Janusauskaite, D.; Antanaitis, S. After-effects of long-term tillage and residue management on topsoil state in Boreal conditions. *Eur. J. Agron.* **2018**, *94*, 12–24. [CrossRef]
40. Brennan, J.; Hackett, R.; McCabe, T.; Grant, J.; Fortune, R.A.; Forristal, P.D. The effect of tillage system and residue management on grain yield and nitrogen use efficiency in winter wheat in a cool Atlantic climate. *Eur. J. Agron.* **2014**, *54*, 61–69. [CrossRef]
41. Borrill, P.; Fahy, B.; Smith, A.M.; Uauy, C. Wheat grain filling is limited by grain filling capacity rather than the duration of flag leaf photosynthesis: A case study using NAM RNAi plants. *PLoS ONE* **2015**, *10*, e0134947. [CrossRef] [PubMed]
42. Tolon-Becerra, A.; Tourn, M.; Botta, G.F.; Lastra-Bravo, X. Effects of different tillage regimes on soil compaction, maize (*Zea mays* L.) seedling emergence and yields in the eastern Argentinean Pampas region. *Soil Tillage Res.* **2011**, *117*, 184–190. [CrossRef]
43. Ali, S.A.; Tedone, L.; Verdini, L.; Cazzato, E.; De Mastro, G. Wheat response to no-tillage and nitrogen fertilization in a long-term faba bean-based rotation. *Agronomy* **2019**, *9*, 50. [CrossRef]
44. Kan, Z.R.; Qi, J.Y.; Liu, Q.Y.; He, C.; Virk, A.L.; Lal, R.; Zhang, H.L. Effects of conservation tillage on wheat growth duration and grain yield in the North China Plain. *Arch. Agron. Soil Sci.* **2022**, *68*, 1019–1033. [CrossRef]
45. Wu, X.; Tang, Y.; Li, C.; McHugh, A.D.; Li, Z.; Wu, C. Individual and combined effects of soil waterlogging and compaction on physiological characteristics of wheat in southwestern China. *Field Crops Res.* **2018**, *215*, 163–172. [CrossRef]
46. Macák, M.; Candráková, E.; Ðalović, I.; Prasad, P.V.V.; Farooq, M.; Korczyk-Szabó, J.; Kováčik, P.; Šimanský, V. The influence of different fertilization strategies on the grain yield of field peas (*Pisum sativum* L.) under conventional and conservation tillage. *Agronomy* **2020**, *10*, 1728. [CrossRef]