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Use of Vegetable Residues and Cover Crops in the Cultivation of Maize Grown in Different Tillage Systems

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Abstract: The purpose of research on alternative variants of soil tillage systems related to fertilization, vegetal residues, and cover crops, in the case of the maize crop, is to elaborate and promote certain integrated technologies on conservation agriculture. This paper presents the results of a study conducted in the Transylvanian Plain during 2019–2021, regarding the influence of certain technological and climatic factors on the yield and quality of maize. The objective of the research was to focus on how vegetable residues and cover crops can be integrated into the optimization of the fertilization system of conservation agriculture. A multifactorial experiment was carried out based on the formula $A \times B \times C \times D - R$: $4 \times 2 \times 3 \times 3 - 2$, where A represents the soil tillage system (a_1 conventional tillage with moldboard plow; a_2 minimum tillage with chisel; a_3 minimum tillage with disk; a_4 no tillage); B represents the maize hybrid (b_1 Turda 332; b_2 Turda 344); C represents the vegetable residues and cover crops (c_1 vegetable residues 2.5 t ha^{-1} + 350 kg ha^{-1} NPK; c_2 vegetable residues 2.5 t ha^{-1} + cover crops mustard; c_3 vegetable residues 2.5 t ha^{-1} + gulle 10 t ha^{-1}); D represents the year (d_1 2019; d_2 2020; d_3 2021); and R represents the replicates. The results emphasized the fact that for the soil conditions from the area taken into account (Chernozem), for maize, a minimum tillage with chisel during autumn + disk harrow in spring + sowing can be considered as an alternative to the conventional tillage system. Yield and quality of maize can be improved and optimized by combined fertilization: vegetable residues and cover crops being supported with different sources of mineral NPK.

Keywords: maize; soil tillage; fertilization; vegetable residues; cover crops; yield; quality

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1. Introduction

Conservation tillage, the diversification of crops, and the use of cover crops play an increasingly important role in conservation agriculture. In order to reduce the degradation of soil and the environment, due to conventional agriculture and certain technologies applied inadequately, resulting in the decreased fertility of agricultural soils [1–3], numerous studies have been conducted to implement new, conservation–regenerative agricultural technologies, the main component of which was maintaining the quality of soil [4–8].

The most recent definition of Conservation Agriculture by the FAO states that [9] “Conservation Agriculture is a farming system that promotes: (i) minimum soil disturbance (i.e., no tillage), (ii) maintenance of a permanent soil cover and (iii) diversification of plant species.” The purpose of these three basic principles (pillars) is to improve the physical regime of the soil (soil tillage system), its chemical and biological regime (vegetal residues, cover crops, fertilization), and the agronomic management regime of the soil (crop rotation). The hydric and thermic regimes of the soil are influenced directly or indirectly by the soil tillage system [10,11]. As demonstrated by several studies [12–16], conservation tillage, combined with soil cover and crop diversification, can significantly reduce soil and water losses, improving carbon sequestration [17,18] and reducing erosion [19,20].

The proper management of the soil vegetal cover represents the most important principle in conservation agriculture, as it has many benefits [21–27]:

- Reducing the effect of hydric and wind erosion [14]: a vegetal cover of at least 40% significantly reduces the loss of soil particles;
- Increasing the infiltration of rainfall water [28]: avoiding crust formation and maintaining a high level of water infiltration in the soil;
- Reducing the loss of humidity by evaporation and increasing the available humidity [29]: it favors the accumulation of humidity supplies available for agricultural crops;
- Reducing thermal amplitudes [30]: the vegetal cover benefits the seed germination, the biological activities and microbiological processes, and the initial development of crops;
- Increasing the content of organic matter [18]: improved soil fertility and productivity;
- Improving the structural stability of soil aggregates [31]: the soil's physical state becomes one specific to the type of soil or is even improved;
- Stimulating soil biological activity [32]: good conditions of humidity and temperature stimulate the activity of microorganisms and fauna;
- Increasing soil porosity [33]: forming a dense network of pores, especially macropores, leading to a global drainage of the soil and to a higher degree of water infiltration;
- Biological control of pests [34]: favorable biological conditions can stimulate a natural control of pests of agricultural crops;
- Reducing the number of weeds [35]: soils with mulch at the surface, as well as adequate agrotechnics, reduce the incidence of numerous species of weeds.

The management of vegetable residues and cover crops inside agricultural technology is not always simple for farmers [36]. In practice, many farmers have a tendency to eliminate them due to technical considerations from conventional agriculture. However, in conservation agriculture, their use becomes simple, economic, and convenient from an agronomic point of view [37], on the condition that adequate equipment exists. The passing to conservation agriculture is stimulated positively by agricultural policies, but it can be influenced negatively by the sources of information [38] and by the socio-economic characteristic of farmers, as well as by age, education, etc. [39]. The results largely depend on the equipment used, especially in the case of direct sowing [40]. Thus, the benefits of using vegetal covers on the soil fertility varies according to the agronomic management compared to pedoclimate conditions [41].

In the case of the maize crop, the soil tillage system depends on the local pedoclimate conditions, which is why, when choosing the soil tillage system, one must take into account the soil technological properties: texture, humidity, soil exhibition, macro and microclimate, humus content, etc. [42]. In the best climate conditions, especially humidity, loamy, clayey-loamy soils rich in humus contribute to the success of the maize crop cultivated in a minimum tillage system [43]. The failure is extending into practice; under the conditions in Romania, certain alternative variants of soil tillage (including direct sowing) have been tied to cultural and technological deficiencies, and lower yield during the first years of application, as it takes at least 10 years for a conservation agricultural system to balance [44,45].

There was a recent increase in the sum of useful temperatures during the vegetation period of the maize crop, to which a poor, uneven distribution of rainfall was added (during the critical moments from June and July), which have determined the promotion of certain hybrids with a longer period of vegetation (from group FAO 300–400), which have a greater resistance to low temperatures (from the first part of the vegetation period)—drought but also heat [46,47]. Still, it is known that the hybrid alone, without proper technology, cannot ensure a high performance [48], and if there are no valuable hybrids, a great part of the expenses with the investment, mainly machines and equipment necessary to practice conservation agriculture, is lost.

This paper presents the results of a study conducted during 2019–2021 on the influence of four variants of soil tillage systems (conventional with plow 30 cm deep, minimum tillage with chisel 30 cm deep, disk 12 cm deep, and direct sowing), and of fertilization and vegetal mulch (vegetable residues and cover crops) on the quantity and quality yield of maize, under the pedoclimate conditions of the hilly area of the Transylvanian Plain. The research hypothesis is as follows: Can maize yield and quality be improved and optimized by combined fertilization, with inputs (pillars) required in conservation agriculture? The novelty of the experiment presented is connected to how vegetable residues and cover crops can be integrated into the optimization of the fertilization system of conservation agriculture.

2. Materials and Methods

2.1. Biological Materials

Two maize hybrids from the same maturity group were used in the experiment (FAO 380) [49]: (i) Turda 332, simple hybrid, 280–290 cm tall, number of leaves 16–17, erect plant, green when mature, cylinder form of corn cob, rows of grains on cobs 18–22, dark yellow semi-dent grain, thousand-grain weight 220–240 g, grain yield 80–82%; (ii) Turda 344, trilinear hybrid, vegetation period from sowing to technical maturity 120 days, 270–290 cm middle-sized to tall, cob insertion at 120–130 cm, number of leaves 12–14, cylinder form of corn cob, average length of 18–19 cm, rows of grains on cobs 18–20, grain yield 82–84%, light yellow dent grain, thousand-grain weight 240–280 g.

2.2. Research Method

The research started from the idea of optimizing the possible existing relationship between the soil tillage system, fertilization level, and structure of crops that emphasizes the genetic characteristics of the new creations obtained at the Agricultural Research and Development Station Turda (ARDS Turda), to obtain a larger, constant, and quality yield. The experimental soil was covered in a 3 year crop rotation: maize–soybean–autumn wheat. After wheat was harvested, the land had not been cleared of vegetal residues and they were kept entirely (2.5 t ha^{-1}). The vegetal residues were chopped to 5–6 cm long. The multiannual average temperature of the study area, the Transylvanian Plain, is 9.2 °C and the multiannual rainfall is 531.4 mm.

The study was conducted using a type of soil representative of the research area, Chernozem. The properties of the soil from the experimental site, at a depth of 0–20 cm, were as follows: clay content (<0.002 mm) 56.07%, fine silt (0.002–0.05 mm) 19.15%, silt (0.05–0.02 mm) 9.15%, fine sand (0.02–0.2 mm) 14.9%, coarse sand (0.2–2.0 mm) 0.73%, clay texture, bulk density 1.13 g cm^{-3}, total porosity 58%, soil organic matter content 3.73% pH of 6.81, total nitrogen content 2050 mg kg^{-1}, mobile phosphorus 35 mg kg^{-1}, and mobile potassium 320 mg kg^{-1}. The soil samples for chemical analysis were sampled at a depth of 0–20 cm.

The potentiometric method was used to establish pH, and the Walkley–Black method was used for soil organic matter; total nitrogen was established using the Kjeldhal method; phosphorous and the content of potassium were established through the Egner–Riehm–Domingo extraction method.

The experiment was based on an $A \times B \times C \times D - R$: $4 \times 2 \times 3 \times 3 - 2$ polyfactorial type, according to the method of subdivided plots. The size of the experimental plots was 48 m^2 (4 m width × 12 m length), and the total experimental surface was 2756 m^2.

The experimental factors are as follows:

A—Soil tillage system:

a_1 Conventional System (CS), plow with Kuhn Huard Multi Master 125T (Kuhn Farm Machinery, Hamburg, Germania) mold plow + preparation of the germinative bed (in spring) with HRB 403 D rotary harrow (Kuhn Farm Machinery, Hamburg, Germania) + sowing and fertilizing with MT-6 seeder (Maschio Gaspardo Padova, Italy) + crop maintenance + harvest;

a_2 Minimum Tillage—Chisel (MTC), the soil was prepared with the help of the Gaspardo Pinochio 2.5 chisel (Maschio Gaspardo Padova, Italy) (in autumn) + preparation of the germinative bed (in spring) with HRB 403 D rotary harrow + sowing and fertilizing with MT-6 seeder + crop maintenance + harvest;

a_3 Minimum Tillage—Disk (MTD), the soil was prepared with the help of the Discovery-4 heavy disk (Kuhn Farm Machinery, Hamburg, Germania) (in autumn) + preparation of the germinative bed (in spring) with HRB 403 D rotary harrow + sowing and fertilizing with MT-6 seeder + crop maintenance + harvest;

a_4 No-Tillage (NT), direct sowing and fertilizing with MT-6 seeder + crop maintenance + harvest.

B—Maize hybrid: b_1 Turda 332; b_2 Turda 344.

C—Vegetable residues and cover crops:

c_1 Vegetable residues 2.5 t ha^{-1} + 350 kg ha^{-1} NPK (16:16:16);

c_2 Vegetable residues 2.5 t ha^{-1} + mustard green fertilizer (*Sinapis arvensis* L.), 10 kg ha^{-1} mustard seed were used in sowing;

c_3 Vegetable residues 2.5 t ha^{-1} + gulle 10 t ha^{-1}.

D—Experimental year (climate conditions): d_1 2019; d_2 2020; d_3 2021.

2.3. Technology Used in the Experimental Site

The organic fertilizer used was gulle type (slurry), from a cattle farm near the experimental site. Gulle is an organic fertilizer obtained from animal manure (consistent and liquid) and it ferments anaerobically in the storing tanks. This fertilizer has an average content of 0.5% N, 0.04% P_2O_5, and 0.9% K_2O. In the experiment, it was applied early in spring as soon as the climate conditions allowed entry to the site.

Sowing was carried out with the help of the MT-6 machine at a thickness of 65,000 plants ha^{-1}, and the seeds were treated with 1.0 L t^{-1} of fungicide substance based on 25 g L^{-1} of fludioxonil and 9.7 g l^{-1} of metalaxyl-M (Mefenoxam 2 AQ commercial product; Syngenta, Bucharest, Romania).

Fighting the weeds was carried out in two phases: in preemergence with 0.4 L ha^{-1} of product based on isoxaflutole 240 g L^{-1} (Merlin Flexx; Bayer, Bucharest, Romania) and iprosulfonamide 240 g L^{-1} + 1.4 L ha^{-1} based on dimethenamid-P 720 g L^{-1} (Frontier Forte; BASF, Kaiserslautern, Germany); in postemergence with 1.0 L ha^{-1} of product based on fluroxypyr 250 g L^{-1} (Tomigan 250 EC; ADAMA, Bucharest, Romania) to fight dicotyledonous weeds (especially *Convolvulus arvensis, Rubus caesius*) + 1.5 L ha^{-1} based on 40 g L^{-1} of nicosulfuron (Nicorn; Pestila, Bucharest, Romania) to fight monocotyledonous annual and perennial weeds (*Agropyron repens, Sorghum halpense, Setaria* sp.). Furthermore, 0.15 L ha^{-1} of product based on thiacloprid 480 g L^{-1} (Calypso; Bayer, Bucharest, Romania) was applied against pests (*Tanymecus dilaticollis*, *Diabrotica v. virgifera*).

The harvest of the maize experiment was gathered manually, by meeting the methodological rules of the experimental technique. This operation consisted of the following steps: collecting the protective strips around the samples; collecting the frontal and lateral margins of the experimental samples (frontal eliminations were of 1 m and lateral eliminations of 1 row were of 0.70 cm. The harvest surface of the experimental lot was 26 m^2. The maize yield (grains) obtained on each experimental lot was weighed and transformed to standard humidity for maize (14%).

2.4. Methods of Analysis and Processing Experimental Data

The determination of the chemical composition of maize grains was made by using standardized methods and techniques, including a spectrophotometer (Nir Tango-Bruker Optik GMBH Germany and a Gerhardt Analytical Systems device-Gerhardt Koenigswinter, Germany). This method is nondestructive, requiring no sample preparation or hazardous chemicals, making it quick and reliable for quantitative and qualitative analysis.

The data were processed by using ANOVA by Anova PoliFact Soft (Cluj-Napoca, Romania) [50]. A Fisher's protected least significant difference (LSD) test was used to determine the significance of the differences among the variance results and control (for *p*-values 0.05, 0.01, and 0.001) for each experimental factor.

3. Results

3.1. Climate Conditions and the Impact on Maize Cultivation Technology

The evolution of climate conditions during April-October 1957–2021 (65 years) at Turda is presented in Figure 1 (Turda Weather Station: long. 23°47′–lat. 46°35′–alt. 427 m).

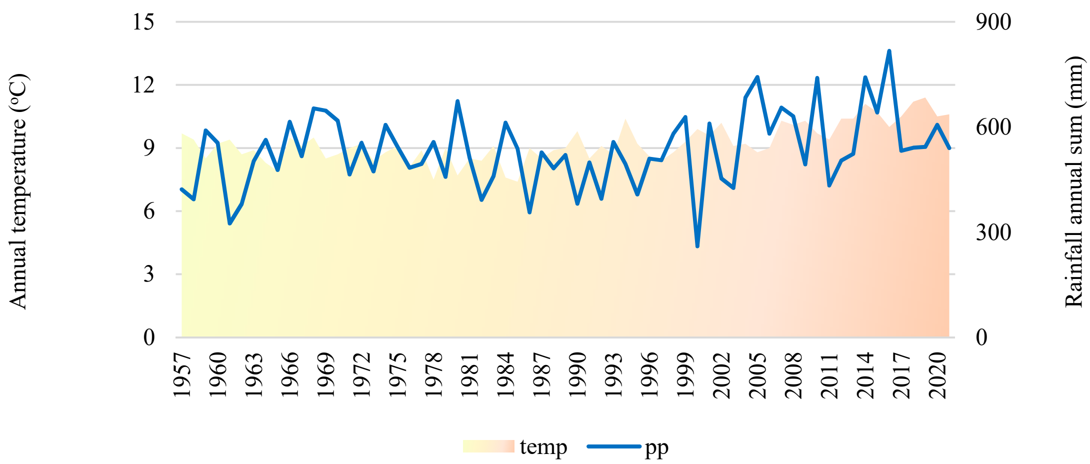

Figure 1. Climate conditions during 1957–2021 at ARDS Turda; temp—annual temperature (°C); pp—annual precipitation (mm).

The climate conditions during April–October 2019–2021 at ARDS Turda are presented in Table 1.

Table 1. Climate conditions during April–October from 2019 to 2021 at ARDS Turda.

			Monthly Temperature (°C)					**Average**
Year/month	IV	V	VI	VII	VIII	IX	X	IV–X
2019	11.3	13.6	21.8	20.4	22.1	17.1	13.5	17.1
2020	10.3	13.7	19.1	20.2	21.5	17.8	12.0	16.4
2021	7.8	14.1	19.8	22.7	19.7	15.0	9.7	15.5
65 years average	10.0	15.0	18.0	19.8	19.5	15.2	9.8	15.3
			Monthly rainfall (mm)					Sum
Year/month	IV	V	VI	VII	VIII	IX	X	IV–X
2019	62.6	152.4	68.8	35.0	63.8	19.4	25.6	402
2020	17.8	44.4	166.6	86.8	58.0	57.4	53.6	484.6
2021	38.4	80.8	45.0	123.1	52.9	39.1	11.6	390.9
65 years monthly amount	15.6	69.4	84.6	77.9	56.1	42.4	35.4	411.4

As can be seen from the data presented in Table 1, during April–October, in 2019, 2020, and 2021, there was an increase in the temperature values compared to the multiannual monthly average in 65 years, except for May, with lower temperatures than the normal ones for this period, and the deviation from the average ranged between −1.4 °C and −0.9 °C. The monthly average temperatures were exceeded during the first two years of research (2019, 2020); in 2019, the deviation was +1.3 °C in April, +3.8 °C in June, +0.6 °C in July, +2.6 °C in August, +1.9 °C in September, and +3.7 °C in October. The monthly multiannual average was exceeded in 2020, too: by +0.3 °C in April, +1.1 °C in June, +0.4 °C in July, and +2 °C in August; the temperature rises were +2.6 °C in September and +2.2 °C in October. The year 2021 had four months colder than the multiannual for this period, with deviations of −2.2 °C in April, −0.9 °C in May, −0.2 °C in September, and −0.1 °C in October. During the three experimental years, July was hotter in 2021 (deviation +2.9 °C). If an average was made of the temperatures for the whole period, one would observe that 2019 was hottest (17.1 °C) with a +1.8 °C deviation, followed by 2020 (16.4 °C) with a +1.1 °C deviation. The year of 2021 (15.5 °C) was the closest in number to the multiannual average for 65 years (15.3 °C) with just a +0.2 °C deviation.

Compared to the average for 65 years during April–October (411.4 mm), the total amount of rainfall increased in 2020 by 73 mm; thus, the average amount recorded was 484.6 mm (little rain). The previous year, 2019, was close (402 mm), with a deficit of 9.4 mm, and in 2021, with a deficit of 20.5 mm, it was a little dry (390.9 mm). However, what is important is not the total amount of rainfall, but its distribution being as uniform as possible during the entire vegetation period of plants. From the point of view of the rainfall regime, in 2019, April was very rainy (62.6 mm), May was excessively rainy (152.4 mm), and June saw a decrease in the amount of rainfall (68.8 mm). The lack of rainfall was felt in July (35 mm), September (19.4 mm), and October (25.6 mm), except for August when the amount of rainfall was 63.8 mm. April (17.8 mm) and May (44.4 mm) 2020 were dry, and the pedological drought continued to mid-June, when the rainfall reached a total of 166.6 mm per month, and was accompanied by strong winds. In July, the rainfall (86.8 mm) exceeded the multiannual average by 8.9 mm, and in August, it was close to the value of the multiannual average for this month (58 mm), but almost the entire amount of rainfall was recorded in the middle of the month. September overall was rainy, although almost the entire amount of rainfall was recorded toward the end of the month (57.4 mm). Unfavorable conditions from the end of September to the beginning of October (rain and fog) maintained a high humidity of corn cobs, and the harvest was gathered after 20 October. Compared to the multiannual average for 65 years, in April 2021, there was little rain (38.4 mm), and sowing the maize did not cause any problems (23 April). In May, the rainfall regime increased; therefore, the average amount recorded was 80.8 mm (little rain) with a good development of the maize crop. June was very dry (45 mm), July had heavy rain (123.1 mm), August (52.9 mm) and September (39.1 mm) were normal in terms of the rainfall regime, and October was dry, with 11.6 mm, but in this case, the harvest was gathered under very good conditions (19.10).

3.2. Maize Yield in Relation to Experimental Factors

The yield obtained by applying different soil tillage systems shows that different results can be obtained, and that the choice of the soil tillage and fertilization variant is decisive. The yield obtained ranges between 6042 and 8683 kg ha^{-1} (Table 2). NT with the MT-6 equipment on the Chernozem type of soil determines a maize yield 30% lower compared to CS, but MTC ensures an appropriate yield (98%).

Table 2. Influence of tillage system on maize yield, 2019–2021.

Tillage System	**Yield**		**Differences**	**Significance**
	kg ha^{-1}	**%**	**± kg ha^{-1}**	
a_1 Conventional System (CS)	8683	100	0	control
a_2 Minimum Tillage—Chisel (MTC)	8545	98	−138	ns
a_3 Minimum Tillage—Disk (MTD)	6894	79	−1789	000
a_4 No-Tillage (NT)	6042	70	−2640	000

Notes: LSD (5%) = 179 kg ha^{-1}; LSD (1%) = 330 kg ha^{-1}; LSD (0.1%) = 730 kg ha^{-1}; ^{000}: Significant at 0.001, ^{ns}: not significant.

The difference between the Turda 332 simple hybrid (witness) and the Turda 344 trilinear hybrid is insignificant (only 64 kg ha^{-1}). The two cultivars belong to the FAO 380 group and stand out for a yield potential of over 7500 kg ha^{-1} grains, which we think is initially due to the superior ability to capitalize on the technological factors applied (Table 3).

Table 3. Influence of hybrid (cultivar, variety) on maize yield, 2019–2021.

Hybrid	Yield		Differences	Significance
	kg ha^{-1}	%	± kg ha^{-1}	
b_1 Turda 332	7573	100	0	control
b_2 Turda 344	7509	99	−64	ns

Notes: LSD (5%) = 72 kg ha^{-1}; LSD (1%) = 119 kg ha^{-1}; LSD (0.1%) = 223 kg ha^{-1}; ^{ns} not significant.

The presence of vegetable residues is a requirement for Conservation Agriculture and especially for the area of research to control soil erosion. However, it is important to specify which is the best combination of fertilizers, both for yield and for the decomposition of vegetable residues. The application of mineral fertilizers (NPK) has a beneficial effect, resulting in a better development of plants and a yield increase, as one can observe from the data presented in Table 4.

Table 4. Influence of fertilization on maize yield, 2019–2021.

Fertilization	Yield		Differences	Significance
	kg ha^{-1}	%	± kg ha^{-1}	
c_1 Vegetable Residues 2.5 t ha^{-1} + 350 kg ha^{-1} NPK	8093	100	0	Control
c_2 Vegetable Residues 2.5 t ha^{-1} + Cover Crops Mustard	7031	87	−1061	000
c_3 Vegetable Residues 2.5 t ha^{-1} + Gulle 10 t ha^{-1}	7499	93	−593	000

Notes: LSD (5%) = 71 kg ha^{-1}; LSD (1%) = 97 kg ha^{-1}; LSD (0.1%) = 134 kg ha^{-1}; ^{000}: significant at 0.001.

The analysis of the variance shows that the maize yield was influenced by the climate conditions from the experimental period (Table 5). In the witness variant (the average of the three experimental years), the maize yield was 7541 kg ha^{-1}, the yield differences recorded in 2019 and 2020 were between 204 and 236 kg ha^{-1} (influence very significantly negative), and 2021 was more favorable for the crop, with the yield exceeding the witness by 440 kg ha^{-1} (influence very significantly positive).

Table 5. Influence of year on maize yield, 2019–2021.

Year	Yield		Differences	Significance
	kg ha^{-1}	%	± kg ha^{-1}	
d_0 Mean	7541	100	0	control
d_1 2019	7337	97	−204	000
d_2 2020	7305	97	−236	000
d_3 2021	7982	106	440	***

Notes: LSD (5%) = 53 kg ha^{-1}; LSD (1%) = 71 kg ha^{-1}; LSD (0.1%) = 93 kg ha^{-1}; ^{000} ***: significant at 0.001 (negative and positive).

3.3. Maize Quality

For maize, the most important quality criteria are the contents of starch and protein, as they are influenced by climate and local conditions (Table 6).

The accumulation and storage of starch in the grains are influenced distinctively, very significantly negatively, by the MTC, MTD, and NT systems compared to SC (control). In the accumulation of starch, a determining role besides the climate factors (temperature and rainfall) is played by the genetic factor. Although the maize hybrids used in the experiment belong to the same FAO group (they are early stage), it seems that in the case of the T344 hybrid, the accumulation of starch in the grain is more reduced (61.48%) compared to the control variant (63.01%); it presents a very significantly negative statistic compared to the difference of 1.54%. The results show that the variant of fertilization with vegetal residues + cover crops mustard contributes significantly positively to the increase in content of starch; in this variant, a value of 62.56% starch is recorded, with a difference of 0.37% compared to the control (62.19% in the variant with mineral fertilization).

Table 6. Influence of experimental factors on grain content in protein and starch, 2019–2021.

Factors	Protein		Starch	
	Yield %	Differences ± %	Yield %	Differences ± %
Soil Tillage System (A)				
a_1 Conventional System (CS)	5.98	0.00^{ct}	64.38	0.00^{ct}
a_2 Minimum Tillage—Chisel (MTC)	5.96	-0.02^{ns}	62.87	-1.51^{00}
a_3 Minimum Tillage—Disk (MTD)	6.07	0.09^{ns}	61.34	-3.04^{000}
a_4 No-Tillage (NT)	6.24	0.26^{ns}	60.39	-4.00^{000}
LSD (5%)	0.29		0.46	
LSD (1%)	0.53		0.85	
LSD (0.1%)	1.16		1.89	
Hybrid (B)				
b_1 Turda 332	6.05	0.00^{ct}	63.04	0.00^{ct}
b_2 Turda 344	6.07	0.02^{ns}	61.48	-1.54^{000}
LSD (5%)	0.19		0.29	
LSD (1%)	0.32		0.48	
LSD (0.1%)	0.60		0.90	
Fertilization (C)				
c_1 Vegetable Residues 2.5 t ha^{-1} + 350 kg ha^{-1} NPK	5.96	0.00^{ct}	62.19	0.00^{ct}
c_2 Vegetable Residues 2.5 t ha^{-1} + Cover Crops Mustard	6.07	0.11 **	62.56	0.37 *
c_3 Vegetable Residues 2.5 t ha^{-1} + Gulle 10 t ha^{-1}	6.15	0.19 ***	61.98	-0.21^{ns}
LSD (5%)	0.07		0.31	
LSD (1%)	0.10		0.43	
LSD (0.1%)	0.14		0.60	
Year (D)				
d_0 Mean	6.06	0.00^{ct}	62.24	0.00^{ct}
d_1 2019	5.92	-0.14^{0}	62.22	-0.02^{ns}
d_2 2020	6.15	0.09^{ns}	63.18	0.93 ***
d_3 2021	6.11	0.05^{ns}	61.33	-0.91^{000}
LSD (5%)	0.12		0.33	
LSD (1%)	0.16		0.44	
LSD (0.1%)	0.20		0.57	

Notes: A, B, C, and D: experimental factors; ^{ct}: control; ^{000}, ***: significant at 0.001 (negative and positive); ^{00}, **: significant at 0.01; ^{0}, *: significant at 0.05; ^{ns}: not significant.

Climate conditions do not have a significant role in the modification of fat content (Table 7), and this is a feature specific to hybrids and does not change significantly. The fiber content has high fluctuations, negative or positive, compared to the control variant, and is influenced significantly positively by the NT system (3.54%), and it is found in the grain in a higher percentage in this variant. A significantly negative influence is exerted by the T344 hybrid (3.11%), and a very significantly negative influence from the fertilization variant vegetal residues + green fertilizer (3.09%). In general, in the three experimental years, climate conditions were favorable to the maize crop and, as with the case of the fat content, it has not significantly influenced the fiber percentage from the grain, being situated at 3.14–3.18%.

Table 7. Influence of experimental factors on grain content in fats and fiber, 2019–2021.

Factors	**Fats**		**Fiber**	
	Yield %	**Differences** ± %	**Yield** %	**Differences** ± %
Soil Tillage System (A)				
a_1 Conventional System	2.76	0.00 ^{ct}	2.94	0.00 ^{ct}
a_2 Minimum Tillage—Chisel	2.82	0.06 ^{ns}	3.10	0.16 ^{ns}
a_3 Minimum Tillage—Disk	2.81	0.05 ^{ns}	3.08	0.14 ^{ns}
a_4 No-Tillage	2.95	0.19 ^{ns}	3.54	0.59 **
LSD (5%)	0.26		0.19	
LSD (1%)	0.47		0.34	
LSD (0.1%)	1.05		0.76	
Hybrid (B)				
b_1 Turda 332	2.75	0.00 ^{ct}	3.22	0.00 ^{ct}
b_2 Turda 344	2.92	0.18 ***	3.11	−0.11 ^{0}
LSD (5%)	0.05		0.08	
LSD (1%)	0.09		0.13	
LSD (0.1%)	0.17		0.25	
Fertilization (C)				
c_1 Vegetable Residues 2.5 t ha^{-1} + 350 kg ha^{-1} NPK	2.79	0.00 ^{ct}	3.22	0.00 ^{ct}
c_2 Vegetable Residues 2.5 t ha^{-1} + Cover Crops Mustard	2.80	0.01 ^{ns}	3.09	−0.13 ^{000}
c_3 Vegetable Residues 2.5 t ha^{-1} + Gulle 10 t ha^{-1}	2.91	0.12 *	3.17	−0.05 ^{ns}
LSD (5%)	0.10		0.06	
LSD (1%)	0.13		0.09	
LSD (0.1%)	0.18		0.12	
Year (D)				
d_0 Mean	2.84	0.00 ^{ct}	3.16	0.00 ^{ct}
d_1 2019	2.86	0.03 ^{ns}	3.14	−0.02 ^{ns}
d_2 2020	2.83	−0.01 ^{ns}	3.17	0.01 ^{ns}
d_3 2021	2.82	−0.02 ^{ns}	3.18	0.01 ^{ns}
LSD (5%)	0.08		0.04	
LSD (1%)	0.11		0.06	
LSD (0.1%)	0.14		0.08	

Notes: A, B, C, and D: experimental factors; ^{ct}: control; ^{000,} ***: significant at 0.001 (negative and positive); **: significant at 0.01; ^{0,} *: significant at 0.05; ^{ns} not significant.

4. Discussion

4.1. Maize Yield in Relation to Experimental Factors

The analysis of the variance and the experimental data shows that the maize yield was affected by the soil tillage system. The difference between CS (8683 kg ha^{-1}) and MTC (8653 kg ha^{-1}) was not very high (138 kg ha^{-1}), but the results showed that MTD and NT had a very significantly negative influence compared to CS, the yield differences being 1789 kg ha^{-1} and 2640 kg ha^{-1}, respectively. Similar research, but over a longer period, conducted by Cociu and Alionte [51] at Fundulea, showed that the average yield for eight years in the case of maize was significantly lower when CS (8820 kg ha^{-1}) was applied rather than MTC (9050 kg ha^{-1}). This is similar to Khan et al. [52], who reported that a higher grain yield was established in NT crops than in CS crops. According to the results of a study in Serbia, under similar soil conditions (Chernozem type), by Simić et al. [53], the highest yield (9190 kg ha^{-1}) was achieved when maize was cultivated in CS, compared to NT (6180 kg ha^{-1}) and minimum tillage (6620 kg ha^{-1}).

Compared to the yield obtained in the fertilization variant with 350 kg ha^{-1} NPK (16:16:16) + 2.5 t ha^{-1} vegetal residues, which resulted in a yield of 8093 kg ha^{-1} (control), the yield dropped by 1061 kg ha^{-1} in the case of fertilization with vegetal residues 2.5 t ha^{-1} + green mustard fertilizer (7031 kg ha^{-1}) and by 593 kg ha^{-1} in the case of the variant with 2.5 t ha^{-1} vegetal residues + gulle 10 t ha^{-1} (yield 7499 kg ha^{-1}). These variants significantly negatively influence the yield of maize grain. Tolk et al. [54] noticed an important increase in the yield in cereals, in the case of the presence of vegetal mulch compared to the yield on open lands [55]. In the case of our variants, when all variants have vegetal residues on the surface, the differences are provided by the amount of nutrients available immediately, as other research also indicates [56–58]. Cover crops need to be integrated into the optimized fertilization system.

Annual climate conditions significantly influence the maize yield, especially the favorable conditions from 2021. This analysis concludes that measures are needed to reduce climate impact on production results in the area, such as shelterbelt and irrigation (even in the use of cover crops and plant residues). These positive differences are due to high soil humidity during July–August resulting from the rain in July and August (123.1 mm + 52.9 mm, respectively). Angearu et al. [59] established for conditions based on Romania that the yield increases above the average when rainfall is distributed as follows: in May 60–80 mm; June 100–120 mm; July 100–120 mm; August 20–60 mm. This favorable distribution of the rainfall was recorded in 2021; at the same time, we can state that, for the conditions based on Romania, the heavy rain during September and October extends the period of ripeness and, on the contrary, does not increase the yield, resulting in a delayed harvest.

4.2. Maize Quality

The irregular distribution of rainfall and high temperatures correlated with extended drought during the experiment period, specific to the area studied, and influenced the crop, including the quality indices [51]. Compared to the control variant, the starch content of grains (62.24% average for three years) fluctuated very significantly in two years (2020 positive, 2021 negative), and in 2019, it remained close to the control variant, at a difference of just 0.02%, which does not present statistical assurance. The year 2020 was richer in rainfall during the vegetation period, with favorable conditions for accumulating starch in grains. Haș et al.'s study [46] during 2003–2005, on starch accumulation, also suggests that due to the fluctuation of environmental factors, a high variability occurred from one year to another, both in the yield of grain and in yield components. As 2004 experienced more rain, the starch content increased (69.3%), and under drought conditions (2003), it decreased (68.3%), but the fat and protein content increased, a fact highlighted by Sluşanschi [60], Grecu and Legman [61], and Hegyi et al. [62].

The accumulation of protein in the grain depends on a number of factors, such as: hybrid, climatic conditions, fertility of the soil, and the doses of nitrogen used [63]. The accumulation of protein in the grain is not influenced by the soil tillage variant [3]; the values of the differences ranged between 0.02 and 0.26%, without presenting statistical assurance, during the three experimental years. On the contrary, Vita et al. [64] and Andrija et al. [65] reported that the highest protein content in the grain was obtained under CS rather than in the case of NT, and Temperly and Borges [66] observed that the protein content was significantly lowered in CS. These differences show that tillage systems should be approached differently [67]. There were no statistically assured differences in the protein content between the two hybrids taken into account in the research. Nonetheless, it is noticeable that the variants of fertilization without chemical fertilizers (with cover crops and gulle) influence positively, very significantly (6.07%), and distinctly significantly (6.15%) the accumulation of protein in the grain. On the other hand, Rafiq et al. [68] stated that an increase in nitrogen significantly increases the grain protein content. The protein content in the grain had lower values only in 2019 (5.92%), the difference compared to the control (0.14 %) being statistically confirmed as significantly negative. When soil mobilization was reduced, the result was a negative contribution (distinct and very significant) on the starch grain content, reducing the depth of the soil processing. We also observed a step-by-step reduction in the starch percentage (CS = 64.38%, MTC = 62.87%, MTD = 61.34%, and NT = 60.39%). Furthermore, by increasing the protein in the grain, the starch percentage is reduced, and there is a negative correlation between these two quality components [69].

The fat content of grains is not influenced by the soil tillage variant [70], and it ranges between 2.76 and 2.95%. The differences compared to the control variant are insignificant and do not present statistical assurance. On the contrary, Cociu and Alionte [71] observed that the crop sown in the NT produced a higher oil (fat) content than moldboard and disk plow variants. The T344 hybrid stood out with a higher fat content (2.92%) than T332 (2.75%); it presents statistical assurance, with a difference of 0.18%. The fertilization variant with vegetal residues + gulle positively influences and contributes to an increase in the fat percentage in grain (2.91%), and in the case of the variant with green fertilizer, the 2.80% of fat is closer to the value obtained in the fertilization variant with vegetal residues + 350 kg ha^{-1} NPK (2.79%). Zamir et al. [72] observed that the oil content in the maize grain has a maximum value in the CS (5.82%), 5.80% in the CS + wheat straw mulch—partially incorporated, 5.43% in NT, 4.95% in the NT + wheat straw mulch—partially incorporated, and just 4.50% in the subsoiler tillage. They show, as in the case of other research [73,74], that the combination of plant residues and cover crops with mineral fertilization can be decisive for the success of the MT and NT.

5. Conclusions

The soil tillage system applied to maize crop can be optimized by using vegetal residues with different sources of NPK fertilization (mineral NPK, cover crops, and gulle), depending on the level and quality of the desired production and conditioned by reducing the impact of annual climate change.

The minimum soil tillage with chisel ensures an average yield of 8545 kg ha^{-1}, very close to the conventional tillage variant (8683 kg ha^{-1}). Under the conditions from the experimental site, where the soil content is very rich in clay, in the case of the maize crop, the minimum tillage system with chisel ensures a yield close to the conventional system ever since the first years of application. A no-tillage system with an MT-6 seeder ensured 70% of the yield of the conventional system. Starting no-tillage without breaking soil compaction will result in poor maize yields.

In the fertilization variant with 2.5 t ha^{-1} vegetal residues + green mustard fertilizer, there was an average yield reduced by 1061 kg ha^{-1} more than in the variant of mineral fertilization with NPK, with the variant of vegetal residues + gulle 10 t ha^{-1} (7499 kg ha^{-1}) being superior, thus confirming the importance of combining vegetal residues with organic fertilizers in maize fertilization. Nutrient deficiencies have to be corrected before starting minimum tillage and no-tillage

The maize hybrids included in the experiment have a greater capacity to capitalize on the technological factors applied, based on the yield data.

The minimum tillage with chisel, minimum tillage with disk, and no-tillage systems positively influence the accumulation of protein, fat, and fiber in the maize grain, and negatively influence the accumulation and storage of starch in grains. In years rich in rainfall, during the vegetation period of maize, the starch content in grains increases and the protein content decreases.

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