STUDY ON THE INFLUENCE OF CLIMATE, SOIL TILLAGE, AND SOME AGRICULTURAL SPECIES ON THE PROCESS OF WATER STORAGE IN THE SOIL IN THE NORTH-EAST BARAGAN AREA

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Abstract

Soil and water are some of the prime components of nature. The development of life depends directly and indirectly on the health and quality of the land. Regardless of its composition, the soil contains substances that allow the growth and development of many plant species and microorganisms. The increase in temperatures, the decrease in rainfall, and the applied agricultural technologies have contributed over the years to ruining the structure and components of the soil, which negatively affected its humidity. The paper aims to identify the type of tillage in the dry-farming system and the agricultural species cultivated, which can achieve optimal harvests without leaving the soil devoid of moisture. The amount of water in the soil in the agricultural year 2019-2020, although it was deficient, exceeded the value of the withering coefficient, thus allowing crops to grow. However, this was not enough to obtain rich harvests.

Key words: dry-farming, soil moisture, climatic conditions, agricultural species

The instability of the climatic conditions brings significant changes both in concepts and technologies as well as in changing the machinery system in Romanian agricultural farms. These changes manifest in the crop plant that grows on the surface of the soil and o the layers of the soil at different depths. For the rational management of natural resources, the system of conservational agricultural works has gained momentum.

If we analyze the application of the classic soil work system, it contributes to the reduction of macroporosity (Jia L. *et al*, 2019), which is why the soil loses its water absorption capacity. Classic works have given good results over the years but considering the current context of climate variations, it becomes vital to use the conservative system of soil works, which has the role of storing as much water as possible, protecting the structure, the microbiological fauna, and chemical elements, all influencing each other.

Even if the crops in some areas of Romania can be irrigated, the purity of the rainfall water is superior from a chemical point of view to that used from the channels of the irrigation system. For this reason, any rainfall water must be conserved and stored in large quantities to be fully useful for agriculture. It is achievable through multiple techniques, among which we mention the cultivation of the land with the disc, the incorporation of plant residues immediately after harvesting the crop, and the choice of a correct rotation from an agrotechnical point of view. From an economic point of view, the conservative system contributes to the reduction of expenses per hectare by saving fuel, and human resources, carrying out the works in optimal execution time, and saving the amounts of pesticides and water used for irrigation.

Some soil works in conservative agriculture have as a technique, chopping and keeping on the surface of the soil the plant residues resulting from the harvesting of crops.

These plant residues can contribute based on the soil, to the conservation of water or to the accumulation of excess water (Munawar A. *et al*, 1990) which can cause the rotting of the root system of crop plants. Also, plant residues reduce water evaporation by forming an insulating layer that protects the soil from the direct rays of the sun and the heat, increasing its resistance to vapor flow by reducing the wind speed (Ling-Ling L. *et al*, 2011).

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MATERIAL AND METHOD

The experience was placed in the Chiscani Experimental Field, within the Agricultural Research-Development Station Braila, in 2019 – 2022. Five tillages were studied, V1 – plow, V2 – paraplow, V3 – scarified, V4 – heavy disc, and V5 – no-tillage. From the cultivated plants, barley - *Hordeum vulgare* L., rapeseed - *Brassica rapa* L., sorghum - *Sorghum bicolor* Moench, and millet - *Panicum miliaceum* L. were analyzed. The monitored parameters were humidity (U%), wilting coefficient (WCo), field capacity (FC), current water supply (CrWS), and minimum water ceiling (MWC) - m³/ha.

RESULTS AND DISCUSSIONS

The 2019-2020 agricultural year was very hot regarding temperatures. The deviation from the multiannual mean temperature was +2.3ºC. Similarly, 2020 – 2021 also recorded a deviation of +1.5ºC from the multiannual average of 10.9ºC *(figure 1).*

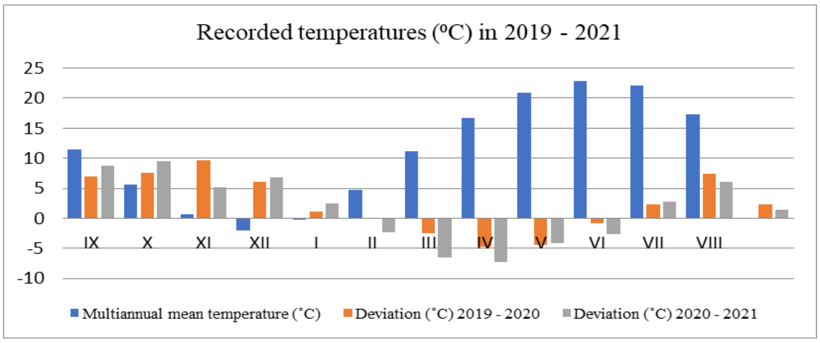

Figure 1 **Deviation of temperatures from the multiannual average in 2019 – 2021**

Regarding rainfall, the 2019-2020 agricultural year was dry *(figure 2)*. It recorded a precipitation deficit of -221 mm compared to the multiannual mean rainfall of 442 mm. On the other hand, the 2020-2021 agricultural year was rich in precipitation, accumulating +176 mm above the multiannual average.

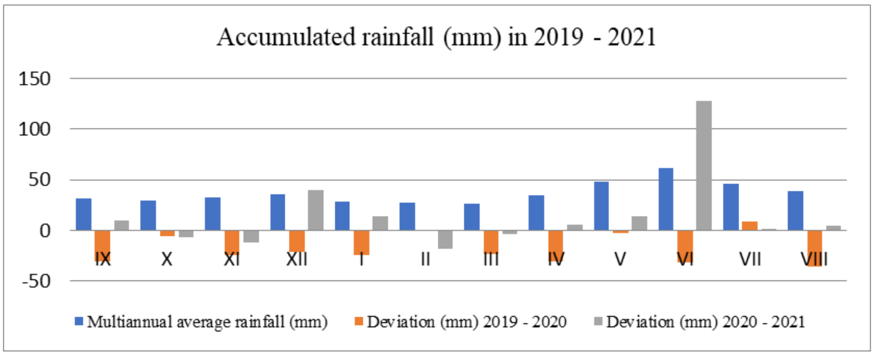

Figure 2 **Rainfall deviation from the multiannual rainfall average in 2019 – 2021**

The meteorological data recorded from September 2021 to March 2022 can place the agricultural year 2021 - 2022 in the category of dry ones. From figure 3, a temperature deviation of +2.2ºC can be observed compared to the multiannual mean temperature and from figure 4, a precipitation deficit of 66.2 mm can be observed compared to the multiannual average of 212 mm.

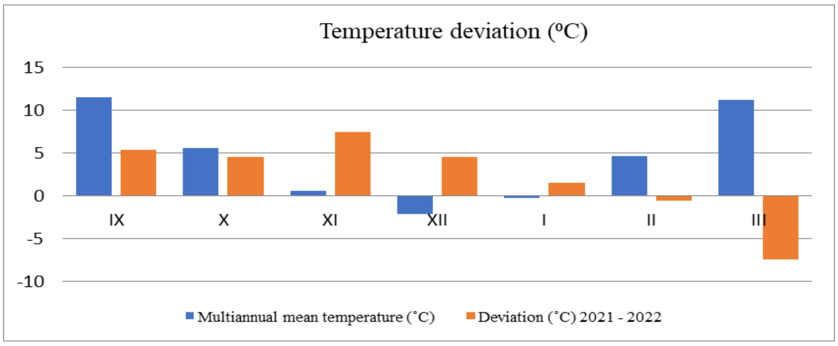

Figure 3 **Temperature deviation from the multiannual average in 2021-2022**

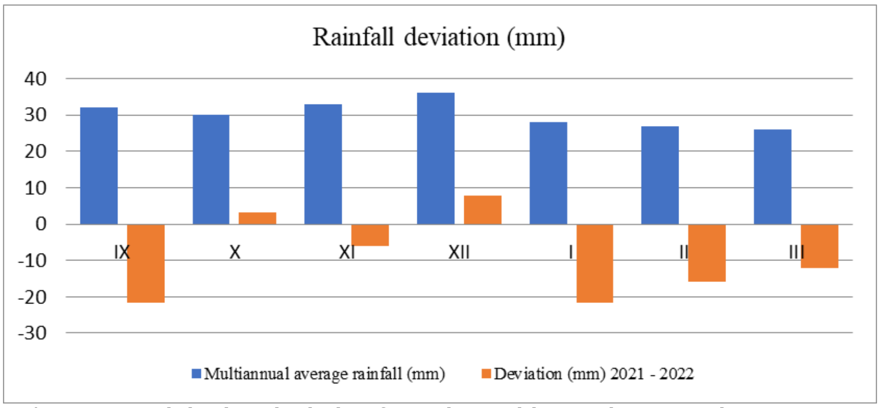

Figure 4 **Precipitation deviation from the multiannual average in 2021-2022**

During the three agricultural years, 2019 – 2022, the weather from September to March was hot, registering positive deviations of +4.1ºC in 2019 – 2020, +3.4ºC in 2020 – 2021, and +2.2ºC in 2021 – 2022. These increased temperatures affect the soil inside and out. On the surface of the soil, the particles are dry and carried out by the wind resulting in erosion. The accumulated water in the soil layer with a depth of 0 - 25 cm, evaporates due to heat. The 0 - 25 cm layer is where the root system of crop plants sown in autumn develops.

Regarding rainfall, in the same period between September and March, the agricultural years 2019 - 2020 and 2021 - 2022 were poor in precipitation, resulting in a deficit of 129.5 mm and 66.2 mm, respectively, compared to the multi-year monthly average of 212 mm. In the agricultural year 2020 – 2021 instead, +23.2 mm of precipitation accumulated in the considered period. This is also evident from the average water reserve of +94 mc/ha compared to the 2019-2020 agricultural year, of -236 mc/ha *(tables 10, 11, 12).*

In the three years of the study, the soil moisture during fall *(figure 5)* highlights the agricultural year 2021-2022 which was well supplied with the accumulated precipitation in the year 2020-2021. In the months of April - August 2021, they recorded +153 mm compared to the multiannual average precipitation stored in the 25-125 cm soil layers.

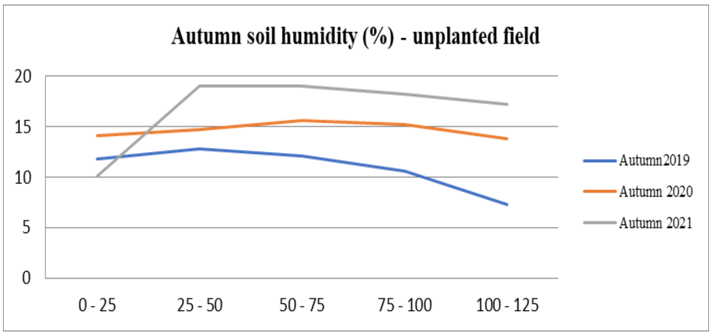

Figure 5 **Average soil moisture in the 0 – 125 cm layers, during the autumns of 2019 – 2022**

The fall of 2021 for the barley crop, had an accumulation of water in the 0-50 cm layers and below average humidity in the 75-125 cm layers.

Barley *(figure 7)* and rapeseed *(figure 8)* crops had lower humidity in the 25 – 125 cm layers in the fall of 2021, which proves that the crop plants consumed water from the soil during germination and emergence.

Table 1

Statistical analysis of average humidities, during the autumn period in 2019 – 2022, in an unplanted field

Layer depth (cm)	Unplanted field - Autumn 2019		Unplanted field - Autumn 2021	
	Difference	Symbol	Difference	Symbol
0 - 25	-2.08	-	-6.59	ooo
25 - 50	1.39	-	2.27	**
50 - 75	1.48	-	2.30	*
75 - 100	0.56	-	1.50	-
100 - 125	-1.34	-	0.51	-

DL 5% =	6.89	DL 5% =	1.58
DL 1% =	10.02	DL 1% =	2.30
DL 0.1% =	15.03	DL 0.1% =	3.46

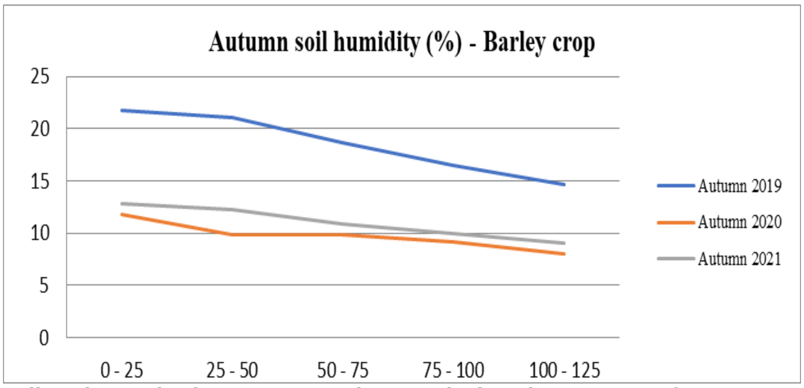

Figure 7 **Average soil moisture in the 0 – 125 cm layers, during the autumn of 2019 – 2022, for barley crop**

The fall of 2021 *(table 2)* shows water accumulation in the 0-50 cm layers and below-average humidity in the 75-125 cm layers.

The autumn of 2021 compared to the autumn of 2019 *(figure 8)*, shows lower humidity in the 0 – 50 cm layers and higher humidity in the 50 – 125 cm layers.

The winter season presented similar soil moisture in all three years of study *(figures 9, 10, 11)* in all observed plots (unplanted field, barley, rapeseed). The amount of water decreased in the 0-50 cm layers and it was relatively constant in the other layers (50-125 cm), which proves that the root system of autumn plants develops at shallow depths until the resumption of vegetative growth in the spring.

The winter of 2021 *(figure 10)* compared to the winter of 2019 shows distinctly higher humidity in the 0-25 cm layer and slightly lower humidity in the 75-125 cm layers.

The winters of 2019 and 2021 show accumulated moisture in the 0-25 cm layer. In 2021, the humidity is constantly low in the 25 - 125 cm layers.

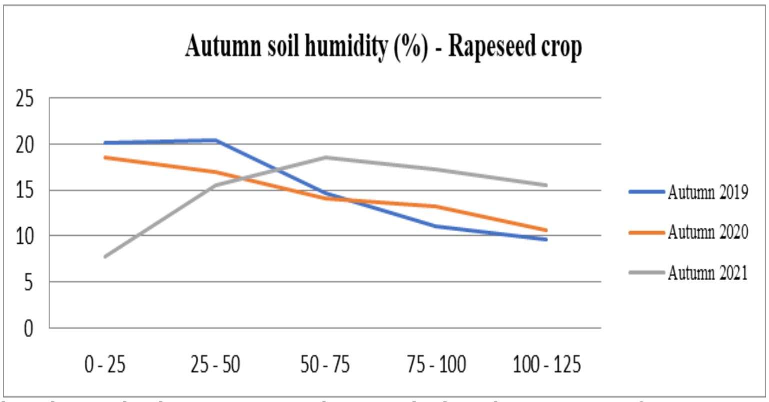

Figure 8 **Average soil moisture in the 0 – 125 cm layers, during the autumn of 2019 – 2022, for rapeseed crop**

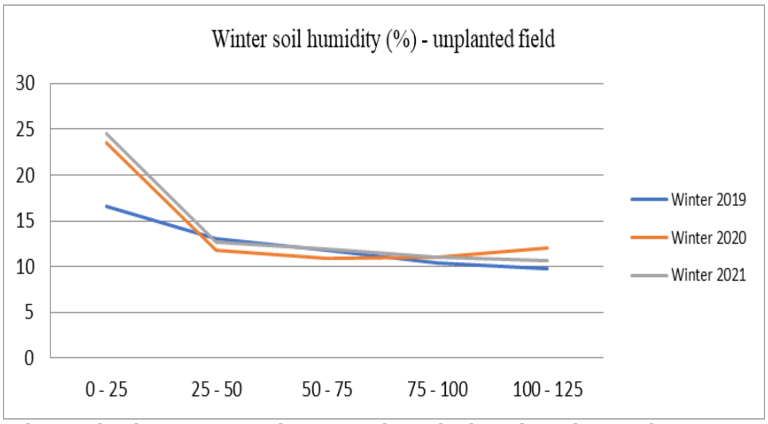

Figure 9 **Average soil moisture in the 0-125 cm layers, taken during the winter of 2019-2022 in the unplanted field**

Table 2

Statistical analysis of average humidities, during the autumn period in 2019 – 2022, for the barley crop

Layer depth (cm)	Barley - Autumn 2019		Barley - Autumn 2021	
	Difference	Symbol	Difference	Symbol
0 - 25	2.40	-	1.87	***
25 - 50	1.33	-	1.27	***
50 - 75	0.03	-	-0.15	-
75 - 100	-1.25	-	-1.03	ooo
100 - 125	-2.51	-	-1.96	ooo
DL 5% =		9.10	DL 5% =	0.31
DL 1% =		13.24	DL 1% =	0.46
DL 0.1% =		19.86	DL 0.1% =	0.68

Table 3

Statistical analysis of average humidities, during the autumn period in 2019 – 2022, for the rapeseed crop

Layer depth (cm)	Rapeseed - Autumn 2019		Rapeseed - Autumn 2021	
	Difference	Symbol	Difference	Symbol
0 - 25	0.55	-	-5.64	ooo
25 - 50	2.69	-	-5.64	ooo
50 - 75	0.80	-	5.15	***
75 - 100	-1.04	-	3.98	***
100 - 125	-3.01	-	2.15	***
DL 5% =		7.45	DL 5% =	0.19
DL 1% =		10.83	DL 1% =	0.28
DL 0.1% =		16.25	DL 0.1% =	0.42

Table 4

Statistical analysis of average humidities during the winter in 2019 – 2022 in the unplanted field

Layer depth (cm)	Unplanted field - Winter 2019		Unplanted field - Winter 2021	
	Difference	Symbol	Difference	Symbol
0 - 25	8.13	**	10.38	***
25 - 50	-0.94	-	-1.43	-
50 - 75	-1.93	-	-2.29	-
75 - 100	-2.62	-	-3.12	o
100 - 125	-2.65	-	-3.54	o
DL 5% =		3.84	DL 5% =	2.86
DL 1% =		5.59	DL 1% =	4.16
DL 0.1% =		8.38	DL 0.1% =	6.24

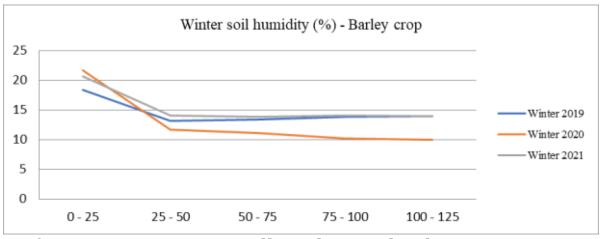

Figure 10 **Average soil moisture in the 0 – 125 cm layers, taken during the winter of 2019 – 2022, for the barley crop**

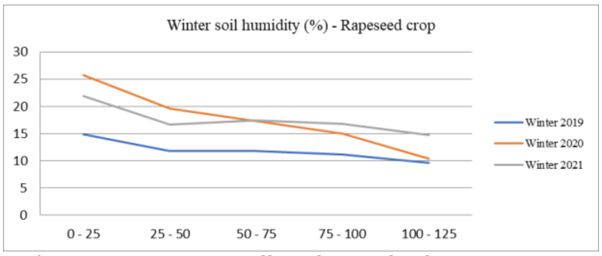

Figure 11 **Average soil moisture in the 0 – 125 cm layers, taken during the winter period of 2019 – 2022, for the rapeseed crop**

Table 5

Statistical analysis of average humidity, during the winter period in 2019 – 2022, for the barley crop

Layer depth (cm)	Barley - Winter 2019		Barley - Winter 2021	
	Difference	Symbol	Difference	Symbol
0 - 25	5.98	**	5.34	***
25 - 50	-1.30	-	-1.24	ooo
50 - 75	-1.47	-	-1.50	ooo
75 - 100	-1.59	-	-1.27	ooo
100 - 125	-1.63	-	-1.34	ooo
DL 5% =		3.41	DL 5% =	0.42
DL 1% =		4.96	DL 1% =	0.61
DL 0.1% =		7.44	DL 0.1% =	0.92

For the rapeseed crop in the winters of 2019 and 2021, there was high humidity in the 0-25 cm layer and below-average humidity in the 25-50 cm layer. The winter of 2021 shows a significant variation in deficit in the layers 75 – 125 cm.

During the spring, higher humidities were observed in 2021 in all studied *plots (figures 12, 13, 14)*. The precipitations accumulated during the winter (+53.9 mm compared to the multiannual average) were stored inside the soil and used by the cultivated plants when the vegetation resumed after vernalization.

Table 6

Statistical analysis of average humidities, during the winter period in 2019 – 2022, for the rapeseed crop

Layer depth (cm)	Rapeseed - Winter 2019		Rapeseed - Winter 2021	
	Difference	Symbol	Difference	Symbol
0 - 25	5.17	-	4.40	***
25 - 50	0.35	-	-0.87	ooo
50 - 75	-0.13	-	-0.08	-
75 - 100	-1.35	-	-0.73	oo
100 - 125	-4.05	-	-2.72	ooo
DL 5% =		7.16	DL 5% =	0.36
DL 1% =		10.41	DL 1% =	0.52
DL 0.1% =		15.62	DL 0.1% =	0.78

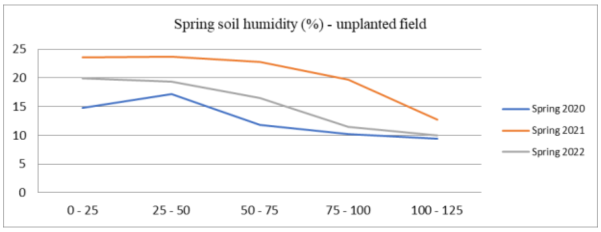

Figure 12 **Average soil moisture in the 0 – 125 cm layers, taken during the spring of the agricultural years 2019 – 2022, in the field**

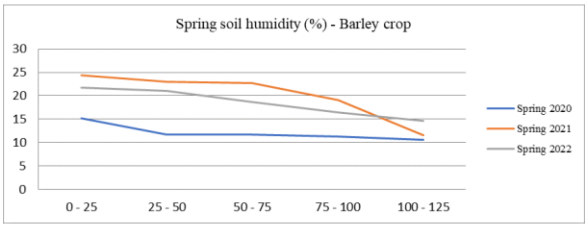

Figure 13 **Average soil moisture in the 0-125 cm layers, taken during the spring of 2019-2022, for the barley crop**

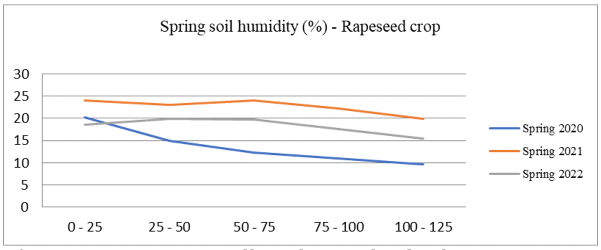

Figure 14 **Average soil moisture in the layers 0 – 125 cm, taken during the spring of 019 – 2022, for the rapeseed crop**

The spring of 2022 *(table 7)* shows high humidity in the 0 – 75 cm layers and below-average humidity in the 75 – 125 cm layers.

The spring of 2022 *(table 8)* compared to the spring of 2020, shows high humidity in the 0 – 50 cm layers and below-average humidity in the 75 – 125 cm layers.

Table 7

Statistical analysis of average humidity, during the spring period in 2019 – 2022, in the unplanted field

Layer depth (cm)	Unplanted field - Spring 2020		Unplanted field - Spring 2022	
	Difference	Symbol	Difference	Symbol
0 - 25	3.18	-	4.44	***
25 - 50	3.89	-	3.95	***
50 - 75	0.81	-	1.00	**
75 - 100	-2.40	-	-3.93	ooo
100 - 125	-5.48	-	-5.47	ooo
DL 5% =		8.02	DL 5% =	0.58
DL 1% =		11.66	DL 1% =	0.84
DL 0.1% =		17.50	DL 0.1% =	1.25

The spring of 2022 *(table 9)* compared to the spring of 2020, shows high humidity in the 0 – 75 cm layers and below-average humidity in the 75 – 125 cm layers.

Table 8

Statistical analysis of average humidities, during spring in 2019 – 2022, for the barley crop

Layer depth (cm)	Barley - Spring 2020		Barley - Spring 2022	
	Difference	Symbol	Difference	Symbol
0 - 25	3.51	-	3.24	***
25 - 50	1.69	-	2.59	***
50 - 75	0.76	-	0.09	-
75 - 100	-1.32	-	-2.07	ooo
100 - 125	-4.63	-	-3.85	ooo
DL 5% =		8.87	DL 5% =	0.40
DL 1% =		12.90	DL 1% =	0.59
DL 0.1% =		19.35	DL 0.1% =	0.88

These humidities *(figures 5 - 14)* confirm that the agricultural year 2019 - 2020 and 2021 - 2022 were dry and the precipitation stored in 2020 - 2021 was preserved inside the layers of the soil, at depths up to 100 - 125 cm.

Table 9

Statistical analysis of average humidity, during the spring period in 2019 – 2022, for the rapeseed crop

Layer depth (cm)	Rapeseed - Spring 2020		Rapeseed - Spring 2022	
	Difference	Symbol	Difference	Symbol
0 - 25	2.77	-	0.26	**
25 - 50	1.15	-	1.69	***
50 - 75	0.50	-	1.52	***
75 - 100	-1.26	-	-0.68	ooo
100 - 125	-3.15	-	-2.79	ooo
DL 5% =		9.17	DL 5% =	0.23
DL 1% =		13.34	DL 1% =	0.33
DL 0.1% =		20.01	DL 0.1% =	0.50

The spring of 2021 accumulated an average amount of +881 mc water/ha above the minimum ceiling of 2444 m³ water/ha, providing the plants with the necessary water for growth and development *(table 10, table 11, table 12).*

The agricultural year 2019 – 2020 recorded a deficit of the water reserve between -444 and -726 m³ water/ha in the unplanted field *(table 10)*, -156 and -541 m³ water/ha in the barley crop *(table 11)*, - 53 and – 581 m³ water/ha in rapeseed crop *(table 12)*. The water storage in the spring of 2021, of +787 m³ water/ha, +732 m³ water/ha, and +1125 m³ water/ha in the unplanted field, barley and rapeseed crops respectively, were used by plants during the summer, in the autumn registering again a water deficit of -712 m³ water/ha for barley and -

97 m³ water/ha for rapeseed, compared to the minimum ceiling of 2444 m³ water/ha. Conversely, +189 m³ of water/ha remained in addition to the minimum ceiling in the unplanted field.

Table 10

Current water supply and soil water reserve, on the 0-125 cm layers, in the unplanted field

Crop	Season/Year	Current water supply (m³/ha)	The wilting coefficient (m³/ha)	Water reserve compared to the wilting coefficient (m³/ha)	Field capacity (m³/ha)	Water deficit compared to field capacity (m³/ha)	Minimum water ceiling (m³/ha)	Soil water reserve (m³/ha)
Unplanted field	Autumn 2019	1718	1362	356	3708	1990	2444	-726
	Winter 2019	1941		579		1767		-503
	Spring 2020	2000		638		1708		-444
	Autumn 2020	2315		953		1393		-129
	Winter 2020	2182		820		1526		-262
	Spring 2021	3231		1869		477		787
	Autumn 2021	2633		1271		1075		189
	Winter 2021	2229		867		1479		-215
	Spring 2022	2435		1073		1273		-9

Table 11

Current water supply and soil water reserve, in the 0-125 cm layers, for the barley crop

Crop	Season/Year	Current water supply (m³/ha)	The wilting coefficient (m³/ha)	Water reserve compared to the wilting coefficient (m³/ha)	Field capacity (m³/ha)	Water deficit compared to field capacity (m³/ha)	Minimum water ceiling (m³/ha)	Soil water reserve (m³/ha)
Barley	Autumn 2019	2917	1362	1555	3708	791	2444	473
	Winter 2019	2288		926		1420		-156
	Spring 2020	1903		541		1805		-541
	Autumn 2020	1537		175		2171		-907
	Winter 2020	2035		673		1673		-409
	Spring 2021	3176		1814		532		732
	Autumn 2021	1732		370		1976		-712
	Winter 2021	2407		1045		1301		-37
	Spring 2022	2917		1555		791		473

Table 12

Current water supply and soil water reserve, in the 0-125 cm layers, for the rapeseed crop

Crop	Season/Year	Current water supply (m³/ha)	The wilting coefficient (m³/ha)	Water reserve compared to the wilting coefficient (m³/ha)	Field capacity (m³/ha)	Water deficit compared to field capacity (m³/ha)	Minimum water ceiling (m³/ha)	Soil water reserve (m³/ha)
Rapeseed	Autumn 2019	2391	1362	1029	3708	1317	2444	-53
	Winter 2019	1863		501		1845		-581
	Spring 2020	2147		785		1561		-297
	Autumn 2020	2309		947		1399		-135
	Winter 2020	2772		1410		936		328

	Spring 2021	3569		2207		139		1125
	Autumn 2021	2347		985		1361		-97
	Winter 2021	2752		1390		956		308
	Spring 2022	2882		1520		826		438

The current water supply between the withering coefficient of 1362 m^3/ha and the field capacity of 3708 m^3/ha, in all three plots observed in the agricultural years 2019 – 2022, shows that although the precipitation was in deficit in 2019 – 2020 and 2021 – 2022, and above the multiannual average in 2020 - 2021, this did not harm the plants in terms of growth but only in terms of production. The values of the current water supply below the withering coefficient produce the death of the plants and above the field capacity, causing puddles that suffocate the plants.

For sorghum crops, different tillages registered humidity between 12 - 14% in the vegetation period of 2020 and between 10 - 13% in the vegetation period of 2021. Scarification, heavy-disc, and no-tillage plots had higher moisture in both 2020 and 2021 compared to the plow and paraplow plots *(table 13)*. Therefore, soil tillages may or may not contribute to the storage and conservation of water, depending on the chosen processing system.

The millet crop's classic soil work system and conservational works had humidity similar to those in the sorghum culture. In 2021, the humidity had higher values for plowing, paraplow and no-tillage works *(table 14)*, which denotes the development of the root system of millet, at greater soil depths, compared to sorghum. development of the root system of millet, at greater soil depths, compared to sorghum.

Table 13

Current water supply and water reserve in the 0-125 cm layers, for the sorghum crop, based on soil works, in the 2019-2021 agricultural years

Sorghum	Soil humidity %		Current water supply (m^3/ha)		Water reserve compared to the wilting coefficient (m^3/ha)		Water deficit compared to field capacity (m^3/ha)		Soil water reserve (m^3/ha)	
Work system	2020	2021	2020	2021	2020	2021	2020	2021	2020	2021
Plow	12	10	1885	1620	523	258	1823	2088	-559	-824
Paraplow	12	10	1943	1563	581	201	1765	2145	-501	-881
Scarification	14	11	2150	1704	788	342	1558	2004	-294	-740
Heavy-disc	14	12	2136	1926	774	564	1572	1782	-308	-518
No Tillage	14	13	2156	2028	794	666	1552	1680	-288	-416
Depth (cm)	0 - 125	The wilting coefficient (m^3/ha)		1362	Field capacity (m^3/ha)		3708	Minimum water ceiling (m^3/ha)		2444

Table 14

Current water supply and water reserve in the 0-125 cm layers, for the millet crop, based on soil works, in the 2019-2021 agricultural years

Millet	Soil humidity %		Current water supply (m^3/ha)		Water reserve compared to the wilting coefficient (m^3/ha)		Water deficit compared to field capacity (m^3/ha)		Soil water reserve (m^3/ha)	
Work system	2020	2021	2020	2021	2020	2021	2020	2021	2020	2021
Plow	14	13	2167	2062	805	700	1541	1646	-277	-382
Paraplow	12	12	1961	1835	599	473	1747	1873	-483	-609
Scarification	14	11	2194	1705	832	343	1514	2003	-250	-739
Heavy-disc	15	11	2322	1803	960	441	1386	1905	-122	-641
No Tillage	14	12	2176	1915	814	553	1532	1793	-268	-529
Depth (cm)	0 - 125	The wilting coefficient (m^3/ha)		1362	Field capacity (m^3/ha)		3708	Minimum water ceiling (m^3/ha)		2444

The higher humidity in the case of no-tillage compared to the classic work-plowing, observed by some researchers (Munawar A. *et al*, 1990; Lampurlanés J. *et al*, 2016; Lafond G. P. *et al*, 1991), also emerges regarding sorghum crop in 2020 and 2021 but regarding millet, in 2020, the humidity was the same for classical and conservational work system. Another advantage of applying minimal tillage is the retention of snow by plant residues (Lafond G. P. *et al*, 1991).

CONCLUSIONS

The 2020-2021 agricultural year was rich in precipitation; the water being absorbed by the poorly supplied soil up to depths of 125 cm.

The amount of water in the 0-50 cm layers, present until the beginning of winter, is essential to increase the resistance of crop plants to aggressive climatic factors characteristic of this season. The decrease in soil moisture recorded in this season during the three years of the study demonstrates that plants consume water for germination and emergence, and the amount of precipitation accumulated since spring is critical for their development.

The precipitation deficit in the 2019-2020 and 2021-2022 agricultural years did not drop below the withering coefficient therefore the plants went through all the growth stages in 2019-2020, but the effects of this deficit were reflected in the production.

The excess rainfall recorded in the 2020-2021 agricultural year did not exceed the field capacity limit, which proves that the soil stored the water that fell from the rainfall at great depths without causing puddles.

The sorghum culture needs water in the 0-50 cm layers, thus being affected by the type of tillage.

Millet crop accessed water from greater depths in 2021, with two types of soil works, characteristic of conservative agriculture – scarified and heavy-disc in 2020 there was no significant variation in humidity depending on the tillage, the reason for which we can deduce the fact that millet lends itself to any system of works, accessing water throughout the depth of 0-125 cm, depending on its presence in the soil.

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