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RESEARCHES ON WATER AVAILABILITY IN FUNCTION OF SOIL TILLAGES

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Abstract

We have researched the water lose in conventional, no-till with and without mulch layer in vegetation vessels and we have found that the upper layer in no-till without mulch layer system conducted to lose of much more water which results in poorer plant development. We have considered that the mulch layer prevents the water lose and improve the better root growing and plant developing. The conventional tillage as well as the minimum tillage helps creating an upper layer with larger pores which slow the water loses, too. Better results of minimal tillage can also be explained by better water keeping due to the loosened upper 5-7 cm of soil. Our conclusion is the need to manage the residue layer in order to reduce water loss which results in better root growth, plant development and better yield than conventional system in high evaporative climates.

Key words*: no-till, mulch, water.*

INTRODUCTION

Like other areas of human activity, agriculture is evolving. If for thousands of years people have cultivated the land by using plowing as a basic work, in recent decades a new method has emerged, namely that of sowing directly into the not tilled soil. It seems, at first glance, inconceivable; against the customs of our ancestors, but the results prove that, through this technique, the soil maintains its fertility and the productions are even higher. In addition, expenses are much reduced, a farmer can work a larger area and earn better.

It is true that research in this field was forced by the oil crises of the 1970s, but this has proven beneficial. The first were American researchers from the universities of Kentucky, Indiana and Ohio who still have the oldest experiences mounted on the topic of no-till.

The soil has only been vigorously tilled by plowing very recently, and plants have been able to grow in the artificially tilled soil since they first appeared on Earth.

These conditions, however, presupposed the existence of a layer of plant debris left over from previous years, in various stages of physical breakdown and microbiological decomposition.

By trying to crop the land without tillage but also without the layer of plant debris, we will create the conditions for the formation of a compacted superficial layer resulting from self-compaction – the basic tillage and preparation of the germination bed applied for decades have led to the fragmentation of soil aggregates and their more compact placement – and the action of rain (Figure 3).

This layer, having lower capillarity than the one in depth, extracts water from the deeper layers, from the active root zone, and loses it through evaporation; in addition, as it dries, its cohesion increases and the root can no longer grow normally in this layer.

No longer able to explore a large volume of soil and no longer having sufficient water, the access of oxygen being, also, hindered by the reduced spaces through which air exchange takes place, the plants growing in these conditions have given extremely low yields.

In order to grow plants without doing soil tillage, which is considered by many researchers abroad to be unnecessary and harmful, the mulch layer on the soil surface is essential. Its role, first and foremost, is to maintain water in the soil and, hence, the advantages but also the disadvantages that arose:

- decrease in soil cohesion and facilitation of root growth;
- improvement of plant water supply;
- increase in the availability of mineral elements;

- formation of a stable hydrological structure;
- slowing down the rate of decomposition of plant resources and the gradual release of nutrients;
- reduction of soil temperature in the summer and reduction of amplitudes between day and night;
- increase in the number of living things in the soil;
- radical decrease in erosion by water or wind;
- reduction of humus losses and increase in soil fertility.

The disadvantages consist of:
- decrease in soil temperature at sowing;
- acidification of the superficial soil layer due to leaching and the predominance of fungi in the decomposition of organic matter;
- increase in the proportion of large, airy spaces within the soil porosity, with effects on the leaching of substances from the soil solution;
- decrease in the soil's water capacity by reducing the capillary spaces that retain useful water;
- technological difficulties in creating this layer;
- the need to change agricultural machinery.

The most important advantages of this system are:
- lower labor requirements;
- higher financial benefits;
- increased soil fertility and reduced erosion (https://istro.org/; http://www.rolf-derpsch.com/en/no-till/; https://conservationagriculture.org/app/uploads/2019/02/STEPS-TO-NO-TILL-ADOPTION-R.-DERPSH.pdf; https://www.no-tillfarmer.com/articles/12148-worlds-longest-continuing-no-till-plots-at-ohio-state-hit-60-years; https://en.wikipedia.org/wiki/No-till_farming; https://pt.wikipedia.org/wiki/Plantio_direto; https://journals.usamvcluj.ro/index.php/promediu/article/view/11870; Triplett G. B. et al., 2007).

The negative effects of intensive and repeated soil tillage on humus content, erosion, water infiltration, flora and fauna, and nutrient loss lead to physical, chemical, and biological degradation of the soil, which in turn leads to lower yields over time and reduced soil productivity.

The introduction of no till requires, first of all, good documentation of experimental results and farmers' experience in different pedoclimatic conditions, the availability of good and cheap herbicides, suitable agricultural machinery, the use of rational rotations that also include green manures or cover crops to create the mulch layer, and a change in mentality.

This new technology is not a fashion but will be imposed by economic and ecological needs. Romania, which has a temperate climate, similar to that of the USA, Argentina, Chile, Paraguay, etc. must follow their example and start research that will lead to the adoption of this new agricultural system (Table 1).

If the first attempts of our researchers failed due to the lack of suitable agricultural machinery and herbicides, now is the time to revitalize this research cause there are very good and cheap herbicides and agricultural machinery, for a start, these can be imported. We need, in addition to the fundamental research in this field, a direct link with farmers. Through their direct involvement, by organizing demonstration plots directly on their farms, information can be disseminated more easily and directly.

Table 1. The surfaces cropped on no till technology around the world till 2018-2919

World's continents	Surface, thousand hectares	Amount of continent cropland
South America	83,001	68.7
North America	65,882	33.6
Australia and New Zealand	23,309	74.0
Asia	17,482	3.6
Russia and Ukraine	6,920	4.5
Europe	5,584	5.2
Africa	445	1.1
World no-tilled surface	205,399	14.7

Source: Kassam, A. et al.,2022.

In Romania, the area cultivated with no-till technology was 583 thousand hectares in 2019, but it is growing very strongly thanks to the new generation of farmers who are becoming more informed and adapting much better.

MATERIALS AND METHODS

Two experiments were located at the Economic Sector of the Botanical Garden of the University of Craiova. The first experiment was conducted in the field and included 5 treatments in 3 replications. The treatments tested were:

- V1: control variant, plowing in autumn and spring bed preparation by harrowing;
- V2: no-till without mulch layer;
- V3: no-till with pea mulch layer
- V4: no-till with triticale mulch layer mixed with peas;
- V5: no-till with triticale mulch layer

The surface of an experimental plot is 40 m^2, i.e. 6 rows at 70 cm on a length of 8 m. The soil tillage was carried out manually, with a spade, in the case of basic soil tillage, simulating plowing and the preparation of the germinal bed, in the spring, with a hoe, simulating disc tillage. The mulch layer was obtained by cultivating peas (V3), a mixture of peas and triticale (V4) and triticale (V5). These special crops for creating the mulch layer (cover crops) were sown in early spring, in March, when it was possible to go out into the field. At the end of April, the mulch crops were herbicided with Roundup and, after a week, chopped to create a layer of plant residues on the soil surface (Figure 1).

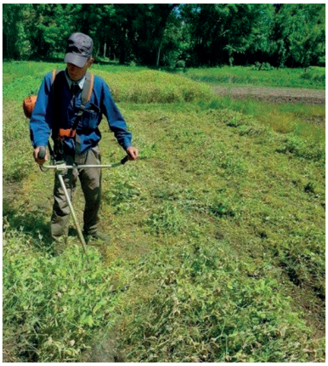

Figure 1. Cutting pea plants for mulch (original)

Weed control was achieved through 2 treatments with Mistral, based on nicosulfuron, because there was a massive infestation with Bermuda grass weed (*Cynodon dactylon*) (Figure 2). During the vegetation period, determinations of the current soil moisture were made by the direct method, by drying in an oven, on two dates: June 10 and July 15. Determinations of the bulk soil density were also made, also by the direct method, after taking the soil in Nekrasov cylinders, on two depths: 0-10 and 10-20 cm. The height of the corn plants was also measured, before harvesting.

Figure 2. Treatment with a layer of pea mulch after applying the Mistral herbicide (original)

In order to determine the amount of water lost by comparing the two systems, we organized an experiment in vegetation pots using the three types of texture: sandy, loamy and clayey. Three vegetation pots were filled with soil from each type of texture. For each type of texture, three types of soil cultivation were organized:
1. scratched at 5-7 cm with a knife;
2. no-till without a layer of mulch;
3. no-till with a layer of mulch.

The vegetation pots were prepared in October and were left outside all winter and spring, to acquire a natural settlement.

The determination of the mass of the vegetation pots began in the spring, in March, and continued until July 15. The weightings were made, as far as possible, daily. At the beginning of May, corn was sown in each vegetation pot and one plant was maintained in each cylinder. In addition to determining the water loss through evapotranspiration, which was done by weighing the vegetation pots, the height of the plants, the dimensions of the ears and roots were also determined. Also, the textural and chemical properties of the three soil types were determined.

RESULTS AND DISCUSSIONS

Results on field experiment

Results obtained in the first year of experimentation:

The results highlight that the main effect of tillage is to keep water in the soil, available to the roots. In the absence of tillage, it forms a superficial compacted layer of 3-5 cm that extracts water from depth and loses it through evaporation. Direct sowing in no-till land requires the presence of a mulch layer to prevent evaporation of water from the soil (Figure 3).

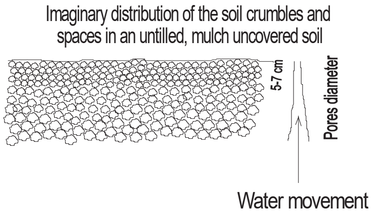

Figure 3. Water movement in a no-till not covered soil (original)

The sowing was done on May 5th and the plants sprouted after 5 days due to the rain (Figure 4).

Figure 4. Seedbed preparation and sowing in the mulch layer variant from the previous year, alongside the tilled variant (original)

Soil moisture was very strongly influenced by tillage or the presence of mulch. Two determinations of soil moisture and bulk density were made, on June 15 and July 10. These results are presented below (Table 2).

Table 2. Soil moisture and bulk density, depending on soil tillage and the presence of the mulch layer and its nature and thickness (original)

Treatment	Depth (cm)	15 June		10 July	
		U, %	Bd, g/cm^3 at 5-15 cm	U, %	Bd, g/cm^3 la 5-15 cm
V1	0-10	13.9	1.30	12.9	1.35
	10-20	14.3		13.5	
V2	0-10	13.5	1.45	12.5	1.44
	10-20	14.5		12.8	
V3	0-10	14.3	1.27	13.5	1.35
	10-20	14.0		13.8	
V4	0-10	14.5	1.33	12.8	1.30
	10-20	14.7		13.0	
V5	0-10	14.8	1.30	13.4	1.35
	10-20	14.9		13.9	

On October 15, the plots were harvested. Due to the fact that the Botanical Garden is a public place, about half of the ears disappeared. For this reason, we made an assessment of the production on each plot, by counting the plants and calculating the production by multiplying the number of plants by the average mass of an ear in each experimental plot. Plant height was also determined, also at harvest. These data were statistically interpreted by analysis of variance. The results are presented in Table 3.

Table 3. Corn yield and plant height depending on soil tillage and mulch layer, at the Botanical Garden of the University of Craiova (original)

Treatment	Height, cm	Yield, kg/ha	%	Diff. kg/ha	Sign.
V1	230	7,973	100	Ctrl,	-
V2	120	3,512	44	-4,461	000
V3	210	6,410	80	-1,563	0
V4	170	4,421	55	-3,553	000
V5	120	2,798	35	-5,175	000

DL 5%=1,156kg/ha; DL 1%=1,623 kg/ha; DL 0.1%= 2,291kg/ha

From these results we can conclude that tillage gave the best yields and the tallest corn plants (Table 3).
The no-till variant with peas as a mulch layer was the best of the three types of mulch due to its thickness and nitrogen content. This variant was close in terms of production and plant height to the control variant, it shows. This proves the possibility of applying no-till technology, provided that the mulch layer is created as thick as possible, with high coverage and rich in nitrogen.
The variants with a mixture of triticale and peas or only triticale, used to create the mulch layer, gave poor results due to the insufficiency of plant material and its poorer nitrogen content.
From this data we can easily see that the best way to keep water in the soil for use by plant roots is to keep it covered with a thick layer of mulch that has a C/N ratio close to 25 to 1. Tilling the soil causes water to be retained in the soil by forming wider spaces in the tilled layer, wider than the ones below. This slows down the water's access to the soil surface, where it is lost through evaporation. This is why tilled soil produces good yields. Untilled soil without a mulch layer forms a superficial layer a few cm more compact than in depth. This leads to the migration of water from the soil to the surface because narrower spaces

attract water more strongly than wider spaces. Once it reaches the surface, the water evaporates very quickly, within a few hours, causing the soil to dry out and harden, which results in plant failure (Figure 5).

Figure 5. No-till variant without mulch layer.
It is observed that the plants have hardly grown at all (original)

Figure 6. The conventional treatment.
The plants developed normally (original)

Figure 7. Pea covercrop treatment (original)

Results obtained in the second year of experimentation.

The sowing was done on April 30. During that period there was a lot of rain and the corn plants grew very well in the first 2 weeks. This year we applied the herbicide Adengo, based on isoxaflutole 225 g/l + thiencarbazone-methyl 90 g/l + cyprosulfamide (safener) 150 g/l. The application was done in early post-emergence. We were surprised that this herbicide did not controlled the species Digitaria sanguinalis which grew unhindered, especially in the plots with and without mulch.

Humidity determinations were made on June 1 and July 10.

Table 4. Soil moisture at June 1 and July 10, depending on the base tillage and the presence of the mulch layer (original)

Treatment	Depth (cm)	Soil moisture, %	
		1 june	10 july
V1 - plow	0-10	12.5	14.4
	10-20	12.9	14.8
V2 – no-till no mulch	0-10	11.7	13.2
	10-20	12.0	13.5
V3 – no-till pea mulch	0-10	13.4	15.4
	10-20	14.2	16.3

From these data we can see that the no-till variant with pea mulch retained the best water in the soil and the no till variant without a mulch layer had the lowest actual soil moisture at both dates (Table 4).

On September 14, the experimental plots were harvested and the yield was weighed. Plant height measurements at harvest were also made. The results are presented in the Table 5.

Table 5. Corn plant height and ear production per hectare depending on basic soil tillage and the presence of mulch layer (original)

Treatment	Plant height, cm	Yield, kg/ha	%	Diff. kg/ha	Sign.
V1 - plow	210	6,845	100	Mt.	-
V2 - no-till no mulch	120	540	7.8	- 6,305	000
V3 - no-till pea mulch	220	7,250	105	405	*

DL 5% = 225 kg/ha; DL 1% = 480 kg/ha; DL 0.1% = 680 kg/ha

From these results we can conclude that the no-till variant with pea mulch yielded better results than the tilled variant this year. The no-till

variant without a layer of mulch yielded almost no harvest (Table 5, Figures 6 and 7).
Similar results have been obtained by (https://growingformarket.com/articles/cover-cropping-notill-systems; https://ohioline.osu.edu/factsheet/SAG-11; http://dasnr54.dasnr.okstate.edu:8080/notill2015/publications/no-till-handbook/Chapter%2012.pdf; https://rodaleinstitute.org/science/articles/choosing-the-best-cover-crops-for-your-organic-no-till-vegetable-system/; https://www.gardeningknowhow.com/edible/grains/cover-crops/no-till-cover-crops.htm; Jacobs A.A. et al., 2022)

Results on pot experiment

From the results of the weightings of the clay soil pots, we can see that during the spring no significant differences were obtained between the variants, probably due to the reduced evaporative potential of the atmosphere in these conditions. However, between the three cylinders of the clay texture, differences can be observed regarding the speed and amount of evaporated water. Thus, the tilled pot and, especially the one covered with mulch recorded lower values of the amount of evaporated water compared to the uncovered and no tilled pot. This can be observed almost every day of weighing. Another aspect of soil moisture is that it is much more fluctuating in the no tilled and uncovered pot than in the tilled or mulched ones.

The following period, from early June to early July, is characterized by very large amounts of water lost through evapotranspiration due to the increase in atmospheric temperature, the decrease in pressure and, consequently, the increase in evaporative potential by increasing the amount of water vapor at which the dew point is reached.

During this period, the greatest differences between vegetation pots are observed. Thus, while the tilled and no tilled-uncovered pots lost water very quickly (almost 1 kg per week), the soil covered with mulch, even no tilled, lost only 1.458 kg of water throughout the month (Table 6).

Table 6. Dynamics of the mass of vegetation pots in an experiment carried out at the Botanical Garden of the University of Craiova (original)

D	CM	CT	C	LM	LT	L	SM	ST	S
22	27	27	27	22	22	22	27	27	27
29	28	28	28	23	23	22	29	28	28
6	28	28	28	23	23	22	28	28	28
11	28	28	28	22	23	22	28	28	28
25	28	28	29	23	23	23	29	29	29
13	28	28	28	23	23	23	29	29	29
15	27	28	28	23	23	22	28	28	28
17	27	28	28	23	23	22	28	28	28
21	26	27	27	22	22	21	27	27	27
23	25	26	26	21	22	21	27	27	27
25	25	26	26	21	21	21	26	26	26
1	26	27	28	21	22	21	28	28	27
5	28	29	30	23	24	23	29	30	30

Legend: D - days within march to july; CM - clay mulch; CT - clay tillage; C - clay, no-mulch, no-till; LM - loam mulch; LT - loam tillage; L - no-mulch, no-till; SM - sand mulch; ST - sand tillage; S - no-mulch, no-till.

The soil temperature at a depth of 5 cm, on May 20, at 11^{00} clock was as follows: CM (clay mulch) = 17°C; CT (clay tilled) = 19°C; C (uncovered clay) = 19°C; LM (loam mulch) = 16°C; LT (loam tillage) = 21°C; L (uncovered loam) = 18°C; SM (sandy mulch) = 18°C; ST (sandy tillage) = 22.5°C; S (uncovered sandy soil) = 22°C.

The mulch layer greatly reduces the evaporation of water from the soil in all soil textural types, but especially in clayey soil. In the spring, when water evaporates more slowly, the method of tillage or soil maintenance did not determine obvious differences between the treatments.

Tilled soil loses less water than no tilled and uncovered soil due to the larger spaces created on the soil surface by tillage, spaces that are larger than those in the depths.

No-tilled and uncovered soil forms a superficial layer of 5-7 cm of soil with lower capillarity than that in the depths. This causes water to migrate from the depths to this superficial layer, which quickly loses it through evaporation. The rapid loss of water through evaporation from no-till bare and soil causes soil hardening, less water available to the plant, a very poor overall development of the plant and, ultimately, a very poor or no yield (Table 7).

Table 7. Air-dried corn cob mass, root length and volume as a function of soil texture and tillage method (original)

Tillage and mulch	Specification	Soil texture		
		Clay	Loam	Sandy
No-till mulch	Cob mass (g)	Missing data	11.149	13.558
	Root lenght (cm)	32.0	27.0	32.0
	Root volume (cm^3)	6	7	6
Tillage	Cob mass (g)	16.500	7.647	10.481
	Root lenght (cm)	32.5	25.0	32.0
	Root volume (cm^3)	6	4	6
No-till bare	Cob mass (g)	12.097	8.482	8.950 (no grains)
	Root lenght (cm)	26.0	24.0	27.0
	Root volume (cm^3)	4	3	4

The roots of corn plants developed differently depending on both the textural type of soil and the way the soil was tilled and maintained. Thus, in no-till soil covered with mulch, fine roots are observed located closer to the soil surface compared to tilled soil. Also, no till soil without mulch causes the formation of a less developed root due to soil hardening caused by rapid water loss through evaporation.

CONCLUSIONS

Conclusions regarding the field experience

Conclusions after the first year of experimentation:

The conventionally tilled variant gave the highest production in the first year of experimentation, of 7,973 kg/ha.

The lowest productions were obtained by the variant with triticale mulch (2,798 kg/ha) and the variant without mulch layer (3,512 kg/ha), very significantly negative compared to the classic variant.

The variant with pea mulch gave, in the first year of experimentation, a production close to the classic tilled variant (6,410 compared to 7,973) significantly negative.

The variant with pea mulch mixed with triticale gave an intermediate production between the classical tilled one and the one with pea mulch.

From these results we can conclude that tillage gave the best productions and the tallest corn plants.

The no-till variant with peas as a mulch layer was the best of the three types of mulch due to its thickness and nitrogen content. This variant was close in terms of production and plant height to the control variant, it shows. This proves the possibility of applying the no-till technology, provided that the mulch layer is created as thick as possible, with high coverage and rich in nitrogen. The variants with a mixture of triticale and peas or only triticale, used to create the mulch layer, gave poor results due to the insufficiency of plant material and its poorer nitrogen content.

Conclusions after the second year of experimentation.

From the results obtained in the second year of experimentation, we can conclude that the no-till variant with pea mulch gave better results than the tilled variant. The no-till bare treatment almost did not yield a harvest.

Conclusions regarding the experience in vegetation pots.

The mulch layer greatly reduces the evaporation of water from the soil in all textural types of soil, but especially in clayey soil.

In the spring, when water evaporates more slowly, the method of tillage or soil maintenance did not determine obvious differences between the variants.

Tilled soil loses less water than untilled and uncovered soil due to the larger spaces that are created on the soil surface by tillage, spaces that are larger than those in the depth.

No-till bare soil forms a superficial layer of 5-7 cm of soil with lower capillarity than that in the depth. This causes water to migrate from deep into this surface layer, which quickly loses it through evaporation.

The rapid loss of water through evaporation from uncultivated and uncovered soil causes soil compaction, less water available to the plant, very poor overall plant development, and ultimately very poor production.

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