RESEARCHING CONSERVATION AGRICULTURE FOR CLIMATE CHANGE ADAPTATION

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Abstract

Conservation agriculture is an agricultural system that significantly contributes to climate change adaptation in many countries around the world. Many farmers in the Republic of Moldova are adopting this system and applying it successfully. Unfortunately, agricultural science has lagged for various reasons. A field experiment was conducted on the lands of the National Centre for Research and Seed Production to identify the main issues in cultivating corn under no-tillage systems compared to traditional agricultural systems. The results were next: the germination of cover crops, both in mixed and pure stands, was successful. The amount of water accumulated in the soil during the autumn-winter period was strongly influenced by soil management methods. The highest amount of water, 126 mm, was recorded in the variant where the soil was covered with plant residues. In the autumn-spring period, the cover crops formed up to 10.5 tons per hectare of above-ground dry biomass. Corn grain production ranged from 2.50 to 5.41 tons per hectare in 2023. The general conclusion was that research in conservation agriculture is highly complex and requires time and resources to be conducted successfully. A new research project has been established. The main objectives have been set, and initial investigations have been carried out. To successfully study conservation agriculture, unique and simple, as well as complex and multifactorial experiments, are necessary, along with the demonstration of result.

***Key words**: Conservation Agriculture, conventional agriculture, cover crops, corn*

INTRODUCTION

According to the National Communications (2009, 2013, 2018) the Republic of Moldova is more likely to be affected by three types of climate impacts: temperature increases; changes in precipitation regimes and increased climate aridity, which are associated with the frequency and intensity amplification of extreme weather events, such as heatwaves and frost, floods, storms with heavy rains and hail, severe droughts. Many studies have shown that the agricultural sector is very vulnerable to climate change. The 2022-2023 and 2023-2024 agricultural years caused enormous losses due to heatwaves, higher temperatures, and drought. Climate change adaptation is the process of adjusting natural and human systems to current climate variability or future climate change, with the aim of moderating damages or taking advantage of beneficial opportunities (Gavrilas and Druta, 2016). Promoting conservation agriculture is one of the agricultural sector adaptation priorities (Update NDC, 2020). Conservation Agriculture is an ecosystem approach to regenerative sustainable agriculture and land management based on the practical application of context specific and locally adapted three interlinked principles of: (i) Continuous no or minimum mechanical soil disturbance (no-till seeding/planting and weeding, and minimum soil disturbance with all other farm operations including harvesting); (ii) permanent maintenance of soil mulch cover (crop biomass, stubble and cover crops); and (iii) diversification of cropping system (economically, environmentally and socially adapted rotations and/or sequences and/or associations involving annuals and/or perennials, including legumes and cover crops), along with other complementary good agricultural production and land management practices. Conservation Agriculture systems are present in all continents, involving rainfed and irrigated systems including annual cropland systems, perennial systems, orchards and plantation systems, agroforestry systems, crop-livestock systems, pasture and rangeland systems, organic production systems and rice-based systems. Conservation Tillage, Reduced Tillage and Minimum Tillage are not Conservation Agriculture, and nor is No-Till on its own (Kassam et al., 2020). The misunderstanding and misinterpretation of the concept of conservation agriculture has slowed the adoption process of this sustainable farming system. Confusing conservation tillage with conservation agriculture has led to significant expenses for farmers who aimed to preserve soil using tillage tools. Nevertheless, the global total Conservation Agriculture cropland area in 2018/2019 was approximately 205.4 M ha, corresponding to about 14.7% of the total global cropland (Kassam et al., 2022). The area Conservation Agriculture in the Republic of Moldova is estimated to be 50-55 thousand of ha. This estimation referred only to the cropland area according to an evaluation undertaken by Mihail Rurac in 2024. The first farmer who began practicing Conservation Agriculture in Moldova is Veaceslav Ciornîi. Starting from 2008 and continuing to the present day, he has applied the most advanced soil management techniques, using cover crops in mixtures, no-tillage seeding, and a diversified crop rotation. Each year, the farmer experiments with new methods, diversifies crops, and conducts numerous small trials to adapt his farm to climate change. To facilitate the exchange of knowledge and practices among farmers who apply climate-smart agriculture, or are interested in this type of farming, the Climate-Smart Agriculture Community of Practice (https://www.cop.cstsp.md/) was established in 2022 with the support of the Food and Agriculture Organization (FAO). The authors of this article actively participate in moderating this community. With the evident climate changes in recent years, farmers' interest in Conservation Agriculture has grown, along with the need for scientific results based on local experience.

MATERIALS AND METHODS

Research on Conservation Agriculture began in 2022 with the establishment of a field experiment at the National Centre for Research and Seed Production. The initial objective was to investigate the viability of growing corn under no-tillage conditions. The study was conducted within a crop rotation sequence of winter wheat followed by corn for grain. After the winter wheat harvest on August 25, 2022, the following experimental variantss were implemented: 1. Witness. After the preceding crop's harvest, ploughing to a depth of 25-27 cm was conducted with a mouldboard plow, followed by spring harrowing and cultivation prior to corn sowing; 2. CA I**.** In this variant, stubble and all plant residues were left on the soil surface without incorporation or further soil tillage; 3. CA II. Mustard was sown as a cover crop on August 25, 2022; 4. CA III**.** Spring vetch was sown as a cover crop on August 25, 2022; 5. CA IV. A mix of cover crops was sown as a cover crop on August 25, 2022; 6. CA V**.** Winter vetch was selected as a cover crop, sown on August 25, 2022, with the intention of terminating it before corn sowing; 7. CA VI. Winter vetch was selected as a cover crop, sown with the intention of terminating it after corn sowing. Variant 1. Witness. Based on conventional agriculture practices. Variants 2-7. CA I-VI. Based on conservation agriculture practices. The experiment was conducted with three replications, with each plot covering 270 m². Cover crops were sown using a Gherardi G117 drill, designed for both conventional and no-tillage systems. Due to significant weed pressure following the wheat harvest, cover crops were sown at higher seeding rates to compensate for uneven distribution of plant residues and the relatively lightweight drill, which could prevent some seeds from reaching the soil. No fertilizers were applied in these trials. The pure seeding rates for individual cover crops were as follows:

- Mustard: 20 kg/ha
- Spring Vetch: 100 kg/ha
- Winter Vetch: 100 kg/ha.

The cover crop mixture composition was:

- Oats: 10 kg/ha (9.97%)
- Millet: 13 kg/ha (12.98%)
- Sorghum: 15 kg/ha (14.98%)
- Mustard: 8 kg/ha (7.98%)
- Daikon Radish: 1.25 kg/ha (1.24%)
- Coriander: 5.98 kg/ha (4.98%)
- Black Radish: 10 kg/ha (9.97%)
- Phacelia: 8 kg/ha (7.97%)
- Soybean: 30 kg/ha (29.94%).

On August 26, 2022, immediately after sowing, the herbicide Ouragan Forte 500 SL (glyphosate 500 g/L, potassium salt) was applied to all conservation agriculture plots at a rate of 4 L/ha. This broad-spectrum herbicide aimed to control both annual and perennial weeds that emerged post-wheat harvest and prior to cover crop establishment. In spring, two weeks before corn planting (April 24, 2023), a mix of 2 L/ha of Ouragan Forte 500 SL and 60 g/ha of 2,4-D 500 was applied to conservation agriculture variants (excluding CA VI). This application targeted surviving spring cover crops, biennial species within the mix, and volunteer wheat from the previous crop. For CA I, which lacked cover crops, this application also controlled emerged weeds. Corn planting across all treatments took place on May 7, 2023, using a KINZE 3505 no-till planter, sowing the Porumbeni 391 hybrid at a density of 62,000 seeds/ha perpendicular to plot layout.

Figure 1. Planting corn into winter vetch. 7.05.2023. (photo M. Rurac)

In CA VI, an additional herbicide application (2 L/ha of Ouragan Forte 500 SL and 60 g/ha of 2,4-D 500) was applied on May 10, 2023, as planting occurred before the autumn vetch was fully terminated. For the conventional agriculture control, a different herbicide, Legenda OD (mesotrione + nicosulfuron, 75+30 g/L), was applied on June 8, 2023, at 1.25 L/ha to control emerging monocotyledonous and dicotyledonous weeds. Following the winter wheat harvest in autumn 2022, 195 mm of precipitation was recorded (12 mm in July, 133 mm in August, and 50 mm in September). During the 2023 corn growing season, rainfall totalled 370 mm, distributed as follows: 173 mm in April, 85 mm in May, 34 mm in June, 75 mm in July, and 3 mm in August. The soil type at the experimental site is a loamy-clay carbonate chernozem, with a humus content of 3.2%, mobile phosphorus (P_2O_5) at 1.9 mg/100g (Macighin method), exchangeable potassium (K_2O) at 24 mg/100g (Maslova method), and a nitrification capacity of 1.4 mg/100g. Throughout the growing season, cover crop and corn plant development were monitored, with soil moisture and water reserves assessed gravimetrically. Green and dry biomass measurements for cover crops were taken at the end of the winter growing period and again after planting in spring, using a metric frame. Corn yields were harvested manually at full grain maturity from sample areas, adjusted to a standard moisture level of 14%, and statistically analysed using Dospehov's methodology (Dospehov, 1985).

RESULTS AND DISCUSSIONS

The climatic conditions of summer 2022 were quite favourable for the cultivation of cover crops. The abundant rainfall in August (133 mm) and the positive temperatures in August-September were sufficient for the emergence and subsequent development of the cover crops. By September 16, 2022, all cultivated species had sprouted, showing 2-3 true leaves. Nodules were observed on the roots of leguminous crops, particularly spring vetch. By the end of October, Daikon Radish from the cover crop mix had developed roots reaching 30 cm in depth, while other species had fully covered the soil surface. On November 12, 2022, green and air-dry biomass measurements were taken from the cover crops, with plant samples collected. The obtained data are presented in Table 1.

Table.1. Green and air-dry biomass of cover crops, November 12, 2022

Variants	CA II	CA III	CA IV	CA V-VI
Green biomass, (t/ha)	10.5	13.9	27.7	27.4
Air-dry biomass, (t/ha)	3.4	4.1	5.4	6.2

In the autumn of 2022, dry matter accumulated in cover crops ranged between 3.4 and 6.2 t/ha. Achieving a rich cover crop biomass under no-till sowing is the first outcome of this experiment. The role of cover crops in maintaining soil health is well documented in Western literature. In Moldova, cover crops are not widely adopted, as it is commonly believed that dry autumns limit soil moisture, preventing successful crop establishment. However, soil moisture measurements at the end of the water accumulation period indicated a difference among the experimental variants. The highest soil moisture content was recorded in Conservation Agriculture I, with 126 mm (Table 2.), where post-harvest winter wheat residues were left on the soil surface, amounting to 3 t/ha. Leaving stubble and straw on the soil surface enhances water infiltration and retention more effectively than conventional tillage, even under limited rainfall.

Table 2. Available soil water reserves by treatment, mm, March 20, 2023

Soil Layer (cm)	Witness	CA I	CA II	C IV
0–10	14.1	12.9	11.0	14.9
10–20	12.1	12.9	10.4	13.4
20–30	12.1	12.8	10.1	13.3
30–40	12.1	11.6	9.8	12.7
40–50	11.9	13.7	10.8	11.8
50–60	11.1	12.7	9.3	11.0
60–70	11.7	12.4	9.3	9.1
70–80	10.6	12.2	8.0	6.4
80–90	11.5	12.7	8.5	6.3
90–100	11.2	12.1	1.2	6.1
Total (0–100 cm)	118.4	126.0	88.4	105.0

Cover crops consume significant amounts of water and must be managed wisely to avoid yield loss in dry years. The 2022-23 winter was mild, so not all spring cover crops froze: some continued growing into spring. On April 24, 2023, herbicide mixtures were applied on Conservation Agriculture plots (I-V) to terminate cover crops, kill volunteer plants, and control weeds. In Conservation Agriculture VI, autumn vetch was terminated post-corn planting on May 10, 2023. Dry biomass measurements of plant residues, cover crops, and weeds on the soil surface indicated that all variants produced different quantities and qualities of residue, aligned with the respective crops planted. Residues included a wide C/N ratio, such as wheat straw, and very narrow C/N ratios, such as vetch. The quantity and quality logically influence soil regimes, particularly nutrients and thermal dynamics.

Corn seedling emergence was staggered. The first seedlings emerged, as expected, in Conventional Agriculture on May 19, 2023. Corn seedlings in Conservation Agriculture VI, where cover crops were terminated post-emergence, appeared on May 29, 2023, showing a ten-day difference between these extremes. In the traditional variant, the soil warmed quickly, promoting rapid corn emergence.

Figure 2. General view on experimental field. In front variant Witness. 10.06.23.

In Conservation Agriculture VI, the soil was covered with more than 10 t/ha of dry biomass (Table 3). Corn plants in Conservation Agriculture variants experienced slower growth compared to those in conventional agriculture, likely due to nutrient limitations, heavy shading during early growth stages, suboptimal seeding in plots with winter vetch cover, and potentially other factors requiring further investigation.

Table 3. Air-dry biomass of plant residues, cover crops, and weeds, t/ha, 10.05. 2023

Treatment	CA I	CA II	CA III	CA IV	CA V	CA VI
Biomass (t/ha)	2.8	4.6	2.5	4.1	9.8	10.5

The drought period in July-August 2023 affected treatments with autumn vetch cover crops (CA V-VI) most severely, causing a sharp reduction in grain yield. The highest survival rate was recorded in the conventional agriculture variant, at 84% (Table 4), likely due to:

- Well adapted for conventional agriculture hybrid,
- Optimal planting timing for this treatment,
- Uniform emergence from rapid soil warming,
- A levelled soil surface from tillage, and
- Deep incorporation of plant residues that did not interfere with corn seed germination.

Table 4. Corn plant survival and grain yield

Variants	Corn plant survival at harvest(thousands/ha)	Survival rate (%)	grain yield (t/ha)
Witness	52	84	5.41
CA I	46	74	2.82
CA II	48	77	3.29
CA III	43	69	3.76
CA IV	49	82	2.74
CA V	47	76	4.26
CA VI	42	68	2.50
LSD 0.5			0.79

All treatments with Conservation Agriculture yielded lower grain production compared to conventional agriculture, with statistically significant differences.

Through our initiated research, we realized that studying conservation agriculture requires consideration of all factors to optimize technological aspects. In this article, we have highlighted some of the errors encountered, though many remain unmentioned. Some additional observations are outlined below.

The soil on the experimental plot was highly susceptible to water erosion. The conservation agriculture variants were not directly affected. Weeds are a notable issue in conservation agriculture, and we do not recommend starting conservation agriculture with cover crops, as this could risk weed infestation across the field. Perennial weeds are difficult to detect within cover crops and may carry over, infesting the subsequent crop. The experiments were conducted on soil that had not undergone chemical analysis, and the low level of mobile phosphorus could also have contributed to the reduced yields in the conservation agriculture variants. Additionally, the experiments were carried out on land with unevenly distributed plant residues, and the field itself was not level.

With the return of 567.8 hectares of arable land to the Technical University of Moldova (UTM), the opportunity has arisen to initiate more extensive research in the field of conservation agriculture. Conservation Agriculture is not a static technology but a dynamic system that will vary based on biophysical and socio-economic conditions and will evolve over time. Research and development programs need to address this need (Friedrich et al., 2008). Contributions from various branches of technical and social sciences, economic disciplines, stakeholders, and interest groups must be combined to develop technologies and systems adapted to diverse conditions and users (Baker et al., 2007).

A new research project is being launched, involving all interested researchers from the Technical University of Moldova. As the research progresses, contributions from outside the university will also be required. Initial trials will be short-term, aimed at acquiring the foundational knowledge necessary to advance the system. Once conservation agriculture yields match those of conventional agriculture, multi-annual and multi-factorial trials will be established. Additionally, the results will be showcased in demonstration plots to engage farmers in the research, obtain feedback, and continually refine the studies. In autumn 2024, the first preparatory work began for establishing trials scheduled for autumn 2025.

The research approach will progress from simple to complex, continuously improving soil management to achieve stable yields and soil regeneration.

Field test N1. Gradual transition from Conventional to Conservation Agriculture

Objective**:** Transition to conservation agriculture without reducing yields but with cost reductions. Start date: Autumn 2024, variants:

1. Recommended for conventional agriculture
2. Conservation variant without phosphorus fertilization
3. Conservation variant with recommended dose of phosphorus
4. Conservation variant with half of the recommended dose of phosphorus

Soil samples will be collected immediately after harvesting the preceding crop to assess the mobile phosphorus content. Phosphorus fertilizer doses will be calculated to stabilize phosphorus levels at the beginning of the trials. The depth of soil tillage will be determined on-site; if a plow pan is present, deep tillage will be recommended. After tillage, the soil will be levelled. In spring, a cereal or corn for grain will be sown, cultivated conventionally, without inter-row tillage. In autumn, winter wheat will be planted using a no-till drill within the conservation system. Over three years, a crop rotation of winter wheat, sunflower, and corn (for grain) will be followed.

Expected Results**:** Understanding the role of balancing accessible phosphorus levels in the soil and identifying and addressing issues arising during the transition to conservation agriculture. Conditions for transitioning to conservation agriculture without yield reduction will be described, and results will be applied across all sectors transitioning to conservation agriculture.

Field test N 2. Understanding key challenges in transitioning to Conservation Agriculture.

Objective: To understand key challenges related to seeding depth, seed placement, drill configuration, residue management, seeding time, and seeding density. Start date: Autumn 2025. Perpendicular to the variants from the first experiment, several variants with different practices will be tested.

The results obtained will provide a foundation for establishing error-free, multi-annual trial.

CONCLUSIONS

Conservation Agriculture is a new agricultural system, fundamentally different from traditional agriculture. The specialized literature highlights essential aspects that must be considered. Neglecting, omitting, or lacking knowledge of these aspects can compromise the system (Derpsch et al., 2014). Research in conservation agriculture must be conducted gradually, meticulously, and with careful prior planning. The involvement of stakeholders and experts from fields related to conservation agriculture can enhance the quality of research. Engaging farmers in the planning, execution, and dissemination of results could potentially help avoid errors and eliminate unnecessary research efforts.

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