TECHNICAL AND ECONOMIC EFFICIENCY OF THE DRIP IRRIGATION SYSTEM AT S.C. TRITICUM S.R.L.

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Abstract

The new global challenges related to climate change, the efficient use of natural resources, sustainability or food security require scientifically based and updated answers in order to create the general framework for ensuring the balance of human-economic activity-nature system. The paper aims to highlight the technical-economic efficiency of the drip irrigation system at S.C. Triticum SRL, an enterprise with agricultural profile from Neamț County, Romania. In order to show the efficiency, the technical description, the analysis of the statistical indicators (based on the data provided by the accounting balances made available), the correlation of the irrigation potential with the yield increase and the identification of the productivity of the drip irrigation system were taken into account. The results of the study indicate a significant increase in yield obtained as a result of using of the system compared to the non-irrigated version (and implicitly an increase in the economic result recorded by the company). The research also identifies a much more efficient use of the amount of water in relation with the increase in production. Drip irrigation systems can be sources of added value in a green economy being elements that can contribute to ensuring the technical-economic performance of agricultural holdings. Even if the initial investment is high, requiring additional efforts on the part of the beneficiary, the calculations highlight the profitability of using such a system and also the results can be extrapolated to other economic units in the agricultural sector with similar characteristics.

Key words: climate change, drip irrigation system, technical and economic efficiency

The importance and necessity of the research subject are given by the unfavorable climate developments in recent years and the increase in the unpredictability of the rainfall amount associated with different crop areas, with the physiological drought affecting a large part of the cultivated areas.

The main issue in agricultural field raising a lot of concern nowadays are crop productivity and saving irrigation water, people becoming increasingly aware of the need for conservation of limited natural resources (Sharaiha R. *et al,* 2020 and Wilde C. *et al,* 2009), the efficient use of agricultural water being named by Ali A. *et al* (2020) as one of the most significant challenges of this century. One of the greatest negative impact on agriculture is determined by droughts (Prepeliţă (Popovici) Cătălina Ionela, 2021), irrigation being essential for increasing the efficiency of input-use and improving crop yields (Luhach M.S. *et al,* 2004).

Technical capital is essential in achieving performance, capital being the main engine of economic growth (Ștefan G. *et al,* 2015). For the majority of the farms the need for irrigation infrastructure is acute. According to Mocanu I. *et al* (2021) rehabilitation of irrigation systems led to capitalizing at a higher level on the agro-productive potential of the areas served, ensuring high yielding agricultural production, reducing prolonged droughts and improving the microclimate.

Developing the necessary infrastructure for water resources and encouraging a good management in this field, is a common policy agenda in many countries (Khalifa W. *et al*, 2020) investments in hydro-ameliorations activities having a direct influence on agricultural production (Vanghele C., 2019).

Modern irrigation technology can be favorable not only for the farmer but also for the national economy by achieving optimal use of resources (Ali A. *et al*, 2020) and as a part of it the drip irrigation system can represent a successful technological model in ensuring high productivity and water saving.

Drip irrigation is the most advanced and efficient method of irrigation. However, the advantages of this technique regarding the additional controlled amounts of water, cannot be obtained if the user is not familiar with related knowledge and does not implement it in the operation and maintenance of the system.

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Drip irrigation system not only reduces the cost of supplied water, but also the costs related to human labour and other cultivation costs and only the lack of knowledge about the water saving and cost effectiveness of the drip system among farmers has led to its limited use compared to other conventional irrigation systems (Yadav A. *et al,* 2022).

According to Vanghele C. (2019) economic efficiency is reflected by the conditions under which the production activity is carried out. Technical efficiency is related to more entrepreneurship features like farmers' environmental and risk attitudes, investment decisions, and socioeconomic characteristics (Belay A. *et al*, 2022).

Yadav A. *et al* (2022) states that it is indispensable to adopt a strategy regarding water-efficient irrigation at a large scale. Drip irrigation system is a solution offered to farmers in order to achieve higher yields and larger water savings.

A study conducted by Jarwar A.H. *et al* (2019) suggests that drip irrigation, apart from advantage of water saving in comparison to conventional irrigation, is highly effective and economically profitable, investments in drip irrigation having a favorable benefit-cost ratio.

Climate changes in recent years favored extreme weather phenomena, such as prolonged drought or lack of snow (such as the winter of 2020), which are the main natural risk factors for agricultural crops. Extreme temperatures and droughts are frequent phenomena and, above all, difficult to anticipate. Therefore, research on the efficiency of irrigation techniques and soil quality has the role of substantiating investment decisions at the farm level and technological decisions for fertilization and fertigation of agricultural land.

MATERIAL AND METHOD

The material case study. The study involved researching irrigation technologies for field crops in order to increase the level of adaptation to climatic challenges (e.g. droughts).

The experimental research fields of modern irrigation techniques were organized at the level of arable land with a total area of 31.07 ha cultivated with maize, in Săvinești Commune, Neamț County, made available for the study by TRITICUM S.R.L..

The 31.07 ha area that is the subject of this paper (part of a larger project) was divided into 7 operating zones, which could operate in optimal parameters, under different operating conditions (for example, different water flows, different periods of irrigation, distinct ways of working the soil, etc.), according to the specific research activities established.

In order to obtain the proposed results, it was carried out the description and technical analysis of the system, the analysis of statistical indicators (based on the data provided by the accounting balance sheets made available), the correlation of the irrigation potential with the yield increase and the identification of the productivity for watering with the drip irrigation system, through comparative analysis.

Economic added value per m^2 of cropland was calculated by subtracting the water irrigation expenses from the production value per unit. To highlight the results, the research followed the evolution of the technical-economic indicators for the 7 research areas (*figure 1*) with differentiated irrigation characteristics. In order to identify the economic impact, only the average water consumption for the entire surface as well as the average yield, were taken into account.

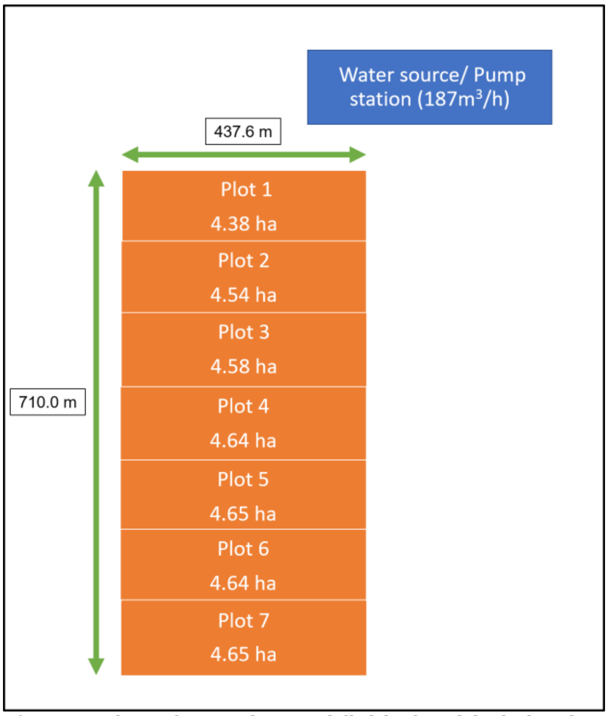

Figure 1 **Plan of experimental fields for drip irrigation - Săvinești, Neamț County**

RESULTS AND DISCUSSIONS

Technical efficiency

In *Table 1* there are presented the technical parameters (as average of the research areas) of the drip irrigation system proposed for the current research using as example the maize crop. The maximum daily consumption was established at 6.00 mm/day, the maximum discharge required being 88.77 m^3/h.

Table 1

Technical parameters of irrigation (average of the 7 research areas)

Parameters	M. U.	Details (average values)
Crop	-	maize (grain)
Irrigation area	ha	31.07
Rows spacing	m	0.70
Plants spacing	m	0.20
Emitter maximum allowed pressure	bar	1.6 – 2.0
Emitter discharge	l/h	0.8 – 1.2
Emitter spacing	m	0.50
Laterals average spacing	m	1.00
Application rate	mm/h	2.00
Maximum daily consumption	mm/day	6.00
Irrigation cycle	days	1.0
Duration of one operation	h/day	3.0
Number of operations	no.	8.00
Maximum daily operation duration	h	21.00
Maximum discharge required	m^3/h	88.77

Source: "AGRIECOTEC" project data

The structure of the drip irrigation system *(figure 2)* is a complex one, comprising several interconnected elements. The components of the system are: 1. Water source; 2. Pumping station; 3. Vent valve; 4. Manometer; 5. Shock direction valve; 6. Damper; 7. Main manual valve; 8. Filter unit; 9. Automatic drainage valve on main filtration; 10. Water meter; 11. Hydraulic valve; 12. Secondary filtration unit; 13. Dosing unit; 14. Tank for fertilizers; 15. Irrigation controller; 16. Main distribution pipe; 17. Secondary distribution pipe: 18. Distribution line; 19. Kinetic valve (non-return valve); 20. Drip line; 21. Washing valve; 22. Drain pipe (washing); 23. Fertilizer filter

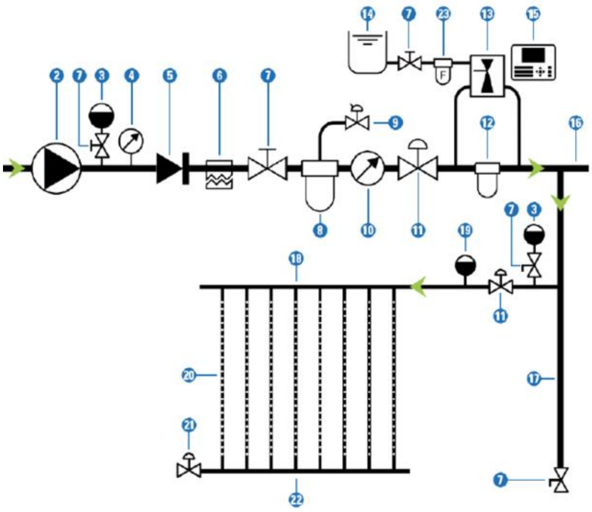

Figure 2 **The structure of the drip irrigation system**

Technical details of the components necessary for the research of underground drip irrigation techniques have been established based on scientific, methodological considerations and practical experiences in the field of irrigation.

The amount of water required to irrigate the entire arable surface of the experimental fields is provided by pumping from the existing river in the northern part of the land, at a distance of approximately 1.15 km.

The analyzed area was irrigated with the help of a pumping station provided by the farmer, which ensures a total flow of 187 cubic meters/hour. Drip line (*figure 3*) chosen for researching underground drip irrigation techniques has an inner diameter of 20-24 mm, with a wall thickness of 0.3-0.5 mm.

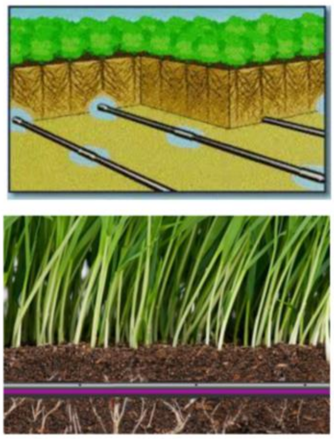

Figure 3 **Drip lines (captioned photos for example)**

The line provides advanced pressure compensation technology. A constant discharge rate is maintained over a pressure between 1.6 and 2.0 bar. The investment includes drip lines with compensated drip, with a distributed flow through the dripper of 0.8-1.2 l/h. The distance between the drippers is 0.50 m and the drip lines were placed at distances of 0.7-1.5 meters.

The environmental effects of the drip irrigation system have been assessed as favorable, ensuring the protection of water, air, soil and subsoil quality.

The research for the present study took place in Lunca Cracăului, in the field of SC Triticum SRL Săvinești (*figure 4*), Neamț county, on a clay chernozem, with a current moisture content of 19% g/g, field capacity (FC) of 23.2% g/g, wilting coefficient (WC) of 14.8% g /g and an apparent density (AD) of 1.36 g/cm^3 (average values over a depth of 80 cm). The application moment for watering was when the soil moisture was decreasing and approaching the value of the minimum ceiling.

Figure 4 **Maize field at SC Triticum SRL (August 2021)**

The values of the distributed water related to the number of turns is presented in *Table 2*:

Table 2

Technical characteristics of the drippers

No. of turns	M.L. (mm)	Discharge (l/h)	V.D.W. (l)
9	680	1.96	19.6
7	530	2.26	22.6
6	455	2.69	26.9
5	380	3.65	36.5

M.L. - Microtube length, V.D.W. - Volume of distributed water

Source: "AGRIECOTEC" project data

The irrigation pipe, placed on the surface of the soil, was suspended at a height of approximately 8 cm above the soil level, on the places where the drippers were located. A collection container was placed under a dropper of each pair, to measure the volume of water distributed directly on the soil surface. The collection containers were kept covered to avoid water loss through evaporation. The amounts of water accumulated in the collection containers were rigorously measured with a graduated cylinder every 30 minutes for 10 hours. Subsequently, the average flow rate for each dropper was calculated. Twenty-four hours after the irrigation, soil samples were taken to determine the moisture values.

The method of determining the moment of application of watering depending on the vegetation phases takes into account the fact that, for each plant, water consumption is higher in some vegetation phases, called critical phases. Since the direct dependence of the harvest on the state of soil moisture during the critical phases was found, managing the irrigation regime by applying watering shortly before the onset of these vegetation phases is rational, considering the fact that the entire surface occupied by the crop can be irrigated in 2 - 3 days.

Determining the moment of application of watering by measuring the suction of the soil with the help of tensiometers, is the method with the prospect of expansion simultaneously with the increase in the degree of automation of irrigation systems.

Two tensiometers were installed in each station: one with the porous probe at the depth of 1/3 H (in the area of maximum spread of the roots) and another, at the H depth. The moment of application of watering is highlighted by the tensiometer that measures the suction at a depth of 1/3 H, when on its screen the indicator needle oscillates between divisions 30-60, depending on the characteristics of the soil (30-40 for light soils, 40-50 for medium soils and 50-60 for heavy soils).

It was highlighted that if the soil suction is kept below 70 centibars in the active root zone, the plants will not suffer from lack of water. On sandy soils where the water storage capacity is low, it is best to start irrigation at lower values, especially if the irrigation process is delayed.

If the soil suction values oscillate between 0-10 centibars for whole days, it means that the soil is saturated with water and it is necessary to improve the drainage conditions to remove the excess water. It is very useful to make a graph of the readings during the growing season. Since an increasingly present challenge in the farm's activity is represented by the severe drought starting from June-August months, special attention is being paid at the enterprise level to the efficiency of new field crop irrigation technologies, the need to reduce the impact of agriculture on the environment being a major topic of interest for the farm management.

Economic efficiency

At the level of the general performance for the study-case farm, for the last period, according to the results obtained (*Table 3*), an increase in the turnover in 2021 of 2.11 times compared to the level recorded in 2020 with incidence on the realized gross profit, is highlighted. A contribution to these results, was made by the investment aimed at current research in addition to effective management practiced at the enterprise level, capitalizing on the technical potential and human resources at his disposal, as well as outlining clear strategies for development and acquiring a technical-economic competitive advantage.

Table 3

The evolution of economic indicators for S.C. TRITICUM S.R.L.

Year	Turnover	Gross profit	Net profit	Income	Costs	Inventory	Number of employees
2021	2833334	982087	917662	4197024	3214937	212079	5
2020	1341547	412483	409975	2185261	1772778	255665	4
2019	1437153	447789	446382	1831804	1384015	52233	3
2018	1262286	268937	266104	1645717	1376780	77956	4
2017	1470777	706516	706516	2041564	1335048	167795	4
2016	1160652	506843	433349	1566194	1059351	115131	3

Source: S.C. TRITICUM S.R.L. balance sheets

The amount of precipitation (rainfall) for the Săvinești Commune, Neamț County, varied quite a lot in relation to the monthly averages. Thus, in May 2022 there was a deviation of -42 mm, in June 2022 of -57 mm, for July 2021 of -42 mm and in August 2020 of -18 mm. Above-average values were recorded in June and August 2021 (+27 mm) (*figure 5*).

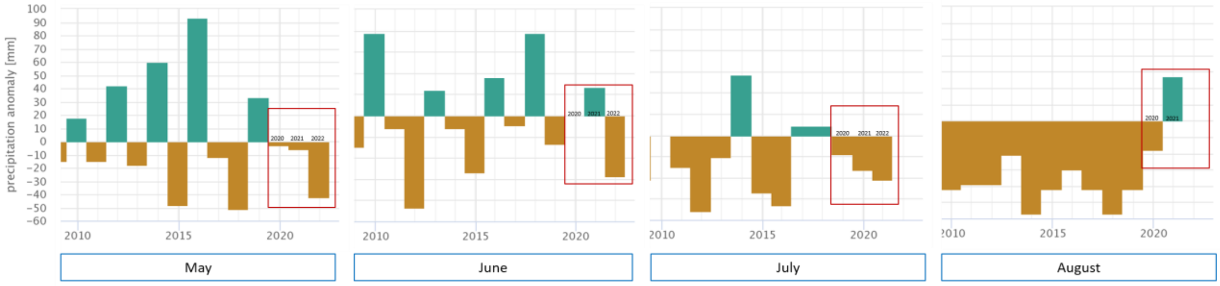

Figure 5 **Climate change - Săvineşti. The precipitation anomaly per month compared to the average**

The water irrigation volume recorded in 2020 average values of 2.31 l/m^2/day for May, 2.15 l/m^2/day for June, 4.74 l/m^2/day for July and 3.28 l/m^2/day for August with variations between plots depending on the watering characteristics initially established (*figure 6*).

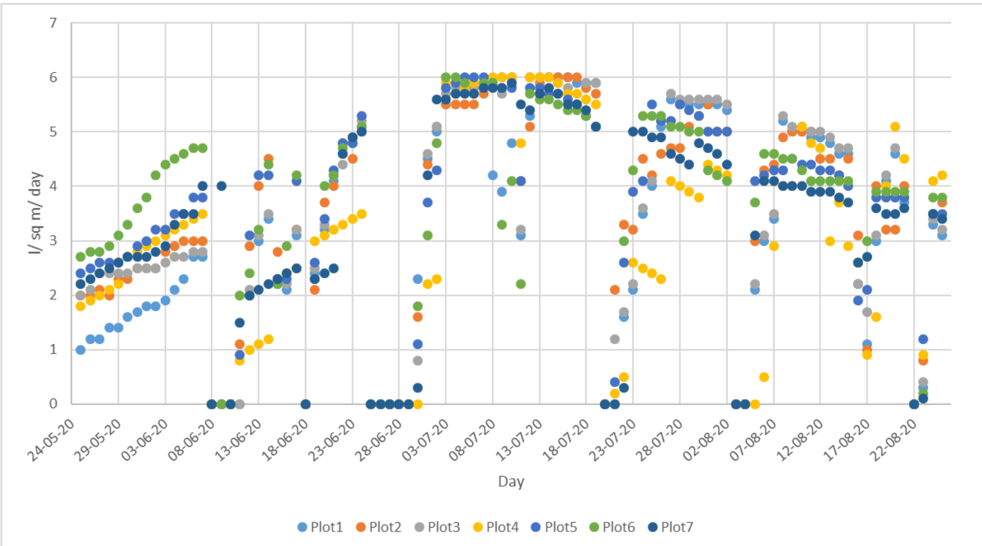

Figure 6 **The evolution of water consumption distribution in the 7 research plots (May-August 2020)**

The average volume of water used in drip irrigation in 2020 was 3.3 l/m^2/day with higher values in the months of July and August when the amounts of precipitation for the Săvinești Commune were below the usual average.

There were few days (on average 14) in which the irrigation system was not activated, thus revealing its necessity at the level of cultivated land (*figure 7*).

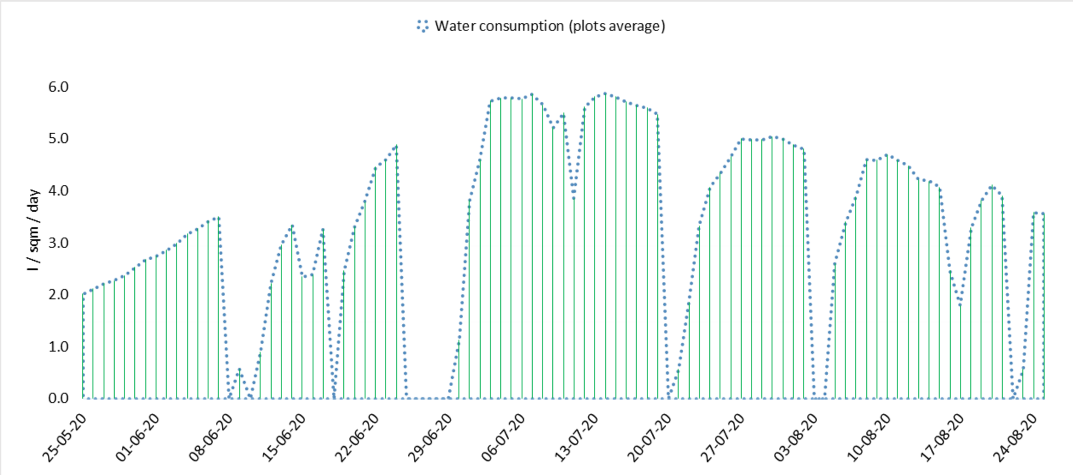

Figure 7 **Evolution of average water consumption in the 7 research plots (May-August 2020)**

In 2021, the watering options on the research areas recorded average values of 2.21 l/m^2/day for May, 1.07 l/m^2/day for June, 3.83 l/m^2/day for July and 0.74 l/m^2/day for August (*figure 8*).

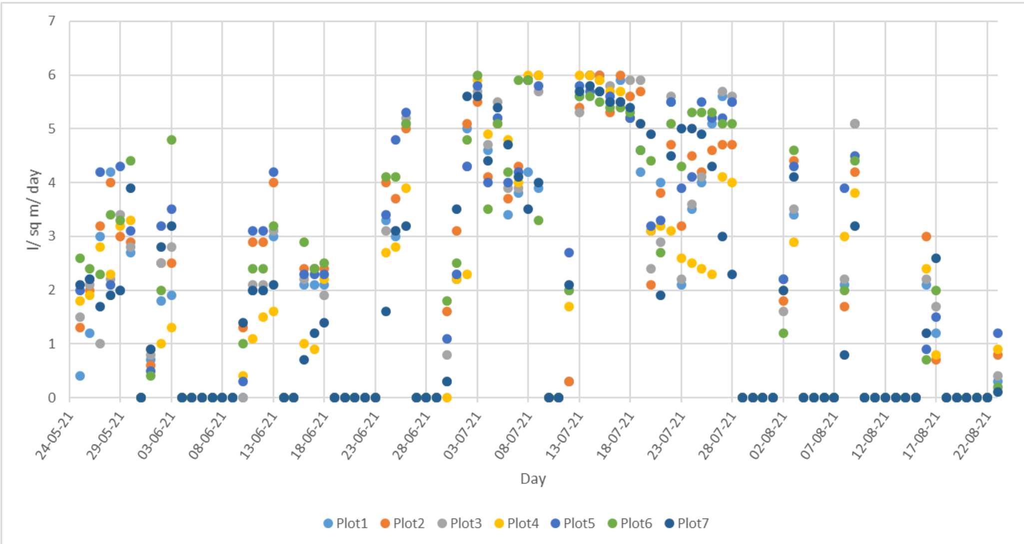

Figure 8 **The evolution of water consumption distribution in the 7 research plots (May-August 2021)**

In 2021, the average volume of water used in drip irrigation was approximately 2 l/m^2/day with low values in the months of May and August when the amounts of precipitation for the Săvineşti area were above the usual average. On average, the number of days when the irrigation system was not activated was 39 (*figure 9*).

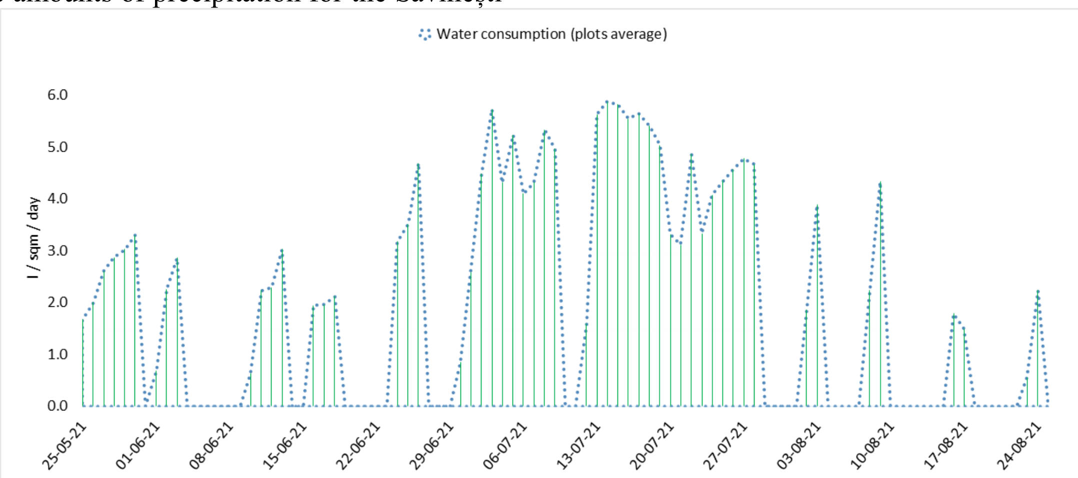

Figure 9 **Evolution of average water consumption in the 7 research plots (May-August 2021)**

The yield recorded in 2020 for the experimental plots was 12192 kg/ha (compared to 7152 kg/ha in the non-irrigated version), in 2021 the yield being 12436 kg/ha (compared to 9311 kg/ha in the non-irrigated control area). Following the evaluation of the drip irrigation system, an average increase in yield for 2020 of 5040 kg/ha and for 2021 of 3125 kg/ha compared to the non-irrigated area was highlighted (*table 4*) given that it was a more favorable year for agriculture from the climatic point of view.

Table 4

Maize yields increase due to drip irrigation (kg/ha)

Indicator	Plot 1	Plot 2	Plot 3	Plot 4	Plot 5	Plot 6	Plot 7	Control
Yield 2020	12219	12194	12151	12223	12229	12246	12277	6751
Increase 2020	*+5468*	*+5443*	*+5400*	*+5472*	*+5478*	*+5495*	*+5526*	-
Yield 2021	12440	12484	12518	12822	12396	12977	12716	9116
Increase 2021	*+3324*	*+3368*	*+3402*	*+3706*	*+3280*	*+3861*	*+3600*	-

Source: own calculations using "AGRIECOTEC" project data

The productivity recorded within the farm, expressed as a ratio between the increase in production (obtained as a result of the use of the innovative system) and the volume of water consumed in the drip irrigation process, was for the year 2020 of 0.0017 kg/l, the value for the year 2021 being 0.0019 kg/l.

Total water consumption was 309.7 l/m^2 in 2020, with a cost of 0.075 lei per m^2 of cultivated land, and 184.7 l in 2021 at a cost of 0.045 lei/m^2.

The yield gain and consequently the total income resulted, decreased in 2021 as the difference compared to the non-irrigated version was no longer as significant (being a favorable year in terms of rainfall).

The economic gain achieved was 0.532 lei/m^2 for 2020 and 0.376 lei/m^2 in 2021 (table 3), a fact that highlights the contribution of the drip irrigation system to the global added value achieved within S.C. TRITICUM S.R.L. enterprise.

Table 5

Economic efficiency analysis of using drip irrigation system

Indicator	M.U.	2020	2021
Total water consumption (in l)	l/m^2	309.70	184.70
Total water consumption (in m^3)	m^3/m^2	0.3097	0.1847
Water cost (per m^3 water)	lei/m^3	0.243	0.243
Water cost (per m^2 land)	lei/m^2	**0.075**	**0.045**
Average yield increase (per ha)	kg/ha	5648.86	3505.85
Average yield increase (per m^2)	kg/m^2	0.5468	0.3505
Selling price for maize	lei/kg	1.11	1.20
Income for the yield increase	lei/m^2	**0.607**	**0.421**
Economic added value	lei/m^2	**+0.532**	**+0.376**

Source: own calculations using "AGRIECOTEC" project data

CONCLUSIONS

The results recorded within the current research carried out, reflected mainly by the yield increase (and consequently the added value obtained) highlight the technical and economic efficiency related to drip irrigation system implementation, promoting it as a strategic tool to limit the negative influence caused by the acute lack of precipitation and at the same time ensuring an agricultural production necessary to achieve economic balance.

Regarding the economic impact of the investment represented by the drip irrigation system for the company TRITICUM S.R.L., it consist in obtaining higher yields at the farm level, reducing the consumption of water, energy and fertilizers, with effects in increasing agricultural production and reducing production costs due to efficient irrigation. Therefore, the investment represented by the drip irrigation system has a favorable impact on increasing the innovation capacity of the enterprise, contributing to the improvement of the overall performance.

In the efficiency analysis it is necessary to take into account the fact that, although it is difficult to quantify, in addition to the results provided by the calculations, the drip irrigation system also has an inherent insurance value, offering the security of a good production in years with severe drought and with minimal resource allocations for maintenance process.

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