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COMPARATIVE ANALYSIS OF DRIP AND SPRINKLER IRRIGATION IN AUTUMN WHITE CABBAGE

Alexandra Violeta LAZIA[1]*, Valentina VOICU, (ORCID: 0000-0001-7774-3054)[1, 2, 3], Nicoleta AXINTI, (ORCID: 0009-0001-7111-3745) [1,2,4], Maria Magdalena TUREK RAHOVEANU, (ORCID: 0000-0001-5238-5641)[1,2]

[1] Faculty of Engineering and Agronomy of Braila, "Dunărea de Jos" University of Galați, 29 Călărașilor Str., 810017 Brăila, România
[2] Research and Consultancy Center for Agronomy and Environment "Lunca" (CCCAM Lunca), 29 Călărașilor Str., 810017 Brăila, România
[3]National Research and Development Institute for Soil Science, Agrochemistry and Environment – ICPA Bucharest, 61 Marasti Blvd., District 1, 011464 Bucharest, Romania
[4] Brăila Agricultural Research and Development Station, Romania, Km 9 Viziru St., Brăila, Romania

*Corresponding author: alexandra.lazia@ugal.ro

Abstract. *In the context of climate change, demographic pressure, and the need to improve resource efficiency, sustainable agriculture represents a strategic area of interest at both national and European levels. The choice of this study topic was motivated by the need to increase profitability in small and medium-sized farms by identifying viable solutions for farmers operating under conditions similar to those in the Însurăței area. The main objective of this study was to analyze the technology applied to autumn white cabbage cultivation under irrigated conditions in the pedoclimatic environment of Însurăței, Brăila County. The experiment was conducted on a 0.5 ha area, where two irrigation systems (drip and sprinkler) were compared on equal plots (0.25 ha each), under similar soil and technological conditions. The analysis included agronomic observations, yield measurements, and economic indicators to evaluate the technical and economic efficiency of each system. From a productivity perspective, the drip irrigation system consistently proved superior to the conventional sprinkler system, regardless of simulated losses. Drip irrigation achieved a yield of 124.34 t/ha, while sprinkler irrigation reached 101.76 t/ha under difficult conditions with 10% losses. To assess the profitability of cabbage cultivation depending on the irrigation method and technological losses, key economic indicators were calculated (gross profit, cost-benefit ratio, and economic return). The results showed that, on 0.25 ha plots, drip irrigation generated a gross profit of 38,590 lei (with 10% losses) and a B:C ratio of 5.80, compared to sprinkler irrigation, which recorded a gross profit of 30,121.78 lei under the same loss scenario and a B:C ratio of 4.75. These findings demonstrate that drip irrigation is more efficient. Crop efficiency increases significantly when fertilization, plant protection treatments, maintenance practices, and irrigation are carefully managed according to crop growth stages. Additionally, strict cost control remains essential for maintaining the profitability of cabbage cultivation.*

Keywords: *water use efficiency; yield performance; cost–benefit analysis; pedoclimatic conditions; farm profitability.*

INTRODUCTION

Current agriculture is increasingly affected by climate change, and one of the most visible problems for farmers is the lack of water during important vegetation periods. In the plain areas of south-eastern Romania, where summers are often hot and dry, irrigation can no longer be seen only as an additional operation, but as an important technological link for maintaining crop production and farm profitability (FAO, 2017; LAKHIAR et al., 2024).

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Autumn white cabbage (*Brassica oleracea* var. *capitata*) is important from both a food and an economic point of view. Cabbage is a vegetable commonly consumed by the population, being used fresh, in different culinary preparations or for preservation. Therefore, its cultivation may represent an important source of income for small and medium-sized farms, especially when the applied technology is adapted to local conditions.

However, cabbage is a crop with high water requirements, especially during the period of intensive growth and head formation. When plants do not have enough moisture during these stages, cabbage heads may remain smaller, yield decreases, and marketable quality may be affected. On the other hand, water application without proper management is not advantageous either, because it may lead to evaporation losses, higher fuel consumption and increased production costs (ALLEN et al., 1998; SEIDEL et al., 2017).

For this reason, choosing the irrigation system becomes an important decision for the farmer. Sprinkler irrigation has the advantage of wetting the entire cultivated area and is a well-known method used in many farms. However, on hot days or under windy conditions, part of the water may be lost before it reaches the plants efficiently. Drip irrigation, instead, brings water closer to the root zone, which may help reduce losses and improve the use of resources. In recent years, several studies have highlighted the advantages of localized irrigation systems in vegetable crops, especially in areas where water is becoming a limited resource (BUTE et al., 2021; SHINDE et al., 2021; DEMIR et al., 2024)

The Însurăței area, Brăila County, provides good conditions for cabbage cultivation, but dry periods may significantly influence production if water is not supplied on time. From this perspective, comparing two irrigation systems, drip and sprinkler irrigation, may provide useful information for farmers growing vegetables under similar conditions. The study was carried out in 2024, on an area of 0.5 ha, divided into two equal plots of 0.25 ha each, using the local cultivar Varză de Buzău as biological material.

The aim of this paper is to comparatively analyse the efficiency of drip and sprinkler irrigation in autumn white cabbage cultivation, under the pedoclimatic conditions of the Însurăței area, Brăila County. The study followed the obtained yield, simulated technological losses, water and fuel consumption, as well as the main economic indicators, namely gross profit, benefit-cost ratio and economic return.

MATERIALS AND METHODS

The study was carried out in 2024, in the area of Însurăței town, Brăila County, in a region specific to the Bărăgan Plain. The area is characterized by hot summers, dry periods and unevenly distributed rainfall, which makes irrigation necessary for autumn white cabbage cultivation. The research was conducted under real farm conditions, not in a classical experimental field, which gives the study an applied character.

The total analysed area was 0.5 ha and was divided into two equal plots, each covering 0.25 ha. Drip irrigation was applied on the first plot, while sprinkler irrigation was used on the second plot. The two plots were managed under similar soil, climate, biological material and crop technology conditions, the main difference being the irrigation system used.

The biological material used was the local cultivar Varză de Buzău, intended for autumn cultivation. The crop was established after an oat crop. The planting scheme was 0.70 m between rows and 0.35 m between plants within the row. This planting scheme resulted in a density of approximately 19,985 plants on the total area of 0.5 ha, respectively about 10,000 plants for each

0.25 ha plot. On the total area, approximately 35 rows were established, of which 17–18 rows were assigned to each irrigation system.

Data were collected through direct field observations and measurements carried out on the plants at harvest. For each irrigation system, three representative samples were analysed, each sample consisting of a block of 5–6 consecutive rows. Several production elements were followed, namely average cabbage head weight, head diameter, head circumference, number of viable plants at harvest, total yield per plot and estimated yield per hectare.

Yield was calculated based on the average cabbage head weight and the number of plants present in each plot. In order to compare the two irrigation systems more easily, the yield obtained on each 0.25 ha plot was reported per hectare. Since under real farm conditions losses may occur during crop maintenance, harvesting, handling, transport or marketing, four scenarios were taken into account: no technological losses, 3% losses, 5% losses and 10% losses.

For the economic part, real crop data were used, including costs related to planting material, fertilizers, plant protection treatments, mechanized works, labour, water, fuel, transport and irrigation equipment. Since the study was carried out under real farm conditions, part of the technological works was performed on the entire cultivated area, not separately for each plot. Therefore, the general crop costs, such as land preparation, planting, fertilization, plant protection treatments, maintenance works, harvesting and transport, were proportionally allocated to the two analysed variants, according to the cultivated area.

The economic differentiation between the two irrigation systems was followed through the obtained yield, water and fuel consumption, and the specific costs of the irrigation installations. For a clearer interpretation, the costs of the components of the drip irrigation system and of the sprinkler irrigation system were presented separately, while the general economic indicators were calculated based on the marketable yield and the technological costs related to the analysed crop.

Gross income was determined by multiplying the marketable yield by the average selling price of cabbage. Crop profitability was analysed by calculating gross profit, benefit-cost ratio and economic return, indicators frequently used in the assessment of the economic efficiency of irrigated agricultural technologies (HUSSAIN et al., 2022; MOURSY et al., 2022)

The economic indicators were calculated using the following formulas:

Gross profit = Gross income – Total costs

Benefit-cost ratio = Gross income/Total costs

Economic return = Gross profit/Total costs × 100

The comparison between the two irrigation systems was made based on the field results, water and fuel consumption, estimated yield and economic indicators calculated for each variant. The study should be interpreted as an applied case study, carried out in a single agricultural season and on a limited area, but the results may provide useful information for small and medium-sized farms cultivating cabbage in areas exposed to drought risk.

RESULTS AND DISCUSSION

The obtained results showed important differences between the two irrigation systems analysed, both in terms of cabbage head development and total yield, as well as economic efficiency. The comparison between drip irrigation and sprinkler irrigation showed that the drip system provided better results in all analysed scenarios, including in the situations where technological losses were simulated.

A first element analysed was the average weight of cabbage heads. In the case of drip irrigation, the values obtained in the three samples were 3.34 kg, 3.45 kg and 3.57 kg/head, resulting in an overall average of 3.45 kg/head. In the case of sprinkler irrigation, the values were lower, namely 2.56 kg, 3.03 kg and 2.90 kg/head, with an overall average of 2.83 kg/head. The difference between the two variants shows that the localized application of water in the root zone favoured better plant development and the accumulation of higher marketable biomass.

These results can be explained by the fact that drip irrigation maintains a more constant moisture level near the root system, reducing water stress during critical vegetation periods. In cabbage cultivation, this moisture stability is important especially during the period of head formation and growth. Similar results have also been reported in other studies concerning cabbage cultivation and the efficiency of localized irrigation systems (BUTE et al., 2021; SHINDE et al., 2021; DEMIR et al., 2024).

Table 1

Yield indicators according to irrigation system and technological losses

Irrigation system	Average cabbage head weight (kg/head)	Yield without losses (t/ha)	Yield with 3% losses (t/ha)	Yield with 5% losses (t/ha)	Yield with 10% losses (t/ha)
Drip irrigation	3.45	138.16	134.02	131.25	124.34
Sprinkler irrigation	2.83	113.07	109.67	107.41	101.76

In addition to the average weight of cabbage heads, differences were also observed in their size. Under drip irrigation, the average head diameter was 27.33 cm, while the average circumference was 78.67 cm. Under sprinkler irrigation, the average diameter was 24.00 cm, and the average circumference was 66.00 cm. These values show that drip irrigation influenced not only the weight of the cabbage heads, but also their morphological development. In practical terms, the plants irrigated by drip formed larger, better-developed cabbage heads, with higher commercial value.

The estimated yield was 34.54 t/0.25 ha in the case of drip irrigation, corresponding to 138.16 t/ha. In the case of sprinkler irrigation, the yield was 28.27 t/0.25 ha, respectively 113.07 t/ha. The yield difference between the two systems was 6.27 t/0.25 ha, equivalent to 25.09 t/ha, in favour of drip irrigation. This difference is important from a practical point of view, especially for small and medium-sized farms, where each tonne marketed may directly influence the final profit.

For an analysis closer to real farm conditions, several technological loss scenarios were taken into account. These losses may occur during crop maintenance, harvesting, handling, transport or due to quality depreciation of the cabbage heads. In the case of drip irrigation, yield decreased from 138.16 t/ha in the no-loss scenario to 134.02 t/ha in the 3% loss scenario, 131.25 t/ha at 5% losses and 124.34 t/ha at 10% losses. In the case of sprinkler irrigation, yield decreased from 113.07 t/ha without losses to 109.67 t/ha at 3% losses, 107.41 t/ha at 5% losses and 101.76 t/ha at 10% losses.

Even in the least favourable scenario, with 10% technological losses, drip irrigation ensured a higher yield than sprinkler irrigation. For a small farm, this difference matters, because losses almost inevitably occur during harvesting, handling or transport. Even under these conditions, the drip irrigation variant remained more advantageous. At the same time, the results follow the trend shown by recent research, according to which localized irrigation systems may contribute to increasing productivity and water use efficiency in horticultural crops (WANG et al., 2022; YANG et al., 2023; GUO et al., 2023).

Another important aspect analysed was water and fuel consumption. In the case of drip irrigation, total water consumption was 3,200 m³, while fuel consumption was 120 litres. Under sprinkler irrigation, total water consumption was 6,400 m³, while fuel consumption was 160 litres. Thus, sprinkler irrigation required twice as much water as drip irrigation, which clearly highlights the difference between the two systems in terms of resource use efficiency. These differences were taken into account in the economic analysis, because water and fuel consumption directly influence the technological costs of the crop.

In the economic analysis, it was necessary to separate the common crop costs from the specific costs of the irrigation systems. The common costs were proportionally allocated to the two plots, because an important part of the technological works was carried out on the entire cultivated area. In contrast, the costs of the irrigation installations were analysed separately, in order to highlight the differences between the two technological variants. For the drip irrigation system, the costs were calculated based on the components effectively used on the 0.25 ha area. The total value of the system was 1,156 lei, including drip tape, tape valves, end caps, connection fittings and tape connectors. Although this system involves an initial investment, the obtained results show that the yield difference and the reduction in water consumption may compensate this cost within the analysed crop.

Table 2

Costs of the drip irrigation system on 0.25 ha

Component	Quantity	Unit	Unit price	Total cost
***Drip tape (16 mm, 6 mil)**	3400	m	0.29	986
Tape valves	17	pcs.	5	85
Tape end caps	17	pcs.	1.5	25.5
Connection fittings to hose	1	pcs.	42.5	42.5
Tape connectors	17	pcs.	1	17
Total				**1156.0**

* Note: 16 mm, 6 mil drip tape refers to drip irrigation tape with a diameter of 16 mm and a wall thickness of 6 mil, equivalent to approximately 0.15 mm.

The component with the highest share in the cost of the system was the drip tape, with a value of 986 lei, representing more than 85% of the total installation cost. This aspect shows that the main investment in the drip irrigation system is related to the material distributed over the cultivated area. However, in relation to the yield and profit obtained, the cost of the system remains justified under the conditions of this study.

For the sprinkler irrigation system, the costs were calculated based on the components used for operating the installation on the analysed area. Unlike the drip irrigation system, sprinkler irrigation requires a higher initial investment, but the equipment can be reused over several crop cycles. In this study, the average useful life of the system was estimated at 5 years, which allowed the calculation of an annual amortized cost.

Table 3

Costs of the sprinkler irrigation system, amortized over 5 years

Component	Quantity	Unit	Unit price	Total cost
PE pipe 90 mm (200 m)	200	m	12.0	2400.0
Sprinklers	17	pcs.	35.0	595.0
Sprinkler stands	17	pcs.	6.0	102.0
End cap	1	pcs.	2.5	2.5
*3-inch hose	100	m	9.0	900
Total				**3999.5**

*Note: 3-inch hose refers to a water supply hose with a diameter of 3 inches, equivalent to approximately 76 mm.

The total cost of the sprinkler irrigation system was 3,999.50 lei. The component with the highest share was the PE 90 mm pipe, with a value of 2,400 lei, followed by the 3-inch hose, with 900 lei, and the sprinklers, with 595 lei. Since the sprinkler system can be reused for several years, the investment cost was related to an average useful life of 5 years, resulting in an annual amortized cost of approximately 799.90 lei/year.

Comparatively, the drip irrigation system had a lower initial cost, 1,156 lei for the 0.25 ha area, but some components, especially the drip tape, may require replacement after one crop cycle. In contrast, the sprinkler system involves a higher initial investment, but it is reusable, which means that the economic analysis must be interpreted not only through the acquisition cost, but also through the duration of equipment use.

This difference in consumption has direct effects on production costs. Under current conditions, where water, energy and fuel represent increasingly important costs for farmers, a system that reduces resource consumption may contribute to improving profitability. Drip irrigation brings an advantage not only through higher yield, but also through a more rational use of water. This aspect is also supported by recent studies on precision irrigation technologies, which show that reducing water losses is one of the main directions for agriculture adapted to climate change (LAKHIAR et al., 2024; PETROVA and BICHEV, 2023; BWIRE et al., 2024).

Based on the obtained yields, the technological loss scenarios, the average selling price of 1.5 lei/kg and the technological costs established for the analysed crop, the main economic indicators of the two irrigation systems were calculated. In their interpretation, it should be taken into account that part of the crop costs were common and proportionally allocated, because the main works were carried out on the entire area. The specific costs of the irrigation installations were highlighted separately in Tables 2 and 3, in order to show the investment differences between drip and sprinkler irrigation. The results are presented in Table 4.

Table 4

Economic indicators of cabbage cultivation
according to irrigation system and technological losses, for the 0.25 ha area

Irrigation system	Loss scenario	Yield (kg/0.25 ha)	Gross income (lei)	Gross profit (lei)	B:C ratio	Economic return (%)
Sprinkler irrigation	No losses	28,266.70	42,400.05	34,361.79	5.27	427.48
Sprinkler irrigation	3% losses	27,418.70	41,128.05	33,089.79	5.12	411.65
Sprinkler irrigation	5% losses	26,853.37	40,280.06	32,241.80	5.01	401.10
Sprinkler irrigation	10% losses	25,440.03	38,160.04	30,121.78	4.75	374.73
Drip irrigation	No losses	34,540.00	51,810.00	43,771.74	6.45	544.54
Drip irrigation	3% losses	33,503.80	50,255.70	42,217.44	6.25	525.27
Drip irrigation	5% losses	32,813.00	49,219.50	41,181.24	6.12	512.39
Drip irrigation	10% losses	31,086.00	46,629.00	38,590.74	5.80	480.24

The data in Table 4 show that drip irrigation generated superior economic results in all analysed scenarios. In the no-loss scenario, the gross profit obtained under drip irrigation was 43,771.74 lei/0.25 ha, compared to 34,361.79 lei/0.25 ha in the case of sprinkler irrigation. The same trend was maintained in the 10% loss scenario, where drip irrigation recorded a gross profit of 38,590.74 lei/0.25 ha, while sprinkler irrigation recorded 30,121.78 lei/0.25 ha.

The benefit-cost ratio confirmed the same direction. In the case of drip irrigation, the B:C ratio ranged from 6.45 in the no-loss scenario to 5.80 in the 10% loss scenario. Under

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sprinkler irrigation, the values were lower, ranging from 5.27 to 4.75. These values show that both systems were profitable, but drip irrigation provided higher economic efficiency.

The economic differences between the two systems mainly result from the higher yield obtained under drip irrigation and from the more efficient use of water. Although the drip system involves a specific installation cost, the yield advantage and the higher gross income compensated this investment within the analysed crop. At the same time, the sprinkler system has a higher initial investment, but it can be reused for several years, which is why its cost was also interpreted through annual amortization.

The obtained results are in agreement with studies showing that the economic analysis of irrigation systems should include not only the obtained yield, but also the costs related to water, energy, labour and equipment used (HUSSAIN et al., 2022; MOURSY et al., 2022).

However, the results should be interpreted with caution. The study was carried out in a single agricultural season, on an area of 0.5 ha, under real farm conditions. For this reason, the results should not be considered generally valid for all areas or for all crop technologies. They rather represent an applied case study, useful for farmers working under similar pedoclimatic conditions. In order to validate the conclusions, multiannual research on larger areas and with experimental replications would be necessary.

Even with these limitations, the data obtained clearly show that drip irrigation was more efficient than sprinkler irrigation in autumn white cabbage cultivation in the Însurăței area. The drip system favoured the formation of larger cabbage heads, a higher yield, lower water and fuel consumption and superior economic indicators. Therefore, this irrigation method may represent a suitable solution for small and medium-sized farms aiming to increase productivity and reduce resource consumption.

CONCLUSIONS

The results obtained in this study highlighted the superior efficiency of drip irrigation compared to sprinkler irrigation in autumn white cabbage cultivation, under the pedoclimatic conditions of the Însurăței area, Brăila County. The drip system favoured the formation of larger cabbage heads, with a higher average weight, which led to a higher yield compared to the sprinkler-irrigated variant.

In all analysed technological loss scenarios, drip irrigation maintained a clear advantage over sprinkler irrigation. Even in the 10% loss scenario, the estimated yield under drip irrigation was higher than that obtained under sprinkler irrigation, which shows better stability of marketable production under real farm conditions.

In terms of resource consumption, drip irrigation allowed a reduction in water and fuel use. This aspect is important especially in areas exposed to drought, where efficient water use becomes essential for maintaining production and profitability in vegetable crops.

The economic analysis confirmed the superiority of the drip irrigation system. Gross profit, benefit-cost ratio and economic return were higher in the drip-irrigated variant in all analysed scenarios. Although the drip system involves a specific installation cost, the higher yield and gross income compensated this investment within the analysed crop.

The results should be interpreted as an applied case study, carried out in a single agricultural season and on a limited area. For broader validation, multiannual research on larger areas and with experimental replications is necessary. However, the obtained data indicate that drip irrigation may represent an efficient technological solution for small and medium-sized farms cultivating cabbage in areas affected by water deficit.

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