THE INFLUENCE OF GROUNDWATER QUALITY ON THE PRODUCTION OF SUMMER AND AUTUMN CABBAGE VARIETIES CULTIVATED IN THE TĂMĂȘEȘTI-BĂLEȘTI AREA, GORJ COUNTY

Cristina ȘCHIOPU, Daniela Liana DUDĂU, Adina Sanda MARIAN, Sorin CORICI, Vasile COTĂRAN, Ioan-Oană STOICA[1]

[(1)]Jiu Water Basin Administration, Nicolae Romanescu street, No.54, Craiova, postal code 200738, Dolj county, Romania
E-mail:cristina.schiopu@daj.rowater.ro

Corresponding author: cristina.schiopu@daj.rowater.ro

Abstract

Groundwater is an important resource of the planet, which is why reliable solutions have been constantly sought in order to preserve the state of quality, this category of natural resources being generally undervalued or less studied, due to the complexity of the formation and conservation process.

In the situation where, at international level, groundwater is used in a percentage of 20% to irrigate crops, the problem arises of the rational use of water for irrigation in order to reduce water consumption by establishing and expanding economic irrigation technologies in irrigated crops. The use of groundwater to irrigate crops requires, as with surface water, the observance of certain threshold values for certain quality indicators that in large quantities become harmful to plants or accumulate in them and become toxic to humans and animals (FOSTER and HARATA, 1998).

The main objective of this study is to quantify the effect exerted by the use of groundwater on the production and quality of cabbage culture irrigated by two methods (furrow and drip), in Bălești locality (vulnerable area to nitrate pollution), Gorj county.

Keywords: vulnerable area, anthropogenic factor, Directive 2006/118/EC for the protection of groundwater, sensitive area, threshold values.

INTRODUCTION

Groundwater represents a critical water resource for human consumption, agricultural irrigation and ecological sustainability. The European Union has recognized the growing challenges of groundwater contamination, particularly from nitrate pollution, through the implementation of targeted legislative frameworks. The European Directive 2006/118/EC stands as a pivotal regulatory instrument designed to protect groundwater resources from agricultural and industrial contamination.

Nitrate pollution poses significant environmental and public health risks, stemming primarily from intensive agricultural practices and improper waste management. The directive aims to establish comprehensive monitoring, assessment and protection mechanisms to mitigate these challenges and ensure sustainable groundwater management.

The origins of groundwater protection in Europe can be traced back to the initial Nitrates Directive (91/676/EEC), which laid the groundwork for addressing nitrate contamination. The 2006/118/EC directive represents a significant evolution in this regulatory approach, providing more sophisticated and nuanced mechanisms for groundwater quality assessment and protection.

One of the primary objectives of the Nitrates Directive 91/676/EEC was the identification of vulnerable areas which are characterized by specific environmental and agricultural conditions that increase the risk of nitrate contamination. Key criteria for identifying these zones include: geological characteristics, soil composition, agricultural land use, proximity to water bodies, groundwater recharge rates, potential contamination pathways.

In Romania, the first designation of vulnerable and potentially vulnerable areas was carried out in 2003 by National Research and Development Institute for

Pedology, Agrochemistry and Environmental Protection together with the National Romanian Waters Administration. In this designation, the areas vulnerable to nitrates from agricultural sources represented the perimeters of 255 localities in Romania, which represents 8.64% of the country's surface area, respectively 13.93% of the country's total agricultural surface area.

Excess nitrates can accumulate in the soil in several ways. First, manure contains both ammonia effluents and organic forms of nitrogen. Organic nitrogen can be converted to ammonia in the soil. This ammonia, along with any ammonia fertilizer that is applied is converted to nitrate by bacteria in the soil in a process called nitrification. Nitrification is important because plants can only use nitrogen in the nitrate form. However, when ammonia is nitrified in excess of what plants can use, the unused excess will accumulate in the soil. Second, applying nitrate fertilizer in excess of what plants can use will lead to high nitrate levels. Nitrates can enter the body through food and drinking water. Once they enter the body, they are equally harmful to both animals and humans.

MATERIALS AND METHOD

In Romania, the use of water for irrigation from medium and deep layers is prohibited, only the use of water from phreatic layer is accepted.

In order to know the effect exerted by the use of groundwater on the production and quality of irrigated cabbage crops, in 2022-2023 was experimented the effect of irrigation in Băleşti (a commune vulnerable to nitrate pollution) using two methods (furrow and drip).

The effect on the production and accumulation of nitrates and other nutrients in cabbage heads and the impact and dynamics of groundwater following intensive cabbage crops in the respective area was monitored. It is worth mentioning that the Tămăşeşti-Băleşti area was declared, according to minister's order no. 1552/2008 of the Ministry of Environment and Sustainable Development and minister's order no. 743/2008 of the Ministry of Agriculture and Rural Development, an area vulnerable to nitrates from agricultural activities, but at the same time, the area is known as a supplier of significant cabbage production, obtained by private producers in their own households.

Two varieties of cabbage were studied: the Buzău variety and Licurişcă variety. The choice of this green vegetable species was motivated by the fact that it is recognized as a species with the capacity to accumulate a great amount of nitrates.

The seeds necessary to obtain seedlings for the establishment of the experimental plot were provided by a product distributor for the Buzău variety and from the Băleşti area for Licurişcă variety.

The Buzău variety is one of the varieties widely used in our country, having been created at the Buzău Vegetable Research Station, approved since 1962. It is recognized for its fine leaves as well as for its special taste qualities. It is a semi-late variety, with a vegetation period of 135-140 days, which also includes the age of the seedling. It has a height of 55-60 cm, and the leaves are 27-29 cm long, bluish-green in colour. The dense heads have a diameter of 23-25 cm and an average weight of 2-3.5 kg. The maximum production is 70-80 t/ha, under normal conditions 50-60 t/ha. The variety is characterized by high resistance to cracking.

The Licurişcă variety is originally from Bulgaria, in terms of the vegetation period it has 135-145 days from the date of sowing for the production of seedlings, it is tolerant to diseases and pests, having vigorous growth. It forms a large rosette of leaves, the head has a flattened globular shape, very dense, bluish green colour, the inner leaves are fine white, succulent. The average weight of the head is 2–3.5 kg.

The Licurişcă variety – autumn was sown for seedlings on 14.05.2022 and 19.05.2022 and planted in the field on 03.06.2023 and 27.06.2023.

The Buzău variety – autumn was sown for seedlings on 10.05.2022 and 02.05.2022 and planted in the field on 28.06.2023 and 15.06.2023.

Fully respecting the scheme adopted by the citizens of Băleşti commune – an area with a tradition in cabbage cultivation, the planting distance has been established at 80 x 40 cm for drip irrigation, as well as on furrow. Planting depth was up to the first normal leaf. Thus, in Băleşti commune, autumn cabbage crops were placed on the experimental plots during the 2022-2023 period, with the 2 varieties described above: Buzău and Licurişcă, using two types of irrigation: through furrow and through drip irrigation.

For furrow irrigation, a rate of 4,810 m3/ha was used, applied in 10 waterings of 481 m3/ha for the Buzău variety and 4,964 m3/ha with a watering rate of 496 m3/ha for the Licurişcă variety, also applied in 10 waterings. For drip irrigation, a smaller amount of water was used, respectively 3,360 m3/ha for the Buzău variety and 3,470 m3/ha for the Licurişcă variety.

Figure 1 General aspects of planting experience

RESULTS AND DISCUSSION

The experimental cabbage plantation irrigated with phreatic water was established on a STAS 2012 alluvial Eutricambosol soil and on the relief generated by the Oltenia Subcarpathian Depression, the Câlnic-Târgu Jiu-Câmpu Mare Intracollinear Depression subunit, having as elements of the main relief form: the meadow of the Rasova, Şuşiţa and Jaleşul rivers with a terrain slope of less than 2%. Soil biological activity is very intense in the surface horizons, where biogenic pedo-features generated by the activity of phytoterra and copraphagous fauna abound: subadjacent rock: fluvial gravels; global natural drainage: imperfect; bioclimatic zone: deciduous forest floor (subfloor of gorun forests); Natural pasture vegetation (Trifolium, Potentila, Galium, Achillea, Taraxacum, Plantago, Matricaria, Lotus etc.).

It is found that the soil with the experimental plot (table 1) has a clayey loamy textural class, a moderate apparent density, which gives a moderate permeability (110 cm2/10-10) and a water compaction capacity of 31.7% g/g, indicating a good water retention capacity in the soil (DUMITRU, 2009).

Table 1 Physical properties of Eutricambosoil gleyed silt – Băleşti Village

Thick sand %	Fine sand %	Dust %	Clay %	Textural class	Apparent density g/cm3	Permeability cm2/10-10	Compaction capacity % g/g
9,4	17,7	21,7	51,2	AL	1,74	110	31,7

Analysing the chemical properties of the soil, it results that it has a neutral reaction, a eubasic base saturation degree, a medium total cation exchange capacity and the sum of exchange bases, a poor nitrogen supply, according to the humus content of 2.3% and the nitrogen index of 1.88. The degree of phosphorus supply is very poor and that of potassium is medium (DODOCIOIU, 2009). Based on these physical and chemical properties, the quality score is 45 points for arable land, being classified in the 3rd quality category. Results obtained regarding the chemical parameters of the water from wells used for irrigation in the experiments carried out during 2022-2023 for the cabbage crop from are shown in table 2. Analysing the quality of the irrigation water from these wells compared to the maximum permitted concentrations, according to Law no. 311/2014 and Order no. 621/2014 regarding the approval of the threshold values for groundwater body, the following results are obtained:

- The nitrate and nitrite content are below the CMA limits;
- The ammonium content is very close to the allowed values compared to the threshold values according to Law no. 311/2014 but compared to Order no. 621/2014 regarding the approval of threshold values for groundwater on the groundwater body is well below its limits;
- The other indicators fall within the limits of the M.P.C. (according to Law no. 311/2014)

Table no.2 Physico-chemical analyses of the water used for irrigation of the experimental plot

Nr. crt.	Parameter	U.M.	2022 first quarter	2022 second quarter	2022 third quarter	2022 fourth quarter	2023 first quarter	2023 second quarter	2023 third quarter	2023 fourth quarter	Threshold value	M.P.C. *
1.	pH (T°C = 20.3)	upH	7.48	7.51	7.49	7.42	7.21	7.1	7.09	7.2	-	6.5/9.5
2.	Conductivity	µS/cm	509	535	564	571	568	561	583	590	-	2500
3.	Filtred residues at105 °C	mg/l	330.85	347.75	366.6	371.15	369.2	365.6	378.9	383.5	-	-
4.	CCOCr	mg/l	4.58	4.46	4.39	4.59	5.1	4.98	4.96	4.93	-	-
5.	NH_4	mgN/l	0.31	0.38	0.41	0.36	0.41	0.43	0.48	0.38	4.4	0.5
6.	NO_2	mgN/l	0.2	0.3	0.1	0.1	0.4	0.33	0.21	0.28	0.5	0.5
7.	NO_3	mgN/l	2.58	2.61	2.79	2.75	3.89	4.58	4.83	4.91	-	50
8.	PO_4	mgP/l	0.131	0.135	0.145	0.148	0.365	0.38	0.36	0.38	0.5	-
9.	Chlorides	mg/l	3.62	3.78	3.73	3.98	4.9	5.1	5.3	5.36	250	250
10.	Ca	mg/l	78.9	81.3	88.6	80.9	83.1	85.6	85.9	90.2	-	100
11.	Mg	mg/l	11.74	12.9	12.6	12.3	12.6	12.9	13.5	11.2	-	50
12.	Hardness	mg/l CaCO3	231.67	242.3	241.9	236.5	223.8	245.3	248.1	226.4	-	Min 5°G
13.	Bicarbonates	mg/l	208.62	209.3	211.3	208.7	201.5	211.4	218.3	198.6	-	-
14.	Fe	mg/l	0.097	0.084	0.086	0.085	0.09	0.07	0.07	0.06	-	0.2
15.	Mn	mg/l	0.020	0.01	0.01	0.015	0.019	0.018	0.015	0.016	-	0.05
16.	SO_4	mg/l	44.3	43.2	40.2	39.1	41.2	43.6	45.8	49.6	250	250

M.P.C.*- maximum permitted concentrations

In conclusion, all the values of the groundwater quality indicators used to irrigate cabbage crops fall within the limits imposed by the legislation in force.

Analysing the average biometric values for the two experimental years (2022-2023) included in Table 3, the following results are obtained: the diameter of the rosette of the cabbage heads was between 20.5 and 21.8 cm. It is first noted that regardless of the variety, the diameter of the cabbage heads is larger with drip irrigation than with irrigation on the gutters because the plants use the water provided by this type of irrigation better. From the point of view of the varieties, the rosette diameter is slightly larger in the Licurişcă variety 21.8 cm compared to the Buzău variety 21.7 cm. The average height of cabbage plants is also significantly higher with drip irrigation than with furrow irrigation 16.9 cm compared to 16.7 cm and 16.8 cm compared to 16.2 cm, and from the point of view of varieties it is still significantly higher with the Licurişcă variety compared to the Buzău variety 16.9 cm compared to

16.8 cm (figure 2). The average weight of a head was higher with drip irrigation than with furrow irrigation. Thus, with the Buzău variety it is 2.614 kg with drip irrigation compared to 2.468 kg with furrow irrigation. The same situation is observed for the Licurişcă variety, where the average weight of a cabbage head is 2.891 kg for drip irrigation and 2.796 kg for furrow irrigation. The average volume of a cabbage head, which is an important quality indicator of the cabbage harvest, especially commercially, evolved in the same way as the other analysed indicators, being higher by 10.40 dm3 and 10.80 dm3 for drip irrigation and 9.75-9.85 dm3 for furrow irrigation; and for this indicator, the Licurişcă variety obtains a greater volume of cabbage heads than the Buzău variety.

Table no.3 The average biometric and productive characteristics of cabbage's head (2022-2023)

Variety	Irrigation option	Rosette diameter/cm	Average height/ cm	Average weight head/kg	Average volume head dm^3	Density kg/dm^3
De Buzău	furrow	20.7	16.2	2,468	9.75	0.253
	drip	21.7	16.8	2,654	10.40	0.252
Licurişcă	furrow	20.5	16.7	2,786	9.85	0.2828
	drip	21.8	16.9	2,891	10.8	0.2676

Figure 2 Cultivation aspects of cabbage in vegetation

Following the analysis of the experimental variety of Buzau cabbage, it was observed that the drip irrigation variant yields a higher production by 6.26 t/ha than the furrow irrigation variant. This variant is also superior to the average of the two variants taken as a control by 3.12 t/ha. With furrow irrigation, the average production over the two experimental years is 75.55 t/ha, lower by 2.13 t/ha than the average of the control sample.

The average production over the two years of experimentation for the Licurişcă variety was between 79.59-83.63 t/ha. The highest production was recorded for the drip irrigation variant, 83.63 t/ha, higher by 2.13 t/ha than the average of the control sample.

With furrow irrigation, a production of 79.59 t/ha is recorded, quite high compared to the productions that are usually obtained in the area, but compared to the average comparison term of the two variants of 81.61 t/ha, it represents only 97.52% of this, being lower by 2.02 t/ha. So, using drip irrigation we obtain the highest production for both the Buzău variety and the Licurişcă variety.

CONCLUSIONS

To highlight how water is used by plants through the two irrigation methods, water consumption by these methods was analysed both per ha and per kg of production obtained. The results are presented in table 4.

Table 4 Consumption of irrigation water for cultivate 1 kilo of cabbage

Nr. crt.	Variety	Significance	Production t/ha	Water consumption	
				m^3/ha	l/kg cabbage
1	Buzău	furrow	70.52	4810	68.2
2		drip	76.78	3360	43.7
1	Licurişcă	furrow	79.59	4964	62.37
2		drip	83.63	3470	41.49

It is observed that different amounts of water are consumed to obtain one kg of cabbage depending on the irrigation method and variety. Thus, for the Buzău variety, the water consumption for one kg of cabbage is between 43.7 l and 68.2 l, being lower when using drip irrigation. For the Licurişcă variety, the water consumption is between 41.49 l for drip irrigation and 62.37 l for irrigation through furrow. Of the two varieties, lower water consumption per kg of production was recorded for the Licurişcă variety, 41.49 l-62.37 l compared to 43.7 l-68.2 l for the Buzău variety.

From the data in table 5 it can be seen that nitrates accumulate in cabbage heads in quantities ranging between 410-525 ppm, the highest quantity being recorded when the cabbage is irrigated on furrows 525 ppm for the Buzău variety and 496 ppm for the Licurişcă variety. This higher accumulation of nitrates in the case of furrow irrigation may be due to the fact that there is a greater quantity of water around the cabbage plants which solubilizes a greater quantity of nitrates but also brings through its composition a greater quantity of nitrates which are not metabolized and accumulates in the form of nitrates in the cabbage heads.

Among the varieties, the Buzău variety has proven to be a more avid variety for nitrates, which is why it assimilates them in larger quantities, this being a characteristic of the variety, as also specified in the specialized literature (DUMITRESCU et al., 1998). Cabbage is, as POPESCU and ANASTASIU show in 2000, a nitrophilic plant, which absorbs a lot of nitric nitrogen, without presenting a different appearance, on the contrary, the appearance of the cabbage heads improves with the increase of this compound. Being a nitrophilic plant, the nitrate content is limited by Order no. 1/2002 and Order no. 150/2005, which show that the maximum permitted concentrations (MPC) for nitrates in cabbage is 600 ppm and from the table presented, it results that in all variants the nitrate content is below the MPC. So, the absorption of nitric nitrogen shows that the cabbage is of good quality.

The phosphorus content in the cabbage heads was between 225 ppm and 258 ppm, indicating that it has normal values. In the specialized literature the normal values of phosphorus absorption in cabbage heads are between 200-400 ppm.

From the point of view of the irrigation method, the highest phosphorus content (245-258 ppm) is recorded in the irrigation on the furrow, compared to the drip irrigation where 225-230 ppm is recorded. Of the two varieties, the highest phosphorus content was recorded in the Buzău variety. And from the point of view of this indicator, the cabbage is of good quality. As for the assimilation of potassium, it is also within normal limits, being below the MPC (975-1,098 ppm) compared to 1,000-2,000 ppm from MPC.

Potassium accumulated in higher amounts with furrow irrigation 1,045-1,120 ppm and in lower amounts with drip irrigation 975-1,098. Among the varieties, the Buzău variety accumulated the highest amount of potassium 1,098-1,121 ppm regardless of the watering method. The amounts of potassium assimilated being within normal limits, it can be stated that from this point of view, too, the autumn cabbage production obtained is of quality.

Table 5 accumulation of nitrates, phosphates and potassium in cabbage heads

Nr. crt.	Variety	Irrigation option	nitrate ppm	phosphate ppm	potassium ppm
1.	Buzău	furrow	525	258	1120
2.		drip	412	225	1098
1.	Licurişcă	furrow	496	245	1045
2.		drip	410	230	975
Maximum permitted concentrations			600	200-400	1000-2000

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