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RESEARCH CONCERNING THE UTILISATION OF THE UNDERGROUND DRIP IRRIGATION IN ORDER TO CONTROL THE WATER STRESS OF GRAPEVINE

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Abstract

The research was carried out in the period 2019-2023 in an experimental polygon with Chardonnay and Sauvignon varieties, in the conditions of a reddish-brown molic soil and Feteasca regala variety under the conditions of an anthrosol hortic, argic, vertic. According to the level of the rainfalls that induced a certain level of soil humidity, four water supplies were yearly applied, the irrigation amount ranging in between the limits of 1100-2225 cubic meters/ha. Therefore, during the whole green period, the irigated variants were supplied with a water reserve in the soil exceeding the minimal threshold by 50% of the Useful water capacity (UC). The results obtained evidenced the positive influence of irrigation both upon the grape yield and its quality. Increased yields of grapes were obtained in comparison with the not irrigated witness control, averagely ranging in between the limits of 12 - 64%, on the background of a better accumulation of sugars in grapes. Under severe conditions of water stress, the application of irrigation proves to be compulsory, in certain years even after the beginning of the grape ripening stage.

***Key words**: water stress, pedological drought, Active Humidity Index.*

INTRODUCTION

In the current context of climate change, which has led to the emergence of different periods of time (longer or shorter), with increased water stress, during the vegetative period, vine irrigation has become a necessity, even in vine-growing areas that two decades ago they were considered wet.

Although the vine easily adapts to drought conditions (having a well-developed root system in depth and with a high absorption capacity) being able to use the moisture from the soil up to values close to the wilting coefficient, the lack of water from the soil can induce critical periods from a physiological point of view, which will reflect not only on the yield of the current year, but also on future harvests.

In order to develop plants with normal vigor, able of producing sustained harvests each year, the vine needs large amounts of water. Thus, a vine bush consumes through transpiration during the vegetation period between 850-1200 l of water, which corresponds to a consumption of 3500-5000 m3/ha (depending on the plantation size) (Plesa et al., 1970; Canarache, 1990).

The highest water requirements are manifested during the period of intense shoot growth and fruit formation (reaching a maximum level in the phenophase of berry growth), until grapes enter the veraison phase. In this interval, consumption is on average around 22.8-23.3 m^3 water/day/ha (Goldhamer, 2005).

In Romania, the grapevine culture in a non-irrigated regime is possible only in the vine-growing areas, where an annual amount of precipitation between 400-700 mm is recorded, of which at least 250 mm evenly distributed during the vegetation period, as useful rainfall (greater than 10 mm) (Oşlobeanu et al., 1980; Grumeza, 1968; Deloire, 2008).

Considering the high water consumption, for normal growth and productivity, the vine requires an optimal soil moisture at the minimum treshhold (Tm), the lower values being favorable for the grape berries ripening, and the higher values for the shoots growth (Stewart, 2005).

A reduced consumption of water is recorded only in the period between the beginning of vine bleeding to bud burst and during the grape ripening period.

If during the autumn-winter period a high reserve of water from rain and snow accumulates in the soil, the vine does not show phenomena of water stress even in some drier summers. Conversely, if a dry autumn-spring period is followed by a dry summer, the effects of the drought become disastrous, going as far as drying out the plants.

MATERIALS AND METHODS

The study was carried out during the years 2019-2023, in the Valea Călugărească viticultural center, in two viticultural plantings with Chardonnay, Sauvignon and Fetească regală varieties.

The soil in the experimental polygon with the Chardonnay variety is reddish brown molic vertic, with a loam clay texture, weak acid pH (6.1), well supplied with humus (2.9%) and useful mineral elements (N, P, K). The soil in the experimental polygon with the Feteasca regala variety is an anthrosol hortic, argic, vertic, with a clay loam texture, weak alkaline pH (7.6) and low nutrient content N, P, K.

The vines were led in a semi-high form, in the form of a bilateral cordon, the cutting was carried out in short fruit elements (renewal spur), with a fruit load of 18 buds/m^2.

The climate data used in this study were provided by the Research Institute for Viticulture and Enology Valea Calugareasca station, for 2019-2023 period. The data consist of daily observations of the monthly average temperature and rainfall.

The mobility and accessibility of soil water was characterized by a series of hydrophysical indices: apparent density (DA); hygroscopicity coefficient (CH), field water capacity (CC), wilting coefficient (CO), usable water capacity (CU), minimum threshold (Tm) for soil moisture.

CO = 1.5* CH; CU=CC-CO

The minimum threshold (Tm) of soil moisture was obtained by using the calculation formula:

PM= CO+f*CU,

where f = the fraction of the accessible moisture range for which we use the value ½, value specific to the clay-loamy texture.

At the beginning of the vegetation period (April), the initial reserve of water in the soil was determined by performing humidity tests on collected soil samples.

Then monthly monitoring continued until the end of September, when the final soil water reserve was determined.

Based on the obtained results, the deficit or excess compared to the minimum threshold of 50% from the usable water capacity, was established.

When watering is applied, in conditions of humidity, different from the minimum threshold, we have to deal with norm of real watering (mr): mr=H*DA*(CC-w), where: H represents the soil layer thickness to be watered (m); DA-apparent density (t/mc); CC-field capacity (% w/w) and w-current soil water moisture (%w/w).

The vine hydration status was assessed also by measuring the leaf water potential in the Scholander pressure chamber (Scholander et al., 1965; Turner, 1988).

The measurements were made from the phenophase of grape berry development until harvest, in the morning, before sunrise, because the hydration state of the leaves is at the maximum level that the water in the soil can provide. (Carbonneau, 1996; Carbonneau et al., 2004; Ojeda et al., 2002).

Depending on the soil characteristics, the precipitation deficit, the vegetative phenophase, the soil water moisture and foliar water potential, the watering rate was established.

Based on the decade and monthly analysis of the soil water, the watering moments were established such that the water from the ground to be maintained above the minimum threshold.

Assessments were made on the grape harvest from a quantitative and qualitative point of view at the technological maturity, at the same stage for all the experimental variants. The following analyses were performed: sugar content - determined by refractometry (OIV 2021a); total acidity - determined by titration with NaOH (OIV 2021b).

RESULTS AND DISCUSSIONS

The meteorological data recorded in the 2019-2023 period indicate a thermal regime characterized by average annual temperatures that oscillate between 11.8°C (2021) and 13.6°C (2023).

Compared with normal (1989-2018), the average temperature during the vegetation period increased by 0.6°C (2022), 0.8°C (2019), 0.9°C (2020), respectively 1.3°C (2023) (Figure 1).

The precipitations level was very low in the winter months, with 1.4 mm (2020) and 5.8 mm (2022) recorded in January compared with the multi-year average, 36.0 mm. This became an excess in May when 84.5 mm was recorded compared with 71.6 mm, the multi-year average. (Figure 2).

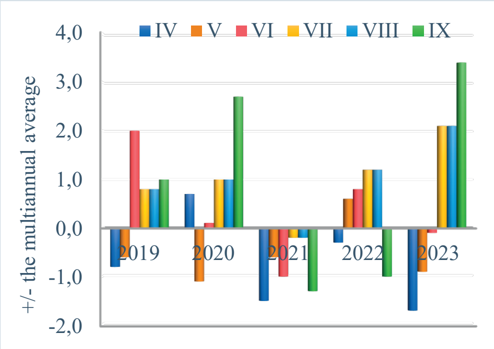

Figure 1. Monthly average temperature during the growing season of the years 2019-2023 compared to the multiannual average of 1989-2018

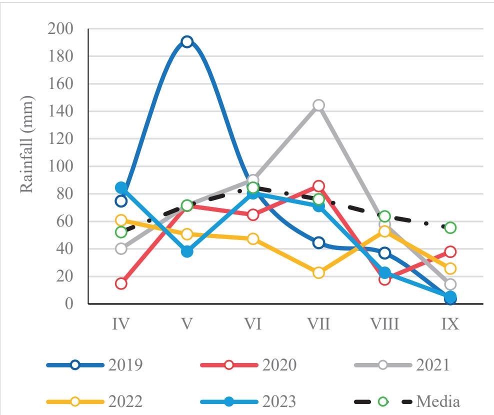

Figure 2. Monthly average rainfall during the growing season of the years 2019-2023 compared to the multiannual average of 1989-2018

The pluviometric characterization of the years 2019-2023 highlighted the fact that the precipitation deficit was recorded, in general, during years 2020, 2022 and 2023. Thus, two intervals with pluviometric deficit were highlighted: in the phenophases from bud burst to the intense growth of the shoots and fruit formation, and more intensively in the phenophases from the veraison to the grapes ripening.

The apparent soil density of the soils shows in the hoeing horizon (0-60 cm), an average values of 1.42 g/cm^3 (reddish brown molic soil), but also a high value (1.65 g/cm3) in the case of anthrosol hortic, argic, vertic.

The values of the main hydrophysical indices (Tables 1 and 2) are mainly influenced by soil texture.

Table 1. The physico characteristics of reddish, mollic, vertic soil (depth 0-100 cm)

Depth cm	Apparent density (DA) t/m^3	Wilting coefficient (CO) %	Field capacity (CC) %	Minumum threshold (Tm) %
0-20	1.38	11.2	23.6	17.4
20-40	1.42	11.4	23.9	17.7
40-60	1.45	11.5	24.5	18.0
60-80	1.46	11.9	24.9	18.4
80-100	1.50	11.2	25	18.1

Table 2. The physico characteristics of hortic, argic, vertic anthrosol (depth 0-100 cm)

Depth cm	Apparent density (DA) t/m^3	Wilting coefficient (CO) %	Field capacity (CC) %	Minumum threshold (Tm) %
0-20	1.69	9.8	20.0	14.9
20-40	1.64	9.9	20.1	15.0
40-60	1.61	9.9	20.2	15.1
60-80	1.60	10.0	20.5	15.3
80-100	1.65	10.2	20.9	15.6

Thus, the hygroscopicity coefficient (CH) registered values between 7.6%, for the mollic red brown soil, and 6.6%, for the hortic anthrosol.

A similar variation is presented by the wilting coefficient (CO) values, which are between 11.4% for the mollic reddish preluvosol and 9.9% for the hortic anthrosol.

The useful water capacity generally recorded values between 12.7% for the soft reddish-brown soil and 10.3% for the hortic, argic, vertical anthrosol soil.

Both soil types were able to store a useful water volume (CU) of 1829 m^3/ha (reddish-brown soil) and 1489 m^3/ha (vertical anthropogenic soil).

By analyzing the evolution of soil moisture at the depth of 0-100 cm during the vine vegetation period, it was found that at the beginning of the vegetation period, April, the soil moisture was at a normal level.

Starting with July, in all the studied years, the soil water reserve values were below the minimum threshold (Tm) of 50% of the usable water capacity (2556 m^3/ha). This fact indicates the onset of soil drought and the need to apply irrigation in the Chardonnay vineyard (Figure 3).

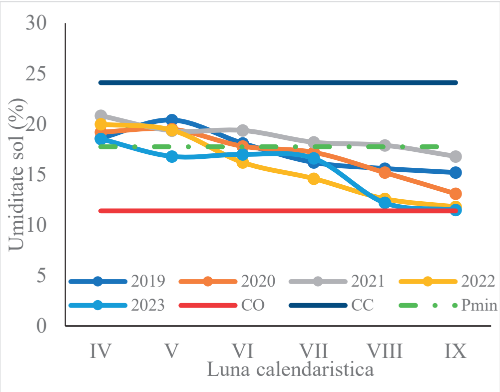

Figure 3. Dynamics of the soil water reserve in the Chardonnay plantation on the 0-100 cm profile

The soil moisture variations during the vegetation period of the Feteasca regala variety, on the 0-100 cm profile, oscillated between 12.3% (2023) and 13.7% (2020) in the phenophase of grapes veraison.

Soil moisture was maintained below the minimum threshold level of 15.2% and in the phonophase of grape ripening with variations between 10.5% (2023), 11.2% (2020) and 12.4% (2022) (Figure 4).

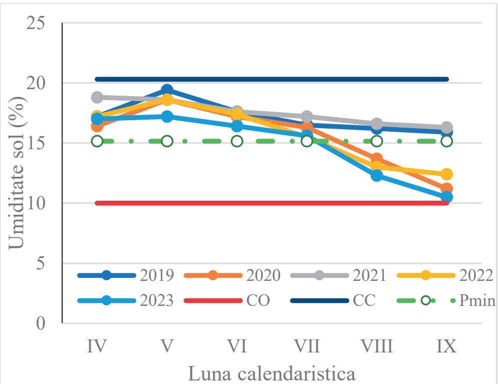

Figure 4. Dynamics of the soil water reserve in the Feteasca regala plantation on the 0-100 cm profile

The occurance of accentuated water stress periods, longer or shorter, during the vegetation phase of the vine required the application of irrigation norms with the provision of water at the minimum threshold level. In order to maintain the soil water reserve at the level of the minimum threshold in the Chardonnay plantation, in the irrigated variants, 3 waterings were carried out, with irrigation norms between 1836 m^3/ha (2020) and 2225 m^3/ha (2023), applied in the period of intense growth of berries until the grape ripening (Table 3).

Table 3. Water regime in the soil during the vegetation period of Chardonnay variety (depth 0-100 cm)

Variant	Initial reserve 1 IV		Norm of irrigation	Final reserve 30 IX	
	m^3/ha	Surplus to Tm m^3/ha		m^3/ha	Difference from Tm m^3/ha
Year 2019					
Non-irrigated	2621	65	-	2102	-454.0
Irrigated	2678	122	1102	2189	+202.0
Year 2020					
Non-irrigated	2419	-137	-	2004	-821
Irrigated	2765	209	1836	2844	+288
Year 2021					
Non-irrigated	2822	326	-	1930	- 626
Irrigated	3000	444	698	2901	+ 482
Year 2022					
Non-irrigated	2722	166	-	1858	- 864
Irrigated	2877	321	2196	2700	+ 144
Year 2023					
Non-irrigated	2592	36	-	1771	-785
Irrigated	2688	112	2225	2772	+ 216

In the non-irrigated variant (control), the water deficit from the soil manifested during the vine vegetation period in all the studied years.

The difference compared to the minimum threshold was - 454 m^3/ha (2019) to - 864 m^3/ha (2022).

In the Feteasca regala plantation, the soil water reserve at the minimum threshold level was maintained by applying irrigation norms of 804 m^3/ha (2022), 886 m^3/ha (2020) and 1230 m^3/ha (2023), in the periods with water stress, from the veraison to the grape ripening (Table 4).

In the variant of the non-irrigated varieties, the decrease of soil moisture at the level of the withering coefficient, during the vegetation period, determined a stoppage of vegetative growth with a strong impact on grape production and its quality, by reducing the process of sugars accumulation in the grape berries. The degree of stress (leaf water potential or LWP) was measured by using the Scholander pressure chamber (Scholander et al., 1965).

Table 4. Water regime in the soil during the vegetation period of Feteasca regala variety (depth 0-100 cm)

Variant	Initial reserve 1 IV		Norm of irrigation	Final reserve 30 IX	
	m^3/ha	Surplus to Tm m^3/ha	m^3/ha	m^3/ha	m^3/ha
Year 2019					
Non-irrigated	2434	252	-	2088	-94.0
Irrigated	2477	295	-	2290	+108.0
Year 2020					
Non-irrigated	2304	122	-	2016	-166
Irrigated	2362	180	886	2499	+317
Year 2021					
Non-irrigated	2477	295	-	2045	- 137
Irrigated	2707	526	-	2347	+ 166
Year 2022					
Non-irrigated	2434	252	-	1757	- 425
Irrigated	2477	295	804	2589	+ 407
Year 2023					
Non-irrigated	2347	166	-	1613	-569
Irrigated	2448	266	1230	2742	+ 560

The pressure chamber, indicates the value of the pressure exerted on the leaf petiole in bars (Carbonneau et al., 2004). The degree of stress for Chardonnay variety was moderate at 12-14 bars (2020, 2022, 2023) in the veraison phenophase, and severe with values of 16.6-17.2 bars (2022, 2023), at the ripening of the grapes.The water availability in the soil layer, explored by the roots, in the plantation of Feteasca regala variety indicates a high stress at the veraison phenophase of grapes, with values from 14.6 bars (2022) to 15.9 bars (2023), and when grapes matured the stress increased, taking over values from 16.2 bar (2021) to 16.6 bar (2022) (Table 5).

Table 5. Water potential of vines (bars)

Year/Month	IV	V	VI	VII	VIII	IX
Chardonnay						
2019	3.6	2.4	4.8	**10.4**	12.8	15.6
2020	4.2	2.8	6.4	**11.9**	14.6	**15.9**
2021	2.6	3.2	5.9	10.7	11.7	**16.2**
2022	3.1	3.6	6.3	**12.8**	12.9	**16.6**
2023	3.7	4.1	7.2	**14.4**	**13.3**	**17.2**
Feteasca regala						
2019	2.1	2.6	3.4	2.7	7.3	7.5
2020	3.6	2.1	3.5	2.6	**15.4**	**16.2**
2021	3.8	2.6	2.7	3.2	6.8	8.4
2022	2.8	3.1	1.8	4.2	**14.6**	**15.8**
2023	3.4	3.5	3.8	5.4	**15.9**	**16.4**

The positive effect of irrigation was more pronounced on the grape yield t/ha and on the average weight of a grape, a fact which sustained, in the irrigated variants, yield increases between 30-65% on average, compared to the non-irrigated control and a weight average of a grape 26-37% (Table 6).

Regarding the quality of production for Chardonnay grapes, expressed by the sugar content and the total acidity of the must, it should be noted that in the case of the irrigated variants, sugar content increased between 7.0 (2019) and 23% (2023), on the background of a relatively constant must acidity, with decreased of 5.0 (2019) and 9.0% (2023).

Table 6. Influence of irrigation on quantitative and qualitative production of Chardonnay grapes

Variant	Yield t/ha	Average weight of a grape, g	Sugar g/l	Acidity g/l H_2SO_4
Year 2019				
Non-irrigated	6.8	68.6	182.7	3.4
Irrigated	8.8	86.4	195.5	3.2
Year 2020				
Non-irrigated	5.4	72.4	194.5	3.6
Irrigated	7.5	95.6	217.8	3.3
Year 2021				
Non-irrigated	7.2	75.8	187.4	4.3
Irrigated	10.9	101.6	219.3	4.0
Year 2022				
Non-irrigated	8	77.2	196.7	3.6
Irrigated	13.1	105.8	232.1	3.4
Year 2023				
Non-irrigated	8	78.9	192.7	3.5
Irrigated	13.2	106.5	237.0	3.2

In case of Feteasca regala variety, under conditions of the years 2020, 2022 and 2023, when at the end of the vegetation period the deficit of water from the soil, in the non-irrigated variant, was approximately 166 m^3/ha (2020), 425 m^3/ha (2022), 569 m^3/ha (2023).

Yield increases between 56-64% were achieved through irrigation with norms between 886 m^3/ha (2020), 804 m^3/ha (2022) and 1230 m^3/ha (2023) were between, 8-21% sugar content and constant acidity (Table 7).

Table 7. The influence of irrigation on the quantitative and qualitative production of Feteasca regala grapes

Variant	Productively t/ha	Average weight of a grape, g	Sugar g/l	Acidity g/l H2SO4
Year 2019				
Non-irrigated	8.6	88.9	190.6	3.9
Irrigated	8.9	94.2	200.1	3.8
Year 2020				
Non-irrigated	8.5	95.7	192.4	4.2
Irrigated	12.1	111.0	215.5	3.9
Year 2021				
Non-irrigated	8.2	86.5	188	4
Irrigated	9.2	98.6	203.0	3.8
Year 2022				
Non-irrigated	6.8	97	186.7	4.6
Irrigated	10.6	128.0	212.8	4.2
Year 2023				
Non-irrigated	7	102	190	4.2
Irrigated	11.5	134.6	229.9	3.9

CONCLUSIONS

The obtained results highlighted the positive effect of irrigation on grape production and its quality.

Through irrigation with input rates between 1836-2225 m^3/ha, for Chardonnay variety (depending on humidity conditions) production increased with 30-65% and a better accumulation of sugars in grapes by 12-23% was recorded. The medium weight of a grape bunch registered increases ranged between 26-35%.

Due to the clayey texture of the anthrosol hortic, argic, vertic, the irrigation norms are reduced, because the water retention capacity was higher, ensuring increases of production.

Regarding the Feteasca regala variety, by applying the irrigation norms of 886-1230 m^3/ha, production increases of 12-64% were achieved, with a grape weight of 14-32% higher and an increased sugar content in must with 8-21%.

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