

The effect of controlled irrigation on the yield and some plant parameters of table grapes from central Romania

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Abstract

In order to obtain high and constant crop yields, irrigation has become essential in the context of climate change. The objectives of this study were to investigate *Vitis vinifera* L. grapevine Augusta, Argessis, and Victoria cvs. responses to the irrigation treatments applied to a young crop, in the climatic conditions of central Romania: full irrigation (100% Etc), non-irrigated treatment (NI) and deficient irrigation (DI) replacing only 50% of the estimated evapotranspiration. The agronomic behaviour of the three varieties of table grapes cultivated in a super-intensive system was analysed and the calculation of the efficiency of deficit irrigation in relation to the particularities of the main quantitative and qualitative indicators, in the climatic conditions, from central Romania. Significant differences of the year of the study and the interaction of the irrigation treatment on the weight of the bunch and the weight of the grains were highlighted, which induced and increased the production, the effect of the irrigation regime on these parameters was found to be different depending on the season. Production increased in the case of complete irrigation as well as in deficit irrigation by 0.4 kg in 2021, respectively by 0.6 kg in 2022, for the Argessis cv. compared to the production recorded in NI. Irrigation at 50% Etc increased the intrinsic effective value of total water use (IWUE). This varied from 11.86 kg m⁻³, which was evident in the case of the non-irrigated version, to 24.8 kg m⁻³, which was recorded in the case of deficient irrigation (50% Etc). The applied irrigation treatments may represent an easy irrigation management tool for the basis of adequate soil water deficits, allowing the determination of the water requirement of the vines in the central area of Romania.

Keywords: regulated deficit irrigation, soil moisture, water productivity, yield component.

Introduction

Climatic changes, especially the prolonged drought in the summer of recent years and the uneven rainfall during a growing season have affected many regions with a tradition of producing table grapes and wines. Increasing temperatures and decreasing amounts of precipitation in the summer months, especially during shoot growth, could affect both vine productivity and fruit quality. For these reasons, considered shortcomings for the productivity of the vine, but also for the quality of table grapes management of irrigation receives special attention in different in different areas of the crop and its application as balanced as possible, taking into the age of the plant, soil type, weather conditions, and other agronomic factors [1], which can influence both yield and quality. Other recent studies [2] showed that deficit irrigation can improve both the yield and quality of grapes in a sustainable agriculture [3]. Deficit irrigation has been studied in many regions either to replace part of the evapotranspiration throughout the growing season [4, 11, 16] or estimated as the product of the reference evapotranspiration and the crop coefficient (Kc), for the phases of vegetation followed. For these reasons, soil characteristics and root exploration, along with soil water content, have become a major objective for the precision irrigation scheduling of fruit crops [5]. Thus, knowing the amount of water in the soil at any given time became the main factor of effectiveness irrigation programming.

Most of the studies regarding the calculation of the water requirement in culture start from the Penman-Monteith equation developed by [6], estimating both Etc and Kc when the stage of plant development must be considered.

Three table grape cultivars Augusta, Argessis and Victoria were investigated in this study. The first two varieties, Augusta and Argessis, were patented by the NRDIBH and recently introduced into cultivation. The Victoria variety, having been recognized since 1978. Many table or wine grape varieties are researched for years in ampelographic collections or in field competitions to study how these varieties adapt to variation. meteorological conditions. The meteorological conditions specific to Romania with high temperatures during the summer, especially in August, and unevenly distributed precipitation during the growing season, with smaller and smaller amounts, could influence the composition and aroma of the grapes [7]. Although drip irrigation consistently increased the yield of the variety in our study, there are few studies on controlled irrigation management in vineyards cultivated with vines in the central area of Romania regarding vine performance in table grape varieties.

All three varieties studied are characterized by high productivity, being known for their biological resistance to cold and late spring frosts and high fertility [8]. The main objective of the research was to analyse the agronomic behaviour of three varieties of table grapes grown in a super-intensive system and to calculate the efficiency of deficit irrigation in relation to the particularities of the main quantitative and qualitative indicators, in the climatic conditions of central Romania.

Material and Method

A young vine plantation cultivated with three local genotypes for table grapes located at the National Research and Development Center for Biotechnology in Horticulture Stefanesti, (NRDIBH), southern Romania was the basis of the study. The wine-growing area is characterized by a humid temperate-continental climate, according to the multiannual averages calculated for the period 1979-2020, where the average annual temperature (T_{mean}) was 9.6°C and the amount of precipitation was 671.8 mm, according to the reports made by [9]. The high amplitude of the meteorological conditions that occurred during the vegetation period from 2022 at NRDIBH Stefanesti, has the specifics of an excessively continental climate, this year's vegetation season being a very dry one (only 530 mm of the multiannual average of 671.8 mm). The driest months were May, June and October, with rains of only 16.2 mm, and 3.6 mm, respectively 7.2 mm, with the number of rainy days being 4-9. In the air, the last minimum temperature was recorded in April (-2.8°C) and the maximum temperature in July 36.08°C. The large amplitude of meteorological conditions occurring during the vegetation period from 2022 at NRDIBH Stefanesti, has the specificity of an excessively continental climate, that year's vegetation season being a very dry one (only 530 mm compared to the multi-year average of 671.8 mm). The driest months were May, June, and October, with precipitation of only 16.2 mm, and 3.6 mm, respectively 7.2, the number of rainy days being 4-9. In the air, the last minimum temperature was recorded in April (-2.8°C) and the maximum temperature in July 36.08°C.

The plantation was established in the spring of 2019, at a density of 4000 plants/ha-1 (2.5 meters between rows and 1 meter between planes per row). The vines were pruned to approximately 10 spurs with three buds on a one-sided cord, trained to a vertical trellis system, and oriented in a north-south direction. Crop level was regulated by thinning shoots in mid-May, leaving 3-5 on each vine. The soil from the experimental data from NRDIBH Stefanesti also described by [9], has a clay content of 30-37% g⁻¹ at a depth of 0-0.7 m with a loamy-clay texture.

During the period 2021-2022, the irrigation treatments explored for the three varieties in the experimental block were as follows: no irrigation treatment (NI), which received only rainwater, controlled deficit irrigation (DI), calculated as 50% of the estimated crop evapotranspiration (ET_c), and, full irrigation (FI), applying 100% Etc calculated.

The different irrigation regimes were applied by changing the watering doses applied in each irrigation event, but maintaining the same irrigation frequency, which varied from 1 to 2 times a week in spring until 5-6 times a week in the middle of summer. The experimental design was a randomized factorial arrangement with three blocks and treatment combinations replicated within each block with 91 vines per plot. To determine the amount of water needed for irrigation at the beginning of the experiment, the SWC % before irrigation was determined, at a depth of 50 cm, the soil water content at the field capacity (mm), as well as the percentage of wetting for the surface of the experimental plot according to the calculation equation:

$$I = (FC - SWC) A \cdot P$$

Where (I) is the amount of irrigation water, FC represents the content of water in the soil at the field capacity (in mm), SWC (%) represents the water content in the soil before applying irrigation at a depth of 50 cm, P % - degree of wetting and A - surface to be referred (m²).

Inside the experimental design, the water in the soil was monitored with soil water potential microsensors Watermark Soil Moisture Sensor 6450WD (Spectrum Technologies, SUA) and sensors to determine the volumetric content of soil water % at 2 soil depths (20 and 50 cm depth) mounted on Watch Dog 1000 Series. SWC (%) data for the three irrigation treatments were recorded at a depth of 0.5 m considering

that vine roots in a young vineyard explore this depth. The readings were recorded every 10 minutes, downloaded and interpreted with the SpectrumPro technology program (<https://www.specmeters.com/weather-monitoring/data-loggers/a-series-loggers/a-series/>).

Results and Discussion

Prediction of yield response to water stress of table grape vines is important in developing strategies and making decisions for use by farmers and researchers for irrigation management under limited water conditions.

Table 1 describes the effect of irrigation treatments and the year of study on the main vigour parameters for Argessis, Augusta and Victoria cultivars. Shoot weight, pruning weigh, and shoot dry weight were higher in full irrigation followed by the most deficient, in all three varieties analysed. This may be due to the exposure of the plant to prolonged water stress during the growing season, although according to [10], this also depends on the variety.

Although in the first season both the shoot weight, pruning weigh, and shoot dry weight was lower than in 2022, this did not lead to significant differences between the years of the study.

Significant differences were evident between the year and the irrigation treatment of all the vigour parameters of the analysed plants, regardless of the variety.

Table 1. Vigour parameters for the Argessis, Augusta, and Victoria cvs. depending on the applied irrigation treatments, during the 2021-2022 experimental period.

Parameter	Treatment	2021	2022	Average	Year	T x Year
Argessis						
Shoot weight (cm)	NI	126 b	132 a	129 b	ns	***
	FI	132 a	140 a	136 a		
	DI	131 a	135 a	133 a		
Pruning weight (kg vine-1)	NI	85 b	93 b	89 b		
	FI	92 a	115 a	104 a		
	DI	87 ab	98 a	93 a		
Shoot dry weight (g/plant)	NI	0.68 b	0.72 b	0.7 b	ns	**
	FI	0.89 a	0.98 a	0.94 a		
	DI	0.76 ab	0.90 a	0.83 ab		
Augusta						
Shoot weight (cm)	NI	112 b	122 b	117 b	ns	*
	FI	129 a	138 a	134 a		
	DI	119 b	129 ab	124 a		
Pruning weight (cm)	NI	62 b	67 ab	65 b	ns	**
	FI	71 a	79 a	75 a		
	DI	69 a	71 a	70 a		
Shoot dry weight (g/plant)	NI	0.49 b	0.53 b	0.51b	ns	**
	FI	0.72 a	0.81 a	0.77a		
	DI	0.69 a	0.71 a	0.7 a		
Victoria						
Shoot weight (cm)	NI	112a	134b	123b	ns	*
	FI	124a	142a	133a		
	DI	117a	137a	127a		
Pruning weight (cm)	NI	58a	63ab	61b	**	*
	FI	64a	72a	68a		
	DI	64a	69a	67ab		
Shoot dry weight (g/plant)	NI	0.58c	0.64b	0.61c	ns	**
	FI	0.79a	0.84a	0.82a		
	DI	0.69b	0.76a	0.73b		

Notes: For each experimental factor and their interaction, different letters indicate significant differences between treatments at 95% ($p < 0.05$).; < 0.05 (*), $p < 0.01$ (**), $p < 0.001$ (***) and ns, non-significant, represent probability levels

Significant differences of the year of study and irrigation treatment interaction on bunch weight and grain weight were highlighted, which also induced greater increases in production, the effect of the irrigation regime on these parameters was found to be different depending on the season (Table 2).

Berry weight was significantly influenced by treatments with lower water availability (DI) and FI, in all studied varieties. Moreover, it is important to emphasize that, although the yield between vines between 2021 and 2022 was not significant, the irrigation treatments induced significant differences in yield regardless of variety. Thus, fruit production increased in 2022 compared to 2021, regardless of variety. This can be put down to the fact that the young plantation is coming into fruition. However, the production in the case of full irrigation as well as in deficit irrigation increased by 0.4 kg in 2021, respectively by 0.6 kg in 2022, for the Argessis cultivar compared to the production recorded at NI.

Prediction of yield response to water stress of table grape vines is important in developing strategies and making decisions for use by farmers and researchers for irrigation management under limited water conditions. Although 'in situ' field tests were conducted throughout the growing period of a vines for table grapes in this study, there is a need to repeat the irrigation experiments in the future years to further optimize sensor combinations [12], establish a reliable and accurate system monitoring system [12], and conducting studies on the diagnosis of water scarcity [13]. The factors responsible for penalizing production are number and weight of berries. According to [14], berry yield and weight losses could be attributed to temperature increase during flowering and fruiting and during the ambient light regime in the microclimate around the clusters associated with soil water loss. Decrease in yield and its components highlighted in NI compared to FI and DI treatments could have been due to the worse water condition of the vine both during the flowering period and during the growth and development of the fruits, the period with a mild level of stress [15], [16] [17] [18]. The intensity of the effect of soil and plant water stress can vary depending on the variety, but in cv. Tempranillo, previous work done in this vineyard reported the significant decrease in the final size of the grains and the yield at harvest when water stress was applied for a long time [19]. In that sense, it should be considered that the degree of controlled water stress that can be induced depending on soil water availability both at flowering, which in turn depends on previous rainfall levels and water used of vines during the spring, as well as when growing grains [20]. In our study, in the case of the non-irrigated variant, the water content in the soil was kept very close to the wilting coefficient, except for the periods when there is precipitation. This led to very small growths of shoots and plant components and very low production.

Table 2. Yield components of the three varieties of table grapes irrigated at different fractions of crop evapotranspiration (denoted NI, DI 50% ETC and FI (100% ETC))

Parameter	Treatment	2021	2022	Average	Year	T x Year
Argessis						
Cluster weight (g)	NI	369b	410a	390a	*	**
	FI	400a	420a	410a		
	DI	385a	410a	398a		
Weight of 100 grains(g)	NI	520ab	569b	545b	*	**
	FI	560a	620a	590a		
	DI	550a	598a	574a		
Production (kg/plant)	NI	2,1b	2,7b	2,4b	**	***
	FI	3,5a	4,1a	3,8a		
	DI	3,1a	3,5a	3,3a		
Augusta						
Cluster weight (g)	NI	380b	399b	390b	ns	*
	FI	440a	479a	460a		
	DI	412a	439b	426a		
Weight of 100 grains(g)	NI	410a	440b	407a	ns	**
	FI	460a	490a	469a		
	DI	430a	470a	460a	**	**
Production (kg/plant)	NI	1,9b	2,50b	2,2b	ns	**
	FI	2,6a	2,97a	2,9a		
	DI	2,33a	2,74b	2,54b		
Victoria						

Cluster weight (g)	NI	420a	438b	429b	ns	**
	FI	460a	490a	475a		
	DI	440a	449a	445a		
Weight of 100 grains(g)	NI	260b	279b	270b	*	**
	FI	320a	389a	355a		
	DI	310b	368b	339a		
Production (kg/plant)	NI	2,2ab	2,4b	2,3b	ns	*
	FI	2,6a	2,9a	2,8a		
	DI	2,5a	2,6ab	2,6a		

Notes: For each experimental factor and their interaction, different letters indicate significant differences between treatments at 95% ($p < 0.05$); < 0.05 (*), $p < 0.01$ (**), $p < 0.001$ (***) and ns, non-significant, represent probability levels.

Conclusions

Deficit irrigation controlled with the supply of 50% of Etc recorded productions very close to those recorded in the case of full irrigation in all analysed varieties, the differences being significant. the vineyard with the three varieties of table grapes studied under different levels of irrigation presented a slight water stress under rainfed treatment suggesting that water supplied by precipitation was not sufficient for the proper functioning of the plant.

In the Argessis variety, production increased by 1 kg in 2021, respectively 0.8 Kg in 2022, in deficient irrigation compared to supported only by precipitation being very close to the productions obtained in full irrigation. In accordance with the mentioned problems, DI in grapevine culture for table grapes could be a suitable irrigation strategy. Therefore, DI (50% Etc) regulated better the temperature and microclimatic conditions reached in the clusters, which is fundamental both for the yield of the crop and for the quality and ripening of the grapes and for their optimal health. In addition, this controlled irrigation deficit system, but also the problem of water deficit, which is faced and is increasing the number of countries, even those with a temperate continental climate, must take into consideration.

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