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Review Paper

The Importance of Irrigation in Viticulture

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Abstract

Viticulture is an important branch of agriculture that has been practiced for centuries in our country. Grape, which have been grown for many years, have a special place in terms of both our economy and our culture. To come across the vine in many villages of Türkiye, to sit in its shadow and rest has been a blessing to many of our colleagues and people. At the same time, grapes have taken place in folk songs, poems and festivals as well as our traditional cuisine, and this has revealed the importance given to it by our nation. Anatolia is among the homelands of the grapevine, and there are 1457 cultivars/genotypes belonging to Türkiye in the Vineyard Research Institute of Tekirdağ Viticulture Research Institute (Uysal et al., 2023) on the world scale, Türkiye ranks 5th in viticulture in terms of area and 6th in terms of produced products. Although it varies from year to year, an average of 4,000,000 tons of grapes are obtained from an area of approximately 420,000 ha in our country. The amount of grapes utilized for table usage is 2,000,000 tons, followed by 1,000,000 tons for wine/must and 1,000,000 tons for raisins. Throughout the country, an average of 620,000 hl of wine is produced annually in a total of 181 wineries spread over 29 provinces. While Türkiye ranks first in the world with an average annual production of 250,000 tons of raisins, it ranks 3rd in terms of table grape production (O.I.V., 2021).

Introduction

There are many factors that affect the water consumption of the vine. These factors are; The climatic characteristics of the ecology in which the vine is grown (annual precipitation and its distribution throughout the year, temperature and relative humidity values, wind speed), soil structure (soil texture, depth and water holding capacity, soil infiltration rate), rootstock and grape variety used, the trellis system is effective on the water consumption of the vine. In ecologies where precipitation is low and temperature is high during the vegetation period, the vine experiences more water loss through evapotranspiration. The genetically drought tolerance level of the grape variety grown under such conditions and the American grape rootstock on which it is grafted (growing the vine in different rootstock combinations) causes a difference in water consumption value. In addition, the water holding capacity of the soil in which the vine is grown causes the water consumption values of the vine to differ. In general, water-holding capacity of sandy-loam soils is lower while the water holding capacity of clay-loam soils has a higher value. The trellis system in which the vine is grown is another factor that affects the water consumption of the vine. Grape varieties grown in trellis systems with high vine stems and large canopy volume such as high Y and pergola have higher water consumption than systems with lower stem and canopy volumes such as wall type. The water requirement of the vine varies according to its phenological development period. Smart and Coombe (1983) stated that the water consumption of the vineyards varies between 480-530 mm, the daily water consumption is 2 mm/day before flowering, 4 mm/day after verasion, and the maximum water consumption is 5.9 mm/day. Van Zyl and Van Hyssteen (1980), on the other hand, found that the irrigation water requirement of the vineyards varies between

351-404 mm from the buds burst to the end of the harvest. Various researchers have reported that the seasonal water consumption of vineyards is between 500 and 1200 mm (Doorenbos & Kassam, 1979, Christensen, 1975, Grimes & Williams, 1990). It is known that the water consumption of table and wine grape varieties differs. When we look at the recent years in irrigation planning studies carried out with different ecologies and table grape varieties in Türkiye; Coşkun et al. (2017) applied an average of 276 mm of irrigation water during the vegetation period of the Michele Palieri table grape variety in Tekirdağ conditions and calculated the seasonal plant water consumption value as 570 mm. In another study, they determined the plant water consumption as 430.81 mm for the Trakya İlkeren table grape and 547.20 mm for the Alphonse Lavallée table grape in Şarköy (Coşkun et al., 2015). Bozkurt Çolak et al. (2014), in the study they carried out on the Royal table grape variety in Çukurova conditions; it has been reported that the amount of plant water consumption varies between 274 mm and 837 mm in the applied subjects over the years. In the literature, daily water consumption values between awakening of the eyes and flowering are 2.7 - 3.5 mm/day in Italia table grape variety (6.75 - 8.75 liters/vine/day), and 2.6 - 3.4 mm/day (6.50 - 8.50 liters/vine/day) in Flame Seedless variety/day) was determined. The average daily water consumption from flowering to the period of veraison is between 4.8-6.7 mm/day in Italia variety (12 - 16.75 liters/vine/day); it varied between 3.2-6.2 mm/day (8 - 15.50 liters/vine/day) in Flame Seedless variety. In the period from veraison to maturity, daily plant water consumption is 6.58 - 7.61 mm/day (16.45 - 19.02 liter/vine/day) in Italia variety; 6.0 - 8.25 mm/day (15.0 - 20.62 liters/vine/day) in Flame Seedless variety (Bozkurt Çolak, 2010). Gündüz & Korkmaz (2008) determined the amount of irrigation water applied as 260.5 mm and the water consumption value as 505 mm, which provides the highest efficiency for the vineyard irrigated with the drip irrigation system in Menemen conditions. Gündüz (2007) stated that 229.2 mm of irrigation water should be applied for the Razaki table grape variety as a result of the study carried out in Tekirdağ conditions.

The amount of water to be given to wine grape varieties suitable for quality wine production varies according to the soil and climate characteristics of the vineyard, age, planting frequency, canopy size of vines in relation to trellis system and pruning (Giorgessi et al.,) It causes an increase in yield but affects the must and wine quality negatively (Azevedo et al., 2004, Bravdo et al., 2004, Salon et al., 2004); on the other hand, it has been proven that the application of moderate water stress reduces the yield but increases the wine quality (Ferreyra et al., 2004). According to the results of irrigation studies carried out in our country in the last period of wine grape cultivation; Coşkun et al. (2022), in the deficit irrigation strategies study they carried out in Tekirdağ conditions, they applied 50% of the required water amount to complete the missing moisture in the soil to the field capacity in case the usable water holding capacity in the soil decreased by 70%, and as a result, the highest quality wine was obtained from the unirrigated subject. They stated that a partial root zone dryness deficit irrigation strategy could be applied for Cabernet Sauvignon wine grape variety if the vine reaches a medium-high stress level by following the stress level of the vine in the dry years. Gündüz (2007) determined that 143.6 mm of irrigation water is needed for the Semillon wine grape variety because of the study carried out in Tekirdağ conditions. Celik et al. (2005), in terms of getting the highest yield of quality wine in Kalecik district of Ankara, in Kalecik Karası variety irrigated by drip method; They stated that when the total evaporation reaches 40-50 mm, it would be reasonable to give 0.75 fold the evaporation amount of irrigation water.

Effects of Water Deficiency and Excess on Vine

In cases where there is not enough moisture in the soil; Inadequate and weak bud awakening in the vine, stagnation in shoot growth, abnormally short internode intervals, poor grain set, early yellowing and shedding of leaves are observed. Under these conditions, there are losses in yield and quality. The effects on shoot tip development, leaf and panicle development of the vine under water stress, and its effects on the vegetative development of the vine are shown as examples (Figure 1; 2; 3; 4).

Just as it is beneficial to irrigate the vine by giving the vine on time and with the required amount of water, excessive and excessive

Figure 1. Effect of water stress on shoot tip development (used with permission from Mark Greenspan).

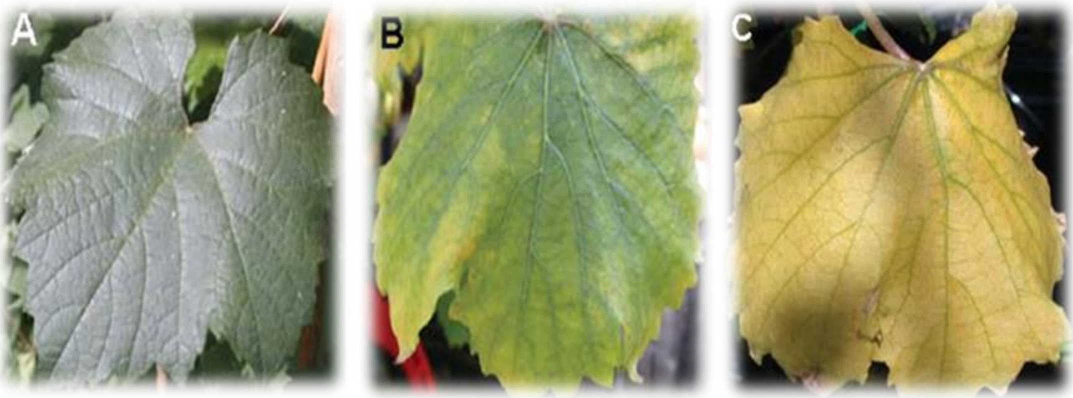

Figure 2. Signs of water stress on leaves; A. Healthy leaf, B. Onset of stress, C. Medium-High stress.

Figure 3. The effect of water stress on the cluster.

Fig.4. Signs of water stress on vine growth.

watering is equally harmful. As a result of excessive irrigation; Excess water accumulates in the root zone, the roots develop outcropping, the roots may suffocate due to lack of air due to excess water in the root zone, this phenomenon is more common especially in heavy and impermeable or less permeable soils. Vegetative development will be stronger, dry matter accumulation in the product will be insufficient, quality will be low and such a product will be less resistant to marketing and storage conditions. As the vine enters autumn, it continues to use the stored nutrients due to excessive watering, and therefore leaf fall is delayed. Since adequate lignification is not provided in the shoots, annual branches and the winter buds on them are damaged by winter frosts. Since a very humid environment will be created around, under and inside the vines with frequent irrigations, fungal diseases multiply, which leads to the use of more pesticides during the cultivation period to combat the diseases. As a result of frequent irrigation, the physical structure of the soil deteriorates and may cause salt accumulation in the soil.

Irrigation Methods Applied in Vineyards

Different irrigation methods such as furrow irrigation, sprinkler irrigation and drip irrigation can be used in viticulture. Among these methods, the most suitable method for irrigation of vineyards is drip irrigation. The drip irrigation method should be applied especially in situations where the water source is limited, the water quality is problematic or it is aimed to obtain products with high market value. With the drip irrigation method, it saves water by 30-50% compared to the surface irrigation methods, and also increases the yield and quality. Another positive feature is that the water application efficiency can be up to 90% with the drip irrigation method. In the climate crisis we have been experiencing in recent years, the efficient use of existing water resources is an important issue that we should pay attention to. The agricultural sector uses 70% of the existing sweet resources, and the average water use efficiency in the sector is 40%. The increase in the efficiency of water use with pressurized irrigation methods such as drip irrigation in agricultural irrigation will contribute to easing the pressure on our water resources.

Irrigation Scheduling in Vineyards

In order to provide the expected benefit in yield and quality with irrigation in the vineyard, an accurate irrigation scheduling is needed. Irrigation planning means giving the plant as much water as it needs when it needs it. The final product (table-wine grape) to be obtained from the vineyard creates differences in irrigation planning in the vineyard. While the aim in table grape cultivation is to obtain homogeneous colored, flamboyant, coarse-grained clusters, it is generally desired that the maturity index value should be between 20 and 30 (14-18% dry matter, 5-7 g/l acidity) in terms of quality. In wine grape cultivation, the aim is to obtain a product with small berries and high dry matter content (22-24% colored, 18-20% white varieties, 7-9 g/l acidity for colored wine varieties, 4-6 g/l white wine varieties). While it is generally not desired for the vine to experience water stress during the vegetation period in table grape cultivation, except for the pre-maturity period, it is known that mild-moderate water stress between flowering and veraison and medium-high water stress between flowering and veraison periods in wine grape growing has a positive effect on quality.

Many different methods are used for vineyard irrigation scheduling. Among these methods, soil moisture monitoring (with gravimetric method or soil moisture sensors), leaf water potential measurements, measuring the daily evaporation amount from pan A and

Table 1. Stress levels in vines according to predawn leaf water potentials (Carbonneau, 1998; Deloire et al., 2004)[1] and midday leaf water potentials (Smith and Prichard, 2002)[2]

Class	[1]Predawn leaf water potential ($\Psi_{şö}$) (MPa)	[2]Midday leaf water potential (Ψ_{go}) (MPa)	Stress level
0	$0 \geq \Psi_{şö} \geq -0.2$	$\Psi_{go} > -1.0$	No stress
1	"	$-1.0 \geq \Psi_{go} \geq -1.2$	mild stress
2	$-0.2 \geq \Psi_{şö} \geq -0.4$	$-1.2 \geq \Psi_{go} \geq -1.4$	moderate stress
3	$-0.4 \geq \Psi_{şö} \geq -0.6$	$-1.4 \geq \Psi_{go} \geq -1.6$	high stress
4	$-0.6 > \Psi_{şö}$	$-1.6 > \Psi_{go}$	severe stress

Table 2. Stem water potential midday reference values (Deloire and Heyns, 2011).

Class	SWP_{md} (ΨSWP, MPa)	Stress level
0	≥ -0.6	No stress
1	-0.7 to -0.9	mild to moderate stress
2	-1.0 to -1.2	moderate stress
3	-1.2 to -1.4	Medium-high stress (varies by variety)
4	-1.4 to -1.6	High and severe stress (depending on the variety; damage may occur at the cell and plant scale)
5	< -1.6	Very severe stress (damage may occur at the cellular and plant scale)

determining the daily plant water consumption (ETc) by using meteorological data are commonly used ones. According to soil moisture monitoring, it is recommended to increase the missing soil moisture to the field capacity value if 50% of the soil usable water holding capacity is consumed for table grape varieties, while for wine varieties, it is recommended to increase the missing soil moisture to the field capacity value if 70% of the soil usable water holding capacity is consumed. However, in wine varieties, it is a more accurate approach to keep the vine within the desired stress ranges in terms of quality by applying limited irrigation strategies or complementary irrigation, rather than removing the missing moisture directly to the field capacity. With the leaf water potential measuring device (pressure chamber), leaf water potential and stem water potential measurements are carried out before dawn and at noon. By applying one of these measurements, the irrigation time in the vineyard can be decided according to the stress level of the vine. For example, in table grape varieties, irrigation should be done when the leaf water potential value is -1.0 Mpa at noon. The stress levels of the vine according to these three methods are given in Tables 1 and 2.

By measuring the daily evaporation amount from the evaporation pot, information about the water consumption of the vine could be obtained. The daily evaporation amount could be applied daily in table grape varieties or by waiting for the total evaporation amount to reach 40-50 mm, irrigation water 1 fold the measured value can be applied. This value may vary in different ecologies. However, the confidence interval of this method is lower than other methods. Another method is to calculate the amount of plant water consumption (ETc) using meteorological data. The recent increase in the number of official and private meteorology stations in Türkiye makes the application of the method very easy. The basis of the method; It is based on applying the value obtained by correcting the calculated reference plant water consumption value with a constant coefficient (Kc) considering the development period of the plant and the ecology it grows in, as the amount of irrigation water. For example, considering the development periods of the vineyard in Tekirdağ runs, the plant coefficient is Kc1: 0.36, Kc3: 0.89, Kc4: 0.51 for table grape varieties, Kc1: 0.34, Kc3: 0.74, Rc4 for wine grape varieties: It is set at 0.50. The study titled "Plant Water Consumption Guide of Irrigated Plants in Turkey" published in Türkiye in 2016 provides detailed information about the application of this method in different ecologies. In addition, thanks to the application named TAGEM-SUET (2023) developed by TAGEM, the daily, weekly and monthly reference plant water consumption values calculated for different ecologies for the past years are offered to the producers.

Another issue to be considered in vineyard irrigation scheduling is irrigation cut off time. In order for the desired dry matter/acid ratio in the grapes, homogeneous coloration, no cracking in the berry, and full ripening of the shoots, irrigation should be terminated a certain time before harvest depending on the soil structure. This period has been reported in the literature as 2-4 weeks earlier in sandy soils and 4-6 weeks earlier in clay soils with high water holding capacity. In our studies in Tekirdağ varieties; The termination of irrigation applications at the beginning of the veraison about 4 weeks before the harvest had a positive effect on the vineyards.

Conclusion

Considering the current scientific data and changing climatic conditions, the importance of irrigation scheduling the vineyards increases. In our country, irrigation in the vineyard is applied intensively on approximately one fourth of the total vineyard areas, that is, on an area of 100,000 hectares, and it is seen that the irrigation practices are carried out according to the traditional knowledge and experience of the producer. Furrow or pan irrigation methods with low water use efficiency are still applied by the producers, while those using the drip irrigation method, on the other hand, make irrigation applications for longer periods of time without taking into account the soil water holding capacity. This situation causes the producers to stay away from the water savings and benefits they will obtain from the drip irrigation method. However, the problems experienced in vineyard irrigation can be reversed by transferring practical irrigation planning methods such as plant water consumption to the producers in the field, in accordance with the knowledge and skills of the producers. If the current situation can be reversed; With modern irrigation planning, only 50 mm of water will be saved from 100,000 ha of vineyard area during the vegetation period, and a total of 50 million tons of fresh water resources will be saved and used in another area. In addition to the water savings to be achieved in this way, there will also be savings in the energy cost that the producer will need for over-irrigation and the amount of agricultural pesticides that will be spent to control fungal diseases caused by over-irrigation. Providing irrigation water at the time and amount needed by the vineyard through modern irrigation scheduling reveals the importance of irrigation in terms of sustainable, quality and efficient viticulture as well as the protection of existing water resources.

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Conflicts of Interest

The authors declare that there is no conflict of interest.

Author Contribution

Author ZC compiled the data of statistics and economy. Author made critical revision of the manuscript for intellectual content. All authors read and approved the final manuscript.

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