Effect of Drip Irrigation Rate (DIR) on Grape Yield and Quality of Table-Grapevine Cultivar "Italia"

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Abstract

The study was conducted during the period 2010-2012, in Prush, Tirana, in the central part of Albania, in a fifteen years old vineyard, with a total area of 0.6 ha. The experimental plot was situated in a uniform flat land with a sloping gradient of 3-4%, 145 m elevation, and a planting density of 1100 vines ha^{-1}. Vines were trained according to Tent system, positioned at 200 cm above the ground. A randomized complete block design (RCBD) with six drip irrigation rates (0, 330, 495, 660, 825, and 990 m^3 irrigation water ha^{-1}) and three replications, with a plot size of 10 vines for each treatment in each replication, was used. Except irrigation, the other cultural practices were the same as normal farmer's practices. Results showed that DIR significantly affected the vegetative and productive characters of table-grapevine cultivar "Italia": yield, single bunch weight, berries weight and size, skin color, total soluble solids and firmness, parameters linked with grape storage and market. Grape yield of control was 3.3-5.9 times lower than irrigated treatments. Although, the use of low drip irrigation rate (330 m^3 irrigation water ha^{-1}) significantly increased the grape yield compared to control, but it was insufficient because mean yield of "Italia" table grape cultivar must be over 250 quintals ha^{-1} to be efficient. The highest grape yield (315.6 quintals ha^{-1}) and higher quality characters were observed for the drip irrigation rate of 660 m^3 irrigation water ha^{-1}, and this rate can be recommended as optimum DIR for this cultivar.

KEYWORDS: drip irrigation rate, "Italia" table-grape cultivar, yield, water use efficiency.

INTRODUCTION

Grape yield and quality are strongly determined by climate, soil and cultural management practices including pruning, crop load, thinning, girdling, etc. (Goldammer, 2013). Vegetative and productive growth of grapevine is under competition, especially if they are not well balanced or if there are limited nutritional resources (Smart *et al.*, 1990).
"Italia" is certainly one of the most popular Italian varieties of table grapes in the world

due to its appearance and flavour, as well as its hardiness in withstanding handling and shipping. “Italia” grapes have large, consistent fruit with a lovely golden-yellow color, and a delicate, pleasant musky flavour (Colapietra, 2004). It was breed by Luigi and Alberto Pirovano in Vapri d’Adda by crossing Bican and Muscat Hamburg in 1911. It is also a grape variety that is used in the production of Peruvian Pisco, a colorless or yellowish-to-amber colored grape brandy produced in wine making regions of Peru and Chili. “Italia” is a self-pollinating cultivar with excellent characteristics such as large bunches with a single bunch weight 800-900 g. “Italia” form large sized berries (9-10 g and 25 mm x 24 mm) with golden-green skin and firm flesh with a flavour that resembles a Muscat variety. Grape maturity and harvest occur from mid-August until mid-September (Susaj, 2012).

Grapevine water management is a key issue for vineyards. Poor water management can result in water stress or over vigorous conditions resulting unbalanced vine growth, reduced yields and inferior fruit quality. How much water is required to grow quality wine and table grapes is dependent upon evaporative demand at the location of the vineyard, stage of vine development, and percent ground cover by the vine’s canopy, and amount of rainfall occurring during the growing season. One of the most effective tools in managing the water needs of a vineyard is irrigation, which is used to supplement natural precipitation so that vines achieve adequate vegetative growth and berry development. The manner in which water is applied to the vineyard encompasses everything from the decision of when to apply the water, how much water to apply, and the best method in which to apply water (Goldammer, 2013). Grapevine water requirements are influenced by vine density, age of vines, the variety, rootstock-to-scion interaction, cover crops, climate (rainfall and evaporation), and crop load, to name a few.

Sotiri *et al*. (1972) have reported that water requirements for 1 quintal grape are 27 m^3, 37 m^3 and 44 m^3 for cultivars “Aligote”, “Saperavi”, and “Muskat”, respectively.

In situations where water salinity levels are high, estimates of vine water use should include an appropriate leaching factor for washing salt beyond the effective root zone. If frost is a concern and if sprinkler systems are used that will have to be considered too when determining vineyard water requirements. Depending upon the phenological stage (budburst, flowering, or véraison), water stress has a wide range of effects on grapevine growth, development, and physiology (Combe and Dry, 2005).

From bud break to flowering grapevine water requirement during this stage is about 9%. This stage is critical for root growth, establishing the vine canopy, and potential yield for the current and the following season. From flowering through fruit set water consumption for the period is about 6 percent of the season’s total. The most sensitive period to water stress is between flowering and fruit set where severe and prolonged water stress may result in poor flower-cluster development, reduced pistil and pollen viability and subsequent berry set (Hardie and Considine, 1976). During the long period from fruit set to véraison water consumption is about 35%, from véraison to harvest (the shorter period), water consumption is about 36% of the annual water requirements. Irrigation during this period should maintain canopy health and avoid any vine stress. From harvest to leaf fall (during the postharvest stage) water requirement is about 14% of annual water consumption. It is still important to maintain a healthy canopy during this period to ensure that the vine is able to build up sufficient carbohydrate reserves in the wood of the vines for the subsequent season before going into dormancy (Goldammer, 2013;

Wample, 2005). Relationship between irrigation rate and yield is not positive linear, but there exists an irrigation rate where grape yield and its quality, are in optimum, according to product destination (Combe and Dry, 2007). Irrigation improves fruit size and yield, while reducing year-to-year variation in the production of grapes (Robinson, 2006).

Efficient use of water affects longevity and product effectiveness of vineyards. Water Use Efficiency (WUE) (tons m^{-3} or kg m^{-3}) is the amount of dry matter or harvestable product (kg ha^{-1} or quintals ha^{-1}) produced per unit of water used by the plant (m^3 ha^{-1}) (Goodwin, 1995).

The manner in which water is applied to the vineyard encompasses everything from the decision of when to apply the water, how much water to apply, and the best method in which to apply water. Vineyards can be irrigated with overhead sprinklers, drip emitters (drip irrigation), micro-sprinklers, or furrow irrigation; each has its particular advantages and disadvantages (Goldammer, 2013; Thomaj, 2007). Drip irrigation is one of the most efficient methods which allows a gradual infiltration of water into the ground and minimize water losses from surface and underground leaks (Proffitt and Ward, 2009). Drip irrigation must be applied at intervals 7-15 days (Susaj, 2009).

In the plains and hilly areas of Albania, during the period 1st June – 1st September, which correspond to the period from véraison to harvest, where mean rainfall is about 80-230 mm (AHMI, 1981), grapevine drip irrigations is a necessity for high grape yield (Combe and Dry, 2007). Irrigations must be interrupted at least 10-15 days before harvest (Sotiri, 1977). The aim of the study was the determination of the most appropriate drip irrigation rate for "Italia" table grapevine cultivar under Tirana climate conditions.

MATERIAL AND METHODS

The study on the effects of drip irrigation rate on yield and quality of table-grapevine cultivar "Italia" was conducted during the period 2010-2012, in Prush, Tirana, in the central part of Albania, in a fifteen years old vineyard, with a total area of 0.6 ha, under the ownership of Shkëlzen Malliku.

Experimental design. The experimental plot was situated in a uniform flat land with a sloping gradient of 3-4%, 145 m elevation, and a planting density of 1100 vines ha^{-1} (3 m x 3 m). Vines were trained according to Tent system, positioned at 200 cm above the ground. Drip irrigation system was constructed since 2000. A randomized complete block design (RCBD) with six treatments (drip irrigation rates) and three replications, with a plot size of 10 vines for each treatment in each replication was used. There were performed six drip irrigations, starting from June 25 up to August 15, every 10 days. Except irrigation, the other cultural practices were the same as for the other part of the vineyard. Six drip irrigation rates (treatments) were:

V1 = control, no irrigation was used;

V2 = 50 L water $vine^{-1}$ or 330 m^3 ha^{-1} $year^{-1}$ (for six irrigations)

V3 = 75 L water $vine^{-1}$ or 495 m^3 ha^{-1} $year^{-1}$ (for six irrigations)

V4 = 100 L water $vine^{-1}$ or 660 m^3 ha^{-1} $year^{-1}$ (for six irrigations)

V5 = 125 L water $vine^{-1}$ or 825 m^3 ha^{-1} $year^{-1}$ (for six irrigations)

V6 = 150 L water $vine^{-1}$ or 990 m^3 ha^{-1} $year^{-1}$ (for six irrigations).

Assessment of the expression level of the main observed vegetative and productivity characters was carried out based on the descriptive methods, codes and evaluation levels described at the OIV, UPOV and IPGRI Descriptors of Grapevine (OIV, 2001; UPOV, 2008; IPGRI, 1997; Susaj, 2009).

Measurements and calculations. For each treatment and replication the cane pruning weight were measured at winter pruning performed in February 20. Grape yield (kg vine^{-1} or quintals ha^{-1}), single bunch weight (g), berry weight (g), berries size (polar and equatorial diameter of berry - mm), berries firmness (g cm^{-2}) and total soluble solids (^{o}Brix) were determined at harvest (August 25). Mean bunch weight was calculated from yield and bunches for vine, while one hundred berries were randomly chosen for each treatment and each replication for mean berry weight determination. Samples for must analysis were performed after de-stemming and crushing of berries. Total soluble solids (^{o}Brix) were measured by a digital refractometer.

Water Use Efficiency (WUE) (tons m^{-3} or kg m^{-3}) was calculated using the formula (Goodwin, 1995):

$$\text{Water Use Efficiency (WUE) (tons m}^{-3}\text{)} = \frac{\text{Yield (tons ha}^{-1}\text{)}}{\text{Used Water per Unit (m}^{3}\text{ ha}^{-1}\text{)}}$$

Statistical analysis. Differences between treatments (irrigation rates) for the yield and its parameters were tested using ANOVA and LSD test (Lekaj *et al.,* 2014).

RESULTS AND DISCUSSION

Effects of drip irrigation rates on yield and other characters of "Italia" table grape cultivar

Yield (quintals ha^{-1}). Observed results showed that drip irrigation rate (DIR) significantly affected the grape yield. Grape yield was significantly increased at all drip irrigation treatments compared to control. The highest yield was observed for V4 (660 m^{3} water ha^{-1}) by 315.6 quintals ha^{-1} (262.8 quintals ha^{-1} or 5.98 times higher than control), followed by V5, V3 and V6 by 286.8, 271.7 and 262.3 quintals ha^{-1}, respectively (Table 1). There was observed a significant yield decrease with the increase of DIR from 100 to 150 L water vine^{-1} (600-900 m^{3} water ha^{-1} (Table 1). Yield increase was much lower than drip irrigation rate. Yield increase was due to the raise of berries and bunch weight. Observed data were similar to Salón et al. (2005).

Single bunch weight (SBW) (g) was increased significantly with the use of drip irrigation, but different drip irrigation rates showed different single bunch weight increase. The highest bunch weight was measured for V4 (1165 g), while the lowest bunch weight was measured for control (246 g).

Water Use Efficiency (WUE) (kg m^{-3}). Besides absolute yield, water use efficiency is an important agronomic factor, especially in agricultural irrigation systems and in climate areas where a limited amount of water from the rainy season has to last for the whole growth period as no further rainfall can be expected (Goodwin, 1995). Water use efficiency is a quantitative measurement of how much biomass or yield is produced over a growing season, normalized with the amount of water used up in the process. Results showed that the highest value of the Water Use Efficiency (WUE) (kg m^{-3}) was observed for V3 (44.2 kg m^{-3} water) followed by V4 (39.8 kg m^{-3} water) (Table 1).

Table 1. Mean values of estimated yield and other productivity indicators, according to different drip irrigation rates (different letters indicate significant difference at $p<0.05$).

Treatments	Drip Irrigation Rate (m^3/ha)	Yield (quintals ha^{-1})	Yield diff with V1	WUE (kg m^{-3} water)	Single bunch weight (g)
V1 (Control)	0	52.8 ^{e}	0	0	246 ^{e}
V2	330	176.3 ^{d}	123.5	37.42 ^{b}	784 ^{d}
V3	495	271.7 ^{c}	218.9	44.22 ^{a}	870 ^{c}
V4	660	315.6 ^{a}	262.8	39.82 ^{ab}	1165 ^{a}
V5	825	286.8 ^{b}	234	28.36 ^{c}	917 ^{b}
V6	900	262.3 ^{c}	209.5	23.28 ^{d}	853 ^{c}

Winter pruning weight (g $vine^{-1}$). Winter pruning weight per vine was increased significantly with the increase of drip irrigation rates. Winter pruning weight per vine was higher for the highest drip irrigation rate, but this increase was not accompanied with the grape yield increase. Grape yield was increased up to 660 m^3 irrigation water ha^{-1}, while for higher irrigation rates (825 and 900 m^3 water ha^{-1}), yield did not follow the same pattern as winter pruning weight (Figure 1).

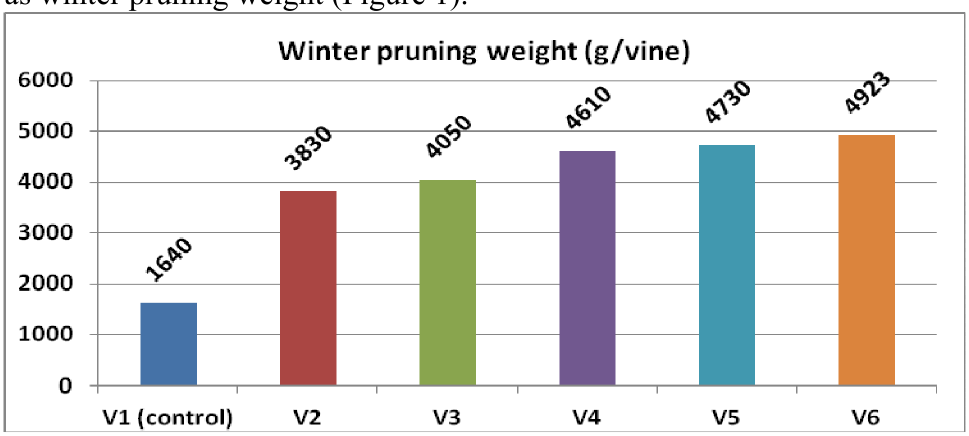

Figure 1. Effect of drip irrigation rate on winter pruning weight (gr $vine^{-1}$).

Effects of drip irrigation rates on berries characters of "Italia" table grape cultivar

Berries weight (g). Drip irrigation rate affected significantly the berries weight (g) and berries size, as well. There were observed significant differences between all irrigated treatments and control and between irrigated treatments as well. Berries weight varied from 6.8 g (V1 – control) to 11.2 g (V4 – 660 m^3 irrigation water ha^{-1}) (Table 2).

Berries size (mm x mm) was significantly affected by drip irrigation rate. There were observed significant differences between all irrigated treatments and control, while differences between irrigated treatments were not significant. Berries size varied from 24.1 mm x 21.3 mm (V1 – Control) to 34.5 mm x 30.2 mm (V4 – 660 m^3 water ha^{-1}) (Table 2).

Fruit firmness (kg cm^{-2} or g cm^{-2}). Fruit firmness is one of the most important quality variables indirectly linked with grape maturity, harvest, transport, storage and market

(García-Ramos *et al.,* 2005). Conditions that affect plant growth will also affect fruit development, ripening, and quality. Temperature, humidity, shading, nutrition, post-harvest O_2 concentration, and salinity of irrigation potentially influence fruit softening due to their effects on cell wall structure and integrity. Fruit firmness increases as the grape ripeness advance. Pectins hydrolysis is accompanied with grape softening and wiltening (Jewell, 2004). There were observed significant differences between treatments and with control for fruit firmness. In the harvest time, fruit firmness varied from 1510 g cm^{-2} (V1 – Control) to 1716 g cm^{-2} (V4 – 660 m^3 water ha^{-1}) (Table 2).

Total soluble solids (TSS or total sugars (^{o}Brix***)*** of the must was affected by drip irrigation rate. TSS (^{o}Brix) was decreased with the increase of drip irrigation rate. TSS varied from 14.9 ^{o}Brix (V6) to 16.5 ^{o}Brix (Control). Observed data were similar to Salón *et al*. (2005). Differences were not significant between drip irrigation treatments, but were significant between control and drip irrigation treatments (Table 2).

Table 2. Mean values of estimated berries characters: weight (g), size (polar and equatorial diameters (mm) and firmness (kg cm^{-2}), according to different drip irrigation rates (different letters indicate significant difference at p<0.05).

Treatments	Weight (g)	Polar diameter (mm)	Equatorial diameter (mm)	Firmness (g cm^{-2})	TSS (^{o} Brix)
V1 (Control)	6.8 ^{d}	24.1 ^{b}	21.3 ^{b}	1510 ^{d}	16.5 ^{a}
V2	8.7 ^{c}	31.2 ^{a}	28.1 ^{a}	1535 ^{c}	15.3 ^{b}
V3	10 ^{b}	32.6 ^{a}	30.1 ^{a}	1617 ^{b}	14.9 ^{b}
V4	11.2 ^{a}	33.5 ^{a}	30.5 ^{a}	1716 ^{a}	15.2 ^{b}
V5	9.7 ^{b}	33.1 ^{a}	30.2 ^{a}	1629 ^{b}	15.1 ^{b}
V6	8.4 ^{c}	33.2 ^{a}	29.5 ^{a}	1614 ^{b}	15.1 ^{b}

Drip irrigation affected the skin color as well. Skin color of control treatments was yellow-gold and for drip irrigated treatments was yellow-slightly green.

CONCLUSIONS

Drip irrigation rate significantly affected vegetative and productive characters of "Italia" table grape cultivar. DIR significantly affected grape yield, single bunch weight, berries weight and size, skin color, total soluble solids and firmness, parameters linked with grape storage and market. There was observed that production from control (without irrigation) did not fulfill the product quality standards and market and consumers requirements, because of small bunch weight (246 g) and small berry weight (6.8 g). Use of low drip irrigation rate (330 m^3 irrigation water ha^{-1}) significantly increased the grape yield compared to control, but it was insufficient because mean yield of "Italia" table grapevine cultivar must be over 250 quintals ha^{-1} to be efficient. The highest grape yield (315.6 quintals ha^{-1}) and higher quality characters were observed for the drip irrigation rate 660 m^3 irrigation water ha^{-1}, therefore this drip irrigation rate is recommended for "Italia" table grapevine cultivar, under Tirana and central Albania climatic conditions.

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