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ORIGINAL ARTICLE

Improvement of fruit quality by moderate water deficit in three plum cultivars (*Prunus salicina* L.) cultivated in a semi-arid region

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Abstract – Introduction. Drought can affect the qualitative and nutritional attributes of plum (*Prunus salicina L.)*. The aim of this work was to study the effect of regulated deficit irrigation (RDI) on the quality of plum fruits. **Materials and methods.** Experiments were conducted during two consecutive seasons (2011-2012) with three cultivars ('Black Diamond', 'Black Gold' and 'Black Star') recently introduced in the region of Regueb (center of Tunisia) characterized by a semi-arid climate. During the fruit growth period, treated trees (RDI 50) received 50% of the irrigation water provided to the control (CI) for three months. **Results and discussion.** Water restriction reduced the diameter and weight of the fruit though the extent depended on the cultivar. However, other measures of fruit quality were improved for all cultivars with an increase of fruit firmness, pH, soluble solids and sucrose content, and a decrease of total acidity. Additionally, 'Black Diamond' fruit from treated trees had high level of total phenolics and flavonoids. **Conclusion.** Regulated deficit irrigation may save water in semi-arid regions and improve fruit quality with only moderate impact on productivity.

Keywords: Tunisia / Regueb / plum / *Prunus salicina* / fruit quality / water stress / climate change

Résumé – Amélioration de la qualité des fruits par une régulation hydrique déficitaire modérée sur trois cultivars de prunier (*Prunus salicina* L.) cultivés en zone semi-aride. Introduction. Sous l'effet du changement climatique, la sécheresse peut affecter les attributs de qualité commerciale et nutritionnelle de la prune. Le but de notre travail est d'étudier l'effet d'une régulation déficitaire de l'irrigation (RDI) sur la qualité des fruits du prunier (*Prunus salicina* L.). **Matériel et méthodes.** Les expériences ont été menées sur deux saisons consécutives (2011−2012) avec trois cultivars de prunier ('Black Diamond', 'Black Gold' et 'Black Star') récemment introduits dans la région de Regueb, au centre de la Tunisie, caractérisée par un climat semi-aride. Pendant la période de croissance des fruits, les arbres traités (RDI 50) ont reçu 50 % de l'eau d'irrigation par rapport au contrôle (irrigation de contrôle, CI) pendant trois mois. **Résultats et discussion.** La restriction en eau a réduit de façon significative le diamètre et le poids des fruits avec des variations dépendant des cultivars. Néanmoins, la qualité des prunes a été améliorée pour chacun des trois cultivars, avec une augmentation de la fermeté du fruit, du pH, de la teneur en composés solubles et de la teneur en saccharose, et une diminution de l'acidité totale. En outre, les prunes de 'Black Diamond' provenant d'arbres stressés comportaient un niveau élevé de composés phénoliques et de flavonoïdes. **Conclusion.** Réguler l'eau d'irrigation est une stratégie permettant d'économiser l'eau dans une région semi-aride, tout en améliorant la qualité des fruits avec un faible impact sur la productivité.

Mots clés : Tunisie / Regueb / prune / *Prunus salicina* / qualité du fruit / stress hydrique / changement climatique

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1 Introduction

Plums are reported to be the most extensively distributed of the stone fruits, the most varied in wild and cultivated species and varieties, and adapted to a wide range of soils and climatic conditions [1]. The genetic variability amongst plum species and cultivars is substantial and has a great influence on the production and consumption of plums worldwide. *Prunus domestica* (European plums) and *Prunus salicina* (Japanese plums) are the two most cultivated species. The global area of plum production was 2.5 million hectares in 2009, with an average yield of 3.4 t ha^{-1} [2]. China and Serbia are the two main world producers, followed by the United States and Romania. Plum trees are widely cultivated in Mediterranean countries. In Tunisia, plum culture is not yet well developed. It is limited to 860 ha, in which 740 ha are located in the north, 90 ha in the centre and 30 ha in the south of the country [3]. Most Tunisian plums are *Prunus salicina*, cultivars.

Plums were recently introduced in the center of Tunisia (Regueb) where irrigation is needed for high yield and quality. Already in this region, the culture of plum cultivars has had a long tradition. Besides fresh fruit consumption, plums are also used for drying, for plum jam and (above all after the year 1835) in the production of distillates. In these Mediterranean-type ecosystems, plum trees have been cultivated in dry-land conditions with irrigation when required. Fruit quality of plums is an important determinate of their market value. It is recognized that plums represent an excellent source of nutrients and other phytochemicals that may contribute importantly to human health [4, 5].

In most Mediterranean regions, the summer-time climate is characterized by long dry periods with a combination of environmental stress factors affecting plant physiology (water deficit, high evaporative demand, high irradiance and air temperature). Worldwide there is a decrease in the availability of fresh water for horticultural production especially in arid and semi-arid regions such as Spain, Australia and Tunisia [6]. In 2050, the amount of precipitation in the countries of North Africa is predicted to be reduced by 20−50% compared to current average values [7].

Minimizing water use in horticulture while maintaining high yield and quality has become a critical issue in some areas due to a drastic decline in rainfall over the past decade possibly due to climate change [10]. Valuable information for fruit growers in Tunisia and in other dry areas would be knowledge about the distinct patterns of water use by various fruit tree species so that new plantings could be matched with water-availability expectations. Being a perennial tree, plum is frequently exposed to drought, especially under semi-arid conditions. As water shortage issues become increasingly serious in Mediterranean regions [9], new irrigation strategies will be needed for plum orchards. The effects of regulated deficit irrigation (RDI) on water saving and yield and quality improvements on perennial fruit crops have been widely investigated [10–13]. For example, RDI applied during fruit development of peach significantly reduced vegetative growth without reduced fruit production until the fourth year when fruit set decreased slightly [14]. RDI also accelerated the maturation of a late-maturing peach (*Prunus persica* L) by one week [15]. Early fruit maturation is beneficial for improving market value.

Figure 1. Location of the experimental site (Regueb, Tunisia).

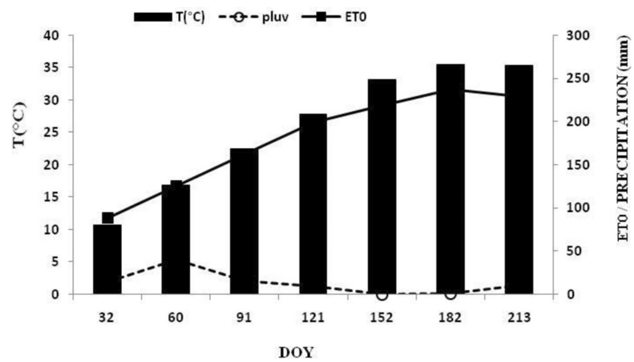

Figure 2. Average of daily mean air temperature (T), rainfall (pluv) and crop reference evapotranspiration (ET0) in terms of DOY (Day of Year) measured for the period 2011–2012. The meteorological station is located 1 km from the experimental orchard.

Our objective was to evaluate RDI treatment to reduce water use and determine its impact on fruit quality Physical and biochemical parameters were measured in three plum cultivars ('Black Diamond', 'Black Gold' and 'Black Star') subjected or not to RDI.

2 Materials and methods

2.1 Plant material, experimental conditions and irrigation treatments

This study was carried out in consecutive seasons (2011−2012) in a commercial plum orchard located 5.28 km north of Regueb city (Center-West of Tunisia) (34° 50'42.23" N, 9° 50'21,61" E) and 160 m above sea level (*figure 1*). This is a semi-arid bioclimatic region characterized by low rainfall and high temperatures (*figure 2*). The soil is a silt-clay-loam.

Table I. Fertigation of nitric acid, magnesium and potassium used in the orchards for both controls and stressed plum tree of three cultivars during the study period (February- July 2011 and 2012).

Date	Treatment	Quantity ha^{-1}
February	Nitric acid	12 L
	Soli-potash	20 kg
March	Nitric acid	6 L
	Magnesium sulphate	15 kg
	Soli-potash	20 kg
April	Magnesium sulphate	5 kg
	Soli-potash	15 kg
May	Potassium nitrate	10 kg
	Soli-potash	10 kg
	Magnesium sulphate	5 kg
June	Magnesium nitrate	10 kg
	Magnesium sulphate	5 kg
	Potasssium sulphate	5 kg
July	Magnesium sulphate	10 kg
	Potasssium sulphate	5 kg

All three plum cultivars, 'Black Diamond'(BD), 'Black Star'(BS) and 'Black Gold'(BG), were grafted on the 'Mariana' wild rootstock. Trees were planted in 2006 at a spacing of 4 m × 5 m. They were irrigated by drip irrigation with two pipes per row. Each tree has received 4 L h^{-1} of water. During the 2-year experiment all cultivars were similarly fertilized with nitric acid, magnesium and potassium (*table I*).

Treatments were distributed randomly in three experimental blocks. Each block contained four rows of the same variety with each row comprised of 18 trees. Two rows received the control treatment (CI) and two rows were subjected to water stress (RDI). The controls were fully irrigated and received full replacement crop evapo-transpiration (ETc) during all developmental phases:

$$ETc = ET_0 \times Kc,$$

data obtained from MODIS (ftp://e4ftl01.cr.usgs.gov/MOLT/MOD11C3.005) where ET_0 is the referential evapotranspiration and Kc the cultural coefficient. The control trees received between 12−30 L day^{-1} depending on the season and the phenological stage. The DI (deficit irrigation) treated trees received half the amount of irrigation as the controls. This water stress treatment was applied during the fruit growth period (May-June-July), which coincides with the dry season in Regueb region.

2.2 Sample processing

Fruits were harvested in July based on full maturity for each cultivar. Immediately after harvest, fruit diameter, weight, firmness, juice content, SSC, TA, and pH were determined on 10 fruits per cultivar per treatment as described below. For biochemical analysis, the fruit are frozen and ground in liquid nitrogen and stored at −80 °C until analysis.

2.3 Fruit quality parameters

Fruit size and composition are the most reliable indicators for fruit quality and contribute substantially to their economic value. The width (cm) of each fruit was measured using a caliper (Mitutoyo, UK) and fresh weight determined using a precision balance. Flesh firmness was measured on a partially peeled fruit using a penetrometer (FT 327, Italy).

Juice content was determined on three freshly harvested plums per replicate. These fruit were pureed in a mixer and the debris removed by centrifugation at 1,500 *g* at 4 °C for 15 min. Juice content was calculated using the following formula:

$$\text{Juice content (\%)} = [\text{Weight of juice (g)} / \text{Total weight of fruit (g)}] \times 100 \quad (1)$$

To determine the soluble solid content (SSC) of the juice, a digital refractometer (Atago-Palette PR 101; Atago Co., Tokyo, Japan) was used and SSC was expressed in °Brix. pH of the juice was measured by a pH meter (MP 220, Mettler Toledo, Switzerland). Multiple readings per sample are made. The determination of total acidity was achieved in two-fold water diluted plum juice by neutralization of the free acids with a solution of 0.1 N NaOH added drop wise until pH 8.2. The results are expressed in terms of % malic acid, the major acid in plum [16].

2.4 Sugar content

To measure soluble sugars, frozen fruit powder (50 mg) was added to 1.5 mL of 80% ethanol, 20% of 100 mM HEPES-KOH (pH 7.1) (HEPES: 2-[4-(2-hydroxyethyl)piperazin-1-yl] ethanesulfonic acid), and 20 mM $MgCl_2$ in an 2 mL tube. This mixture was incubated at 80 °C for 1 h and then centrifuged at 12,000 *g* for 5 min. 150 mL of charcoal suspension (100 mg mL^{-1}) was added to the supernatant, vortexed, and then centrifuged at 12,000 *g* for 5 min. The supernatant was stored at −20 °C until required for metabolite determinations. Glucose, fructose, and sucrose were measured in the supernatant using an enzyme-coupled spectrophotometric method [17]. The assay mixture contained 100 mM HEPES-KOH (pH 7.0), 5 mM $MgCl_2$, 0.5 mM DTT, 0.02% (w/v) BSA, 1 mM ATP, 0.5 mM NAD+, and 3U of hexokinase. The reaction was initiated by adding 1 U of glucose-6-phosphate dehydrogenase to measure glucose. Fructose and sucrose were then measured in sequence, after the addition of 1 U of phosphoglucose isomerase and 100 U of invertase, respectively.

2.5 Flavonoid content

Total flavonoids were measured by a colorimetric assay developed by Zhishen *et al.* [18]. A 1 mL aliquot of 10-fold diluted sample or standard solutions of catechin (20, 40, 60, 80 and 100 mg L^{-1}) was added to a 10 mL volumetric flask containing 4 mL ddH_2O. At zero time, 0.3 mL 5% $NaNO_2$ was added to the flask. After 5 min, 0.3 mL 10% $AlCl_3$ was added.

At 6 min, 2 mL of 1 M NaOH was added to the mixture. Immediately, the reaction flask was diluted to volume with the addition of 2.4 mL ddH_2O and thoroughly mixed. Absorbance of the mixture, pink in color, was determined at 510 nm versus a prepared water blank. Total flavonoids were expressed on a fresh weight (FW) basis in mg 100 g^{-1} catechin equivalents (CE). Samples were analyzed in three replications

2.6 Total phenolic content

Bioactive components of plum fruit are not only sugars, acids, and enzymes, but also phenolics, which are major constituents essential for fruit preservation and contribute to its nutritional value. The phenolics in 10 g samples of frozen powder were extracted by an ultrasound-assisted method [19] using 100 mL of 80% aqueous methanol. The mixture of freeze-dried powder and 80% aqueous methanol was sonicated for 20 min with continuous nitrogen gas purging. The mixture was filtered through Whatman 2 filter paper (Whatman International Limited, Kent, England) using a chilled Büchner funnel and rinsing with 50 mL 100% methanol. Extraction of the residue was repeated using the same conditions. The two filtrates were combined and transferred into a 1 L evaporating flask with an additional 50 mL of 80% aqueous methanol. The solvent was evaporated using a rotary evaporator at 40 °C. The residue was first dissolved in 50 mL of 100% methanol and diluted to a final volume of 100 mL using distilled deionized water (ddH_2O) obtained with a NANO pure water system (Barnstead, Dubuque, Iowa, USA). The mixture was centrifuged at 4 °C at 10,000 *g* for 20 min and supernatant was stored at –4 °C until analyses.

The concentration of total phenolics was measured by the method described by Singleton and Rossi [20] with some modification. Briefly, an aliquot (1 mL) of appropriately 10-fold diluted extracts or standard solutions of gallic acid (20, 40, 60, 80 and 100 mg L^{-1}) was added to a 25 mL volumetric flask containing 9 mL ddH_2O. A reagent blank using ddH_2O was prepared. One milliliter of Folin & Ciocalteu's phenol reagent was added to the mixture and shaken. After 5 min, 10 mL of 7% Na_2CO_3 solution was added with mixing. The solution was then immediately diluted to volume (25 mL) with ddH_2O and mixed thoroughly. After incubation for 90 min at 23 °C, the absorbance versus prepared blank was read at 750 nm. Total phenolic contents were expressed as mg gallic acid equivalents (GAE) 100 g^{-1} fresh sample (FW). All samples were analyzed in three replications.

2.7 Statistical analysis

The experiments were applied during two consecutive years (2011–2012). Results are presented as average values of three replications. Statistical analyses (ANOVA, Duncan test) were performed using the SPSS statistical software (version 13 for Windows).

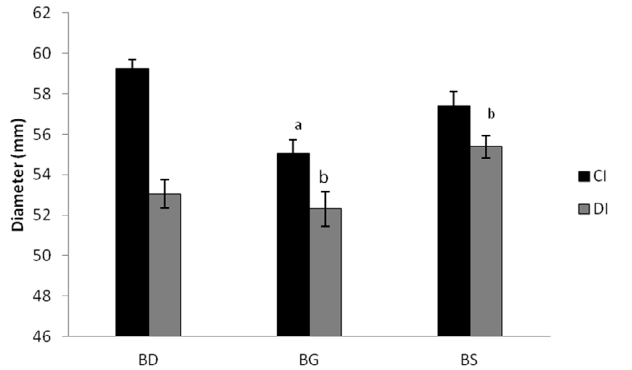

Figure 3. Change in mean diameter of fruits in the three plum cultivars 'Black Star' (BS), 'Black Gold' (BG) and 'Black Diamond' (BD) subject (stressed: DI for deficit irrigation) or not (control: CI for control irrigation) to moderate water stress (50% CI). Each histogram represents the mean (± SE, n = 10). Different letters above error bars indicate significant difference between treatments.

3 Results and discussion

3.1 Fruit quality parameters affected by deficit irrigation

Deficit irrigation affected the average fruit size of the studied plum cultivars (*figure 3*). The effect of the irrigation regime on fruit diameter was the lowest on 'Black Star' (BS) (about 1.6 or 1.7 mm in comparison with the control diameter), while 'Black Diamond' (BD) fruits were highly affected (approximately 97% of the control).

Deficit irrigation also decreased the mean fresh weight of plum fruits (*table II*). BS and BD fruits from the stressed trees achieved a fruit weight of about 87% of the control whereas BD fruits were more seriously affected (about 81% of the control. However, the water content of plum fruit was not affected by water deficit (data not shown). These results are in agreement with other work on plum [22], peach [21] and apple [23]. On the other hand, fruit tissue expansion is very sensitive to water deficit [21]. Therefore, water deficit inevitably influences the growth of fruit tissue and results in decreased fruit weight and diameter.

Fruit maturity is a strong determinate of quality attributes such as total acidity (TA), soluble solids concentration (SSC), firmness and shelf life potential. In general, TA and SSC determine consumer acceptance In this experiment, non-stressed BD had the highest acidity (3.96% malic acid equivalents), while BS had the lowest acidity (3.65%). Water stress reduced TA in all cultivars (*table II*). This result is in agreement with previous work on other fruit species [26].

Conversely, deficit irrigation increased the SSC of fruit from all three cultivars (*table II*). BD fruit juice had the highest °Brix values, ranging from 16.66 °Brix for the control to 17.80 °Brix for the stress treatment, the difference between treatments was significant. On the other hand, BG fruit juice had the lowest SSC(14.66−14.93 °Brix). These results confirm those of Thakur and Zora [21] for nectarines and Pérez-Pérez *et al.* [24] for sweet orange. Other studies on apple [23] or peach [25] have also reported that RDI increased SSC,

Table II. Variation of physico-chemical parameters (pH, firmness, soluble solids (SSC), total acidity (TA) and sugar/TA ratio) of the fruits of three plum cultivars: BD: Black Diamant, BG: Black Gold, and BS: Black Star, exposed or not during three months to moderate deficit irrigation (50% of control irrigation).

Cultivars treatment	Irrigation	Fruit weight (g)	pH	TA (% malic acid)	SSC (°Brix)	Firmness (kg 0.5cm^{-2})	Ratio Total sugars/TA
BD	Control	96.3 ± 4.09 a	3.60 ± 0.04 a	3.96 ± 0.08 a	16.66 ± 0.12 a	5.22 ± 0.28 a	1.87 ± 0.01 a
	Stressed	78.4 ± 2.14 b	4.04 ± 0.04 b	3.75 ± 0.03 b	17.80 ± 0.15 b	5.58 ± 0.68 a	2.19 ± 0.00 b
BG	Control	89.6 ± 2.82 a	3.20 ± 0.02 a	3.70 ± 0.09 a	14.60 ± 0.06 a	6.46 ± 0.11 a	1.82 ± 0.02 a
	Stressed	77.78± 3.02 b	3.26 ± 0.00 b	3.54 ± 0.00 b	14.93 ± 0.10 b	7.57 ± 0.19 b	1.74 ± 0.05 a
BS	Control	104.57± 2.14 a	2.96 ± 0.04 a	3.65 ± 0.03 a	15.13 ± 0.10 a	2.11 ± 0.20 a	2.14 ± 0.01 a
	Stressed	90.64 ± 2.99 b	3.19 ± 0.03 b	3.49 ± 0.01 b	15.73 ± 0.16 b	2.78 ± 0.02 b	2.84 ± 0.02 b

Letters in a column indicate significant difference between treatments. Each value is the mean of 6 replicates ± S.E.

especially when stress conditions were imposed towards the end of fruit growth and expansion. According to Stefanelli *et al.* [8], this increase isdue to the concentration of sugars associated with the decrease in fruit size. Intrigliolo and Castel [22] found that installation of a water stress treatment at the final stages of growth of plum fruits significantly decreased fruit size, but accelerated fruit maturation and increased SSC. Thus, a deficit irrigation regime imposed during fruit maturation increases SSC at the ripe stage a critical parameter forconsumer acceptance regardless of acidity [27].

Sugars being the major components of SSC apart from organic acids, amino acids and soluble pectins any water deficit treatment would therefore significantly increase sugar/TA ratio in the varieties 'Black Diamant' and 'Black Star' (as seen in *table II*). RDI is reported to increase sugar/TA ratio in strawberry [12] and Ningbo *et al.* [28] found that severe water deficit during the fruit maturation stage increased the sugar/acid ratio of pear-jujube. Since soluble solids including organic acids would decrease the fruit juice water potential, it may promote cell absorption of water and nutrients and relieve the negative effects of the water stress which has already been observed and reported [26].

The application of a moderate water stress also decreased the juice content of plum fruit, depending on cultivar. It was not significant for for BS (−3.8%) and BG (−4.23%) but significant for BD (−6.41%) (*figure 4*) respectively. These results could be explained by a poor water use when SSC increased while fruit size was limited, resulting in a low juice content.

At harvest fruit firmness was significantly ($P = 0.001$) higher for the three cultivars under RDI (*table II*). Comparing cultivars, BG fruits exhibited a significantly ($P = 0.001$) higher firmness and BD fruits remained generally firmer than BS fruits. Increased firmness of water-stressed fruit has already been reported in apple [29] and attributed to an increased cellular density due to a reduction in fruit size. Hence, there must be physiological regulation affecting firmness apart from fruit density and fruit size. Decreased cellular hydration as a result of reduced irrigation may also increase the dry matter concentration.

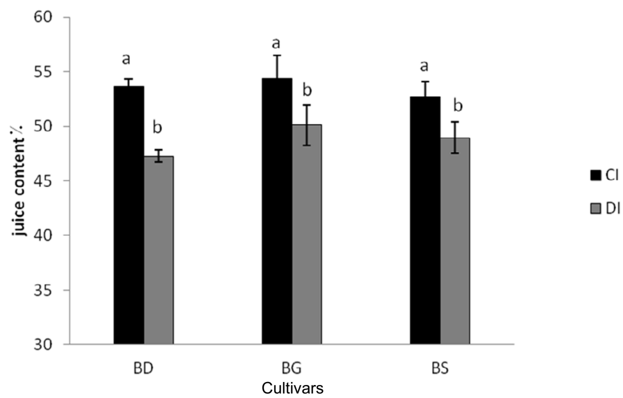

Figure 4. Juice content (in %) in three plum cultivars 'Black Star' (BS), 'Black Gold' (BG) and 'Black Diamond' (BD) subject (stressed: DI for deficit irrigation) or not (control: CI for control irrigation) to moderate water stress (50% CI). Each histogram bar represents the mean (± SE, n = 10). Different letters above error bars indicate significant difference between treatments.

3.2 Fruit sugar content

In all cultivars the major sugar component at harvest was sucrose (*figure 5*). RDI significantly ($P = 0.5$) influenced the changes in concentration of sucrose, glucose and fructose. The concentrations of sucrose increased significantly in the different varieties (*figure 5*). The proportion of sucrose (relative to the total sugar content) increased three times (from 2.65 mg 100 g^{-1} FW in CI to 6.82 mg 100 g^{-1} FW in RDI) in BS and more than two times in BD (2.45−5.84 mg 100 g^{-1} FW), whereas the content of this non-reducing sugar increased more slightly in BG (2.58−4.06 mg 100 g^{-1} FW). Similarly, Kobashi *et al.* on peach [30] and Thakur and Zora on nectarine [21] reported that a water stress applied to the trees resulted in higher amounts of sucrose and total sugars in the fruit. Total and reducing sugar contents in plants would increase after they were subjected to a certain degree of water stress [26]. Higher synthesis of sucrose may be responsible for higher amounts of sucrose in the RDI treated plum fruit of any variety at harvest. The accumulation of higher sucrose and total sugars in fruit under RDI treatments is probably related to a higher concentration of sugars (main part of the SSC) and to the significant reduction in fruit size as discussed by Stefanelli *et al.* [8]. These observations would suggest a higher synthesis or translocation of sucrose in our plum cultivars. A decline of sink activity in vegetative organs could also be considered one of the factors contributing to the sugar accumulation in

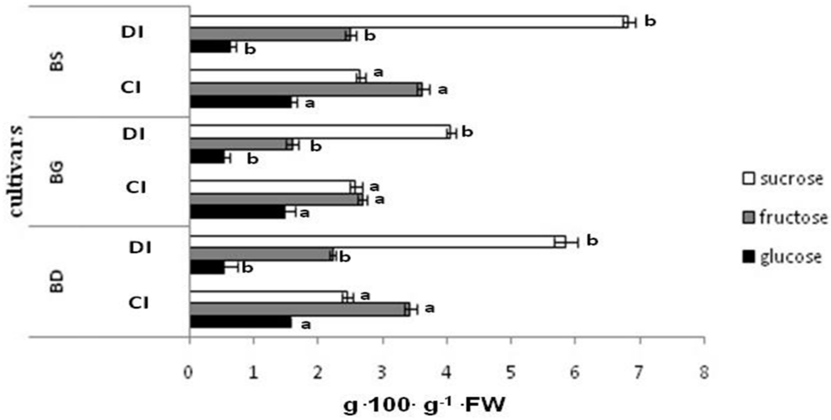

Figure 5. Determination of sugars (sucrose, fructose and glucose expressed in g 100 g^{-1} FW) in the fruit of plum cultivars 'Black Star' (BS), 'Black Gold' (BG) and 'Black Diamond' (BD) exposed (DI) or not (CI) to moderate water stress (50% CI). Each histogram bar represents the mean (± SE, *n* = 10). Different letters beside error bars indicate significant difference between treatments.

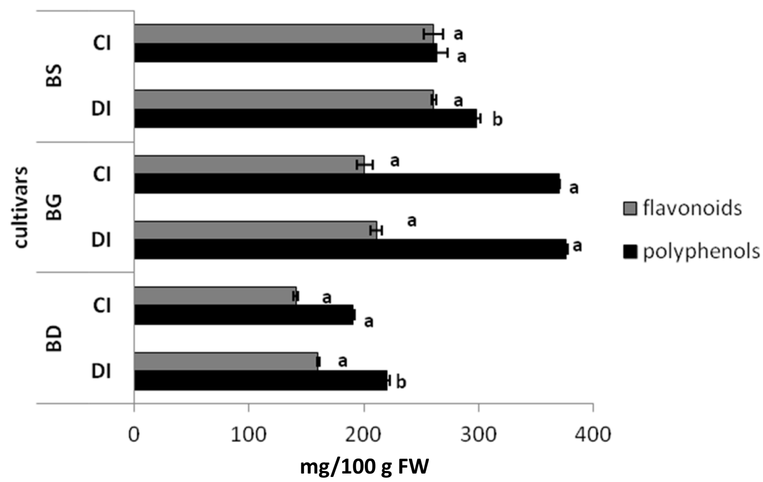

Figure 6. Concentration of flavonoids and polyphenols (mg 100 g^{-1} FW) in fruits of three plum cultivars 'Black Star' (BS), 'Black Gold' (BG) and 'Black Diamond' (BD) exposed (DI for deficit irrigation) or not (CI for control irrigation) to moderate water stress (50% CI). Each histogram bar represents the mean (± SE, *n* = 10). Different letters beside error bars indicate significant difference between treatments.

fruits under water stress [34]. Increased carbohydrate translocation from vegetative organs to the fruit sink under water stress might be responsible for the resulting increase of sucrose in the plum fruits.

The opposite trend was observed for glucose and fructose contents which drastically decreased at harvest in RDI treated trees of the three cultivars compared to the controls (*figure 5*). The fructose content reduction ranged –30% to −40% in any cultivar (*figure 5*). In parallel, such a decrease was even greater in glucose content for which we recorded −60% reduction in any plum variety. The biggest drop in glucose was recorded for BD and BG (about −65% compared to the controls). At harvest, the irrigation strategy strongly influenced the sugar contents in BS and BD plum fruits. The decreased concentrations of glucose and fructose and the increased one of sucrose during fruit maturation is reported to be due to a reduction in sucrose hydrolysis, hence in a decreasing activity of acid or neutral invertase enzymes, which converts sucrose (from elaborated sap) into glucose and fructose [21]. Sucrose is mainly synthesized by sucrose synthase from glucose and fructose as carbohydrate storage [31]. A decrease of reducing sugars might express higher utilization in respiration (catalysis) or higher storage in fruit after conversion into sucrose (biosynthesis) [32,33]. In the case of mild water stress, as in our study, fruit of citrus and orange are known to accumulate higher levels of soluble carbohydrates without strong effects on the fruit yield [35]. In other works, sorbitol (not analyzed in our study) also contributed to the stress response as a compatible solute [36]. It is generally agreed that fruit tree species tend to have higher sugar contents in their fruits in the years of low rainfall during fruit maturation, although the full mechanism remains unclear. There are a few cases, however, which cannot be explained merely by this regulation [35].

3.3 Fruit flavonoid and total phenolic contents

Across cultivars, BS fruits exhibited the highest flavonoid content (260.23 mg CE 100 g^{-1} FW), followed by BG (200.24 mg CE 100 g^{-1} FW) and BD (140.80 mg CE

100 g^{-1} FW) (*figure 6*), but RDI had no significant effect on flavonoids content of the juice of any cultivar. On the other side, The content of total phenols differed according to treatments and cultivars (*figure 6*). It ranged from 190.8 mg GAE 100 g^{-1} FW for BD fruits to 369.8 mg GAE 100 g^{-1} FW for BG fruits. The polyphenols content increased significantly in varieties BS and BD. The distribution and composition of phenolic phytochemicals are known to be affected by several factors such as: genetics, maturity, climatic conditions and cropping systems [37].

Moderate water stress induced an increase of phenol content in BD (+15.2%) and BS (+13.1%) plum fruits Similar observations have been made in other fruits species such as peach [38]. The concentration increase of these secondary metabolites following a water stress would not only result from a decrease in fruit size, but also from a stimulation of the biosynthetic pathway of phenolics [10, 39]. Given that all cultivars were grown under similar conditions and at the same location, one can clearly see the genetic variability, which is quite typical of plum [19].

4 Conclusion

The results of the present study confirmed the feasibility of reducing water applications by at least 50% through regulated deficit irrigation (RDI) without drastically affecting fruit growth. Our study also confirmed that RDI could maintain or improve fruit quality in *Prunus salicina* depending on the analyzed parameters. Hence, applying such an irrigation regime would cause only slight losses in fruit weight, improve several fruit quality attributes, and substantially save water. However, it is clear that plum cultivars differ in their response to RDI. The plum 'Black Star' appeared most suitable for cultivation under a semi-arid climate like in the Regueb region with low irrigation water supply. This water regime strategy seems less applicable for the 'Black Diamond' cultivar.

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