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Evaluation of New Cultivars of Plum (*Prunus salicina*) under Deficit Irrigation in a Semi-Arid Zone of Tunisia †

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Abstract: The lack of precipitation influences the salinity of irrigation water. The experiment was conducted in a plum orchard in the Rgueb region. Two water regimes were applied. Stressed trees received 50% crop evapotranspiration (ETc) and the controls received 100% ETc. During the experimentation period, the phenological stages, flowering period and some pomological criteria were surveyed. The different parameters followed confirmed that the Black Star cultivar, with a shorter cycle, was the most resistant to water deficits and salinity. According to this study, it will be strategic to encourage the cultivation of the Black Star cultivar in the semi-arid region of Tunisia.

Keywords: Black Star; phonologic stage; plum fruit; salinity; water deficit

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1. Introduction

In Tunisia, in arid and semi-arid areas (such as Regueb, Tunisia), low annual rainfall and high evaporation rates affect the production of fruit trees, which require a water supply for orchards. Moreover, the excessive exploitation of water resources for irrigation accompanied by an uncontrolled use of fertilizers increases salinity. It is generally known that moderate water stress is a method that increases a plant's water use efficiency and improves fruit quality without affecting size, weight and even yield [1]. However, previous studies in mid-maturing Japanese plum have shown that water stress in a period close to harvest reduces fruit size and vegetative vigor [2]. In this context, the aim of this work is to evaluate the acclimatization of three plum cultivars (Black Diamond, Black Gold and Black Star) introduced in the Regueb region. The impact of climate and especially water deficit and high salinity on the development, production and quality of fruits is investigated.

2. Materials and Methods

2.1. Experimental Site and Plant Material

The orchard is located 4 km north of the town of Regueb. It covers an area of 4 ha with a dispositive in crisscross. It was installed in 2006. It contains three plum cultivars: Black Diamond (BD), Black Star (BS) and Black Gold (BG). The trees are irrigated by drip irrigation (4 L/h) with salinity of around 2.4 g EC (dS/m). The farmer applies an identical fertilization program for all the trees. These cultivars are characterized by the earliness of ripening of their fruits.

2.2. Water Treatment of the Plum Tree

Two water regimes were applied. For each cultivar, the trees considered as controls received between 12–30 L/d depending on seasons and phenological stages (100% ETc).

However, the treated trees received half of the irrigation water from the controls (50% ETc); this treatment can be considered as a moderate water stress (MWS) during the months of May–June–July.

2.3. Phenological Stages of Plum Trees

To define the phenological stage, we referred to the work published by [3] focusing on plum tree phenology. Each phenological stage was designated by a letter. The phenological stages of each cultivar were followed from budburst to fruiting.

2.4. Pomological Parameters of Plum Fruits

The fruits were harvested at the commercial ripening stage (full maturation stage). The extraction of sugars was performed according to the method described by [4] with some modifications. The carbohydrate content was determined according to [5]. Total acidity (TA) was determined according to [6]. The concentration of total phenols was measured by the method of [7]. Total flavonoids were measured according to [8].

2.5. Statistical Analysis

Statistical analysis (ANOVA and Duncan's test) was performed using SPSS statistical software (version 13 for Windows). For the comparison of the pomological parameters, the variables were subjected to a multivariate analysis using a general linear model including two fixed factors (cultivars and water treatment).

3. Results

3.1. Phenological Stages

The beginning of budburst takes place in February for BD and BG and March for BS (Table 1). The end of flowering and the appearance of fruits take place in May for the three varieties. The duration of the reproductive cycle from the bud swelling stage (B) to the young fruit stage (J) differed between cultivars. It was 68 days for the BD and BG cultivars; however, BS had the shortest development cycle (59 days). An intra-cyclic variability exists between the durations of the stages. All cultivars reach the fall of petals stage (I) together.

Table 1. Phenological stages of three plum cultivars grown in the Regueb region.

Varieties	Bud Swelling	First Bloom	Full Bloom	Post Bloom	Fruit Set	Young Fruit
Black Diamond	02/03	15/03	21/03	30/03	05/04	08/05
Black Gold	02/03	20/03	24/03	05/04	18/04	08/05
Black Star	13/03	20/03	30/03	10/04	18/04	08/05

3.2. Effect of Water Stress in the Pomological Parameters of Plum Fruits

The result of the variation of total sugar in the three plum cultivars studied under deficit irrigation strategy is shown in Table 2. We found that the level of total sugar contents in the plum fruit varied between 26.23 and 40.63 g/100 g FW. In addition, our results show that the sugar content in the stressed plum cultivars was higher than that in fruits harvested from the control trees BD and BS (37.90 and 40.63 g/100 g FW, respectively). However, deficit water irrigation did not affect the concentration of sugar in the fruits of Black Gold (Table 2).

The results shown in Table 2 show that, at the ripening stage and under full irrigation conditions, BS had the lowest level of acidity (3.65% malic acid), while BD fruits were the most acidic (3.96 % malic acid). In addition, MWS has a negative impact on the total acidity in all cultivars (Table 2). Our results show that the level of polyphenols in plum depends on the cultivars. Indeed, BG plums contain the highest levels (369.84 mg/100 g FW), followed by BS (263.52 mg/100 g FW). The lack of water leads to a slight improvement in the rate of these compounds in both BD and BS fruits. Furthermore, the results show a significant variation between the three cultivars concerning the level of flavonoids (Table 2). In fact, under control and deficit irrigation, BS plums were the richest in flavonoids with a concentration that reached 26 mg/100 g FW. The fruits of BD had the lowest concentration of flavonoids (did not exceed 16 mg/100 g FW).

Table 2. Variation of pomological parameters in the fruits of the three plum cultivars subjected (stressed) or not (control) to moderate water stress.

Varieties	Total Sugar (g/100 g FW)		Total Acidity (% Malic Acid)		Total Polyphenols (mg/100 g FW)		Flavonoids (mg/100 g FW)	
	Control	Stressed	Control	Stressed	Control	Stressed	Control	Stressed
Black Diamond	27.66 ^{cB}	37.90 ^{bA}	3.96 ^{aA}	3.75 ^{aB}	190.82 ^{cB}	219.96 ^{cA}	14.89 ^{cB}	16.01 ^{cA}
Black Gold	26.23 ^{bA}	27.10 ^{cA}	3.70 ^{bA}	3.54 ^{bB}	369.84 ^{aB}	375.57 ^{aA}	20.64 ^{bA}	21.71 ^{bA}
Black Star	30.53 ^{aB}	40.63 ^{aA}	3.65 ^{cA}	3.49 ^{cB}	263.52 ^{bB}	298.20 ^{bA}	26.23 ^{aA}	26.66 ^{aA}

Values are the means of three different samples (n = 3) ± standard deviation. The lowercase letters [a], [b] and [c] indicate significant differences ($p \leq 0.05$) among the three cultivars for each treatment separately. Capital letters [A] and [B] indicate significant differences ($p \leq 0.05$) for irrigation treatments.

4. Discussion

Phenology is one of the indicators used and accepted by many scientists to monitor climate change; it is an ideal manner to demonstrate the effects of global warming on the living world [9]. For all the cultivars studies, the flowering period extended from mid-March to the second week of April. However, in a previous study carried out on other plum cultivars grown in Romania, the flowering occurred from the end of March to the beginning of May [10]. In addition, the analysis of phenological data showed that the duration of flowering varied according to the variety, a characteristic that is influenced by climatic and genetic factors. In fact, the BS cultivar showed the longest flowering period (21 days). Moreover, according to [10], the longest flowering period is a positive characteristic of a cultivar's adaptation to unfavorable conditions. In addition to its impact on plant phenology, climatic conditions and irrigation strategies have a significant influence on fruit quality. In our study, the results show that the application of MWS can improve plum fruit quality. In fact, we found that water stress increased the concentration of total sugars, especially in BS fruit. According to [11], this increase is due to the overconcentration of sugars following the reduction in fruit size. Our also results show a decrease in the total acidity of plum fruit under MWS. Similar results were found for peach fruit [12]. In fact, according to [13], the decrease in total acidity can be explained by the decrease in malic and citric acid levels after their use in the processes of gluconeogenesis, fermentation and amino acids. Phenolic compounds are also major constituents of plum fruits [14]. There is a strong correlation between the richness of fruits in phenolic compounds and their antioxidant activity. Our study shows that moderate water stress increased the concentration of flavonoids and total polyphenols in plum fruits in the three cultivars studied. The same findings have been observed in other fruit species, such as the peach [15]. According to [16], the increase in these secondary metabolites is due, not only, to the reduction in fruit size under restrictive water conditions, but also to the fact that water stress stimulates the biosynthesis of phenolic compounds.

5. Conclusions

In conclusion, studies on the environmental factors' impact on phenology in fruit-tree species allow us to make decisions on suitable assortments for different culture zones, depending on local ecological conditions. According to the results obtained in this study, we found that the Black Star cultivar had the shortest phenological cycle, the longest flowering period and its fruit was improved by moderate water stress (high sugar and phenolic compound concentrations). Therefore, this cultivar may be appropriate for growing in the Regueb region (with a semi-arid climate).

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