



Water Stress Alter Leaf Hydric Status and Flower Bud Development in Apricot cv. “Royal”

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Authors' contributions

This research was carried out in collaboration among all authors. Authors HR, AIMA and AZG designed the study, wrote the protocol, managed the experimental process, analyses of the study, performed the laboratory analysis and wrote the manuscript. Authors DJC and JAVQ managed the literature searches. All authors read and approved the final manuscript

Article Information

DOI: 10.9734/IJPSS/2020/v32i930322

Editor(s):

(1) Dr. Mirza Hasanuzzaman, Shere Bangla Agricultural University, Bangladesh.

Reviewers:

(1) Mahaveer Suman, Agriculture University of Kota, India.

(2) Prashant Kaushik, Polytechnic University of Valencia, Spain.

(3) B. N. Hazarika, Central Agricultural University, India.

Complete Peer review History: <http://www.sdiarticle4.com/review-history/59154>

Original Research Article

Received 07 May 2020
Accepted 13 July 2020
Published 24 July 2020

ABSTRACT

Aims: The apricot (*Prunus armeniaca* L.), is a drought-sensitive deciduous fruit. This concept arises from the fact that soil moisture stress can: Decrease the number and quality of flower buds differentiated; delay the time of flower differentiation and decrease the number of flower buds per shoot. The objectives of this investigation were to determine: The extent to which drought influences water status in the leaves; its effect on flower buds development and on bloom in apricot cv. “Royal”.

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Study Design: Trees were divided into 6 groups of six replicate each under a random block design. Results were analyzed using the statistical program 'RStudio' for Windows version 10 and data obtained subjected to a comparison of means with the Tukey ($P \leq 0.05$) test.

Place and Duration of Study: The experiment was conducted at the Department of Horticulture in Universidad Autónoma Agraria Antonio Narro, Saltillo, Mexico, during 2018-2019.

Methodology: Seven-year-old apricot trees growing in containers were subjected to a 4 to 5week period of water stress at different times during the growing season. Leaf water potential was periodically measured and flower bud development was followed from early differentiation up to full bloom.

Results: Leaf water potential in water stressed trees was constantly low. Water stress early in the season induced a delay in bud development during late summer and fall. Water stress late in the season did not appreciably affect the rate of bud development. Full bloom was delayed when water stress was applied in late summer and fall. Water stress at flower bud initiation and differentiation, together with high temperatures, may have induced flowers with double pistils. Water stress from April through October did not induce flower drop.

Conclusion: Soil water stress severely affect leaf water potential; delays flower bud development and may induce flowers with double pistils without flower drop.

Keywords: Apricot; water stress; flower's double pistil; fruit quality.

1. INTRODUCTION

The apricot (*Prunus armeniaca* L.), a deciduous fruit, is considered a drought-sensitive species. This concept arises from the fact that soil moisture stress can: a) decrease the number of flower buds differentiated; b) delay the time of differentiation of many flower buds; c) decrease the number of flower buds per shoot; d) decrease the growth of the shoot; e) decrease the quality of fruit and f) reduce yield [1,2]. The apricot is not adapted to withstanding drought; it is not able to reduce its water consumption to very low levels in comparison with some other fruit trees, such as fig. Long periods of hot weather with dry soil seem to cause injury. In places around the world where apricots are grown, it is well known that good irrigation makes possible greater yields and larger fruit size. Low yields occurring in some years on unirrigated trees are associated with depletion of soil moisture at the time of floral differentiation, which occurs sometime after harvest. If adequate irrigation is applied at this time, satisfactory yields of apricots are produced the following year [3]. The reports by some researchers indicate that differentiation and development of fruit buds in peach and in apricot are stimulated under temporary dry soil conditions at the early stage of growth, and they are greatly reduced if the soil conditions are either extremely dry or wet throughout the growing season [4,5]. There is an increasing demand for knowledge of when during the growing season drought is most critical to fruit trees and how it affects them. This demand seems to be stimulated mainly by

awareness in developing countries of the importance of water in fruit production, by an awakened concern in the industrialized nations for water as a critical resource, and by progress in understanding the different aspects of plant-water relations [2,6].

The objectives of the present investigation were to determine: The extent to which drought at different times during the season influences water status in the leaves; possible effect of drought on the flower buds at different stages of development and on time and uniformity of bloom.

2. MATERIALS AND METHODS

2.1 Plant Material, Site and Design

The present investigation was conducted during the period 2018-2019 at an experimental field facility belonging to the Horticulture Department, Universidad Autónoma Agraria Antonio Narro in Buenavista (102°11' W and 25° 26' N, at 1,533 MSL), Saltillo, Coahuila, México.

Table 1. The water stress treatments in 2018 were as follows

| Treatment No. | Period of water stress (2018) |
|---------------|-------------------------------|
| I | April 15– May 20 |
| II | May 20 – June 24 |
| III | June 24 – July 29 |
| IV | July 29 – Sept. 2 |
| V | Sept. 2–Oct. 7 |
| VI | Control |

Thirty-six 7-year-old apricot (*Prunus armeniaca* L.) trees cv "Royal", each growing in a 200-litres container, were used for the experiments during the growing season of 2018 and into the spring of 2019. The trees were about 1.5 metres tall, with a good bearing surface for their age. The soil in the containers was classified as loam. The trees were divided into 6 groups of six trees each under a random block design. Each group, except the control, was kept under water stress for about a month at different times in the growing season. Since the trees were in containers with no reserve of moisture to sustain them during the stress period, small amounts of water (700 cc) were added to the soil surface at 4- or 5- day intervals to prevent excessive wilting and obvious tree injury. The control and treated groups were irrigated every 4-7 days when not under water stress. The field capacity (1/3 bar) of the soil averaged 13.1% of the dry weight of the soil samples taken from around the thirty-six trees.

2.2 Leaf Water Potential

In order to characterize treatments as to degree of plant stress, during May through August, 2018, water potential in fully expanded leaves was measured periodically using a portable Scholander pressure chamber (Model 600, Soilmoisture Equipment Crop, Santa Barbara, California, USA) to compare the relative tree water status among the different treatments. Measurements were made early in the morning (6:30 a.m. to 8:30 a.m.) taking 4 leaves per tree (24 leaves per treatment). Also on several occasions, frequent measurements were taken throughout the day.

2.3 Flower Buds

To determine the influence of the different treatments on the development of buds, samples of flower buds and later, flowers, were taken for microscopic examination at monthly intervals from July 16, 2018, until full bloom in March, 2019. The material for examination was fixed in formalin (45%): propionic acid (35%): alcohol (1%) solution. Dehydration was carried out in a tetrahydrofuran series, and the samples were embedded in paraffin and subsequently sectioned. Sections were stained with Heidenhain's hematoxylin and fast green [7]. Bud development was indexed on the numerical scale of 0 to indicate undifferentiated buds through 10 to indicate full bloom. A descriptive key to the various stages of bud development is given in Table 3. Four branches (north, south, east and

west) in each tree were selected and total flower buds counted on January 26, 2018. On February 22 when blooming had already started, fully opened flowers and those in the popcorn stage were counted. At full bloom, the total number of normal flowers as well as those with double pistils were determined. The results obtained were analyzed using the statistical program 'RStudio' for Windows version 10 and the data obtained was subjected to a comparison of means with the Turkey ($P \leq 0.05$) test.

3. RESULTS AND DISCUSSION

3.1 Leaf water Potential

Table 2 shows early morning leaf xylem water potentials as indicated by pressure bomb readings. Values on May 25, May 28, and June 6, 2018, for treatments I, II, and VI illustrate how low leaf water potential can become in container-grown trees when sufficient irrigation is withheld. No difference in water potential was found between treatment VI (control) and treatment I (water stressed Apr. 15 – May 20 but adequately irrigated thereafter), indicating a complete recovery by May 28. Treatment II which was subjected to water stress from May 20 to June 24, showed higher pressure bomb readings on all these 3 dates of measurement. The water potential of the leaves in this treatment was more than 15 bars less than in plants of the irrigated treatments. It should be noted that the water potential in treatment VI (control) remained constantly high (-7 bars) from May 25 to May 28 and then decreased about 5 bars to June 6. This showed that the irrigation applied on May 25 kept the plant water potential high for several days. Treatment II (unirrigated) showed a water potential of -30 bars. After a small amount of water (700 cc) was applied, the water potential increased by May 25 to -27 (still extremely stressed), decreasing again by June 6 to a water potential of -32. In the absence of added soil water, both plant and soil water potentials decrease over a period of days until the water potential of the plant equals the water potential of the soil and the plant ceases to absorb water because there is no longer a gradient in water potential from soil to roots. In July, treatments III (June 24 – July 29) and IV (July 29 – Sept. 2) showed the highest negative leaf water potential. In values measured from August 21 to August 25 it can be seen that treatment IV was still under water stress on those dates. No significant difference in pressure bomb readings was found among treatments I, II, III, V and VI, all irrigated

during that period of time. The highest pressure bomb reading (lowest water potential) for treatment IV on August 22 was over twice that of the irrigated treatments. However, it should be noted that once a small amount of water (700 cc) had been applied to each tree, leaf water potential increased to a level close to those of the irrigated treatments. This suggests that the amount of water applied was more than it should have been to keep the treatment under stress. By the third day after the application of the limited amount of water, a decrease of water potential in treatment IV had taken place whereas in the well irrigated treatments, the water potentials continued to remain high. In September, treatment IV showed the highest water potential on day 25th, whereas treatment V presented the highest values on days 10th and 15th when compared with rest of treatments. The leaf water potential parameters studied were sensitive to water stress periods. This response may also be related to changes in the evaporative demand of environmental atmosphere [2,3,5], as well as to the soil water conditions during the experimental period. The high values of leaf water potential in the control treatment suggest the absence of limiting factors in soil-plant-atmosphere relationship as has been supported by Domingo et al. [8]. Perez-Pastor et al. [6] have found that variations in plant water status during the day were related to changes in soil moisture tensions and environmental conditions. Therefore, on July 11, 2018, pressure bomb measurements of previously water stressed and later irrigated trees and present stressed trees were taken at intervals during the day (Fig. 1). Similar changes in water potential were found in treatments I, II and VI (all well-irrigated). The maximum water potential (least negative) for treatments I, II, and VI was at 5 to 6 am with a water potential between -5 and -7 bars, and the minimum (most negative) was between 12:00 noon and 1:00 pm. Treatment III, which was under water stress, showed a constantly low water potential, with the maximum at 5 am (-27 bars) and the minimum at 3 pm (-33 bars). It should be noted that recovery in water potential of the well-irrigated treatments (I, II and VI) began taking place after 2 p.m. while in treatment III (water-stressed) recovery began later (after 3 pm). This delay in recovery was the result of lower rate of water absorption since the soil water potential was lower in the water-stressed treatment. In water stressed treatments, the relative reductions in leaf water potentials with respect to the control treatment were evident throughout the evaluated

day. This effect may reflect a connection between the level of water stress in fruit tree and the evaporative demand of the atmosphere as has been suggested by Ruiz-Sanchez et al. [2] and by Septar et al. [3].

3.2 Flower Buds

The comparative development of the flower buds during 2018-2019 from the different water stressed treatments and the control is shown in Table 3. As expected, the earliest, most uniform and normal flower bud development occurred on control trees (Treatment VI). In treatments I and II which were under water stress April 15 – May 20, and May 20 – June 24, respectively, evidence of differentiation appeared later than in the control. There was consequently a range of delayed bud stages observable at each sampling date from trees of treatments I and II. Bud development on treatment III trees (water stressed June 24 –July 29) and IV (water stressed July 29 –Sept. 2) was not delayed as much as on trees of treatments I and II. Bud development on treatment III trees (water stressed June 24 –July 29) and IV (water stressed July 29-Sept. 2) was not delayed as much as on trees of treatments I and II. The progress of bud development on treatment V (water stressed Sept. 2 - Oct.-7) was nearly equal to that of the control. The delay in flower bud development in late summer on treatments I and II might have been caused by the early period (May and June) of water stress acting on flower bud initiation in some way. Perhaps, as has been reported by Ramirez et al. [9], the level of promoting endogenous hormones in the bud tissue was extremely low at that time of flower initiation. Pérez-Pastor et al. [6] found in apricot that prolonged periods of dry soil conditions during July, August and or September resulted in a delay in the time of differentiation of flower buds and a slower rate of development of buds which were differentiated at the normal time giving fruits of less marketable quality. In this experiment the post-harvest water stress on treatments III, IV and V did not appreciably delay the timing or rate of bud development as compared to the control. Perhaps the water stress period for each of the treatments was not much detrimental to the rate of flower bud development, or it could be that water stress during the periods concerned was not uniformly low as indicated by the pressure bomb readings in treatment IV (Table 2) where leaf water potential rose close to the water potential of the control after the routine minimal

Table 2. Leaf water potential in apricot cv. “Royal” as affected by water stress during 2018

| Treatment | Leaf water potential (bars) | | | | | | | | | | | |
|-----------|-----------------------------|------------------|------------------|------------------|------------------|------------------|------------------|------------------|------------------|------------------|------------------|------------------|
| | May | | June | | July | | August | | | September | | |
| | 25 | 28 | 06 | 13 | 17 | 21 | 22 | 23 | 24 | 25 | 10 | 15 |
| I | -12 ^{bz} | -07 ^b | -15 ^b | -5 ^b | -08 ^b | -11 ^b | -12 ^b | -9 ^b | -8 ^b | -09 ^b | -08 ^b | -07 ^b |
| II | -30 ^a | -27 ^a | -32 ^a | -10 ^b | -09 ^b | -13 ^b | -14 ^b | -6 ^b | -8 ^b | -08 ^b | -09 ^b | -08 ^b |
| III | -11 ^b | -09 ^b | -10 ^b | -25 ^a | -22 ^a | -14 ^b | -15 ^b | -9 ^b | -8 ^b | -09 ^b | -07 ^b | -08 ^b |
| IV | -08 ^b | -10 ^b | -09 ^b | -8 ^b | -09 ^b | -18 ^a | -32 ^a | -10 ^a | -11 ^b | -17 ^a | -10 ^b | -09 ^b |
| V | -09 ^b | -8 ^b | -10 ^b | -7 ^b | -10 ^b | -11 ^b | -10 ^b | -12 ^a | -11 ^b | -10 ^b | -27 ^a | -28 ^a |
| VI | -07 ^b | -7 ^b | -12 ^b | -6 ^b | -09 ^b | -12 ^b | -11 ^b | -7 ^b | -7 ^b | -08 ^b | -08 ^b | -06 ^b |

^z: values with the same letter are statistically same between columns (Tukey P≤0.05)

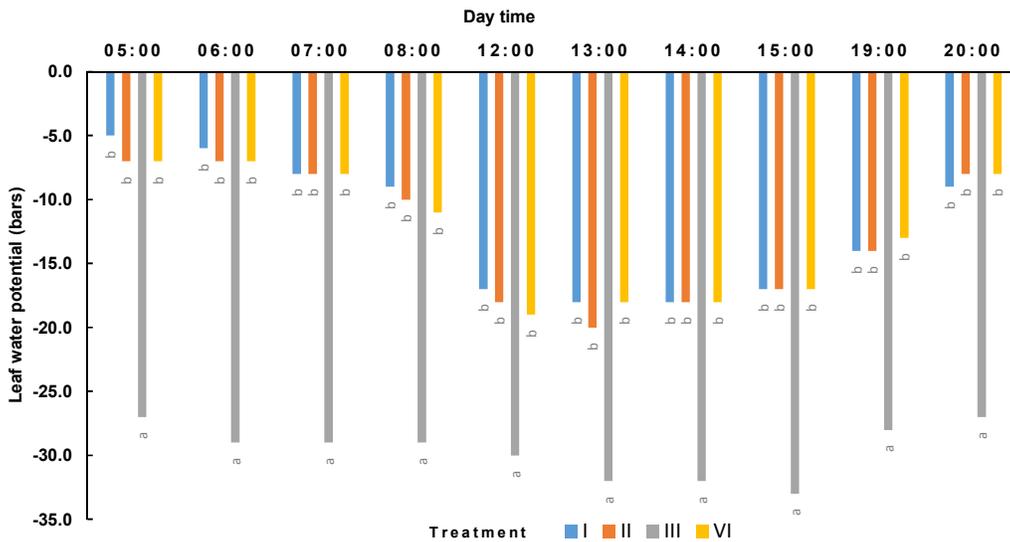


Fig. 1. Leaf water potential on 11, July, 2018 in apricot cv. “Royal” as affected by water stress
 Different letters indicate the statistically significant difference (Tukey P≤0.05)

irrigation was applied to the water stressed trees every 4-5 days. Goldhamer, et al. [10] suggested that periods of water stress very early in the season reduces the percentage of fruit bud differentiation in almond; interpreting then, that flower rate development is not appreciably affected by short periods of water stress later in the season as seen in this study.

An interesting observation was the presence in all treatments of double pistils, especially in treatments II (water stressed May 20- June 24) and V (water stressed Sept. 2- Oct. 7) which showed significant differences from the control (Table 4). In treatments I (water stressed April 15- May 20), III (water stressed June 24- July 29), IV (water stressed July 29 –Sept. 2) and control, a few double pistils were noticed but the number was small. Figs. 2 (A, C, E, and G) and 3A show buds from trees in treatment VI (control). Figs. 2 (B, D, F, and H) and 3B show flower buds with double pistils from treatment V.

At full bloom both pistils of the double-pistil flowers usually appeared to be about the same size and to hold equally prominent positions. Since the apricot flower is differentiated in the fruit bud during the season previous to bloom [11,12], the conditions responsible for forming double apricot flower pistils must have existed during the summer of 2018. The occurrence of flowers with double pistil can be a serious problem in apricot. This phenomenon is the result of a twin pistil formation at the time flower bud initiation is taking place [7]. Philip [13], working with sweet cherry in 1933, found mainly fruits with double pistils in the hot interior valleys of California where the summer temperatures were severe in 1932. In the coastal valleys with lower summer temperatures, no abnormal flowers were found and he concluded, it was probable that this abnormal development and the production of double and malformed fruits may be associated with climatic conditions, possibly high temperatures during the summer previous to

blossoming, particularly during the period of fruit bud formation. Tucker [14] later reported experiences in cherry made the same year in the Lewiston district of Idaho. The temperatures and fruit malformations were much less severe than in the interior valleys of California. The Napoleon cultivar in Idaho produced less than half the percentage of malformed fruits reported on that cultivar in California. Beppu et al. [15] reported that exposure of potted 'Satohnishiki' sweet cherry trees to temperatures of 35°C/25°C, day/night in Kagawa, southwestern Japan induced flowers with double pistil.

A: Control, Sept. 13. All floral organs had emerged but stamens and pistil had not begun to differentiate; x28. B: Treatment V, Sept.13. Approximately the same developmental stage as A with two pistils forming in the center; x28. C: Control, Oct. 4. The floral organs had enlarged somewhat, but no signs of differentiation of stamens; two pistils were present; x28. D: Treatment V, Oct. 4. The structure is much like that in C, including presence of two pistils; x28. E: Control, Nov. 13. All parts had lengthened as compared to those in C. The stigma was beginning to differentiate and the ovary had expanded slightly; pollen sacs had formed and the pollen was developing; x34. F: Treatment V, Dec. 1. Differentiation of anthers was almost complete, and locules were developing in both of the pistils; x34. G: Control, Jan. 9. The locule in the ovary had enlarged somewhat; x34. H: Treatment V, Jan. 9. The anthers had completed development; x34 (Fig. 2).

The conclusions drawn by these researchers concerning cherry doubling may not apply entirely to the results found in this experiment with apricots. Temperatures during the time when trees were subjected to water stress were compared with temperatures at that time for the previous year (2017) since the 2018 crop had practically no doubles. Temperatures in 2018 were higher during the period of treatment I (April 15-May 20) whereas in the other period of water stress, temperatures were not greatly different from those in 2017 (Table 5). Therefore, it appears improbable that double pistils were directly associated only with high temperature. Instead, they could be associated more with water stress during certain stages of bud development, especially during flower bud initiation and pistil differentiation, the stages of bud development during the water stress period in treatments II and V, respectively. Patten et al.

[16] found that peach trees subjected to water stress during the period of flower bud formation increased up to 21% the number of flowers with double pistil. This effect is also mentioned in cherry trees by Engin and Ünal [7]. Therefore, it is possible that the stage of flower bud differentiation is a target issue, in particular when pistil or twin pistil tissue differentiation is sensible to occur influenced by the environmental conditions as has been experienced by Beppu et al. [15] in cherry and by Goldhamer et al. [10] in almond.

Full bloom in treatment VI (control) occurred on Feb. 25, 2019. At that time most of the flower buds in treatments I, II and III were at the popcorn stage, whereas in treatments IV and V they were still in the redbud stage (Table 3). Full bloom in treatments I, II and III was on Feb. 27, only two days after full bloom in the control. This suggests that water stress conditions during the period when those treatments were under stress did not appreciably affect the time of bloom. In treatments IV and V some flowers had opened but most were at the popcorn stage by Feb. 27. The bulk of the flowers on these treatments reached full bloom on March 4, 2019. Probably water stress late in the previous summer and early autumn delayed the opening of the flowers in these treatments. The importance of water relations on flower bud differentiation on apricot was first reported by Brown [17]. Uriu [18] pointed out that the soil water content at the time of flower bud initiation would determine the response of tree to flower formation and development. In this study, it can be seen that treatments where trees were subjected to water stress at the initial stage of flower bud development, the rate of bud tissue development was slow when compared to control buds (Table 3). However, the time when full bloom reached on these trees, it was closely behind the control samples. It seems then that water stress present early in the growing season does not delay significantly the time of full bloom. This effect has also been reported by Dejampour et al. in apricot [19]. The treatments under water stress during late summer and early fall showed a seven days delay in full bloom when compared to the control. It is probably that this behavior reflects that the drought periods at that time have provoked a slow rate on flower bud parts differentiation as can be seen in Table 3. Albuquerque et al. [20] and Septar et al. [3] have experienced similar fruit buds behavior in apricot trees exposed to water and temperature adverse conditions.

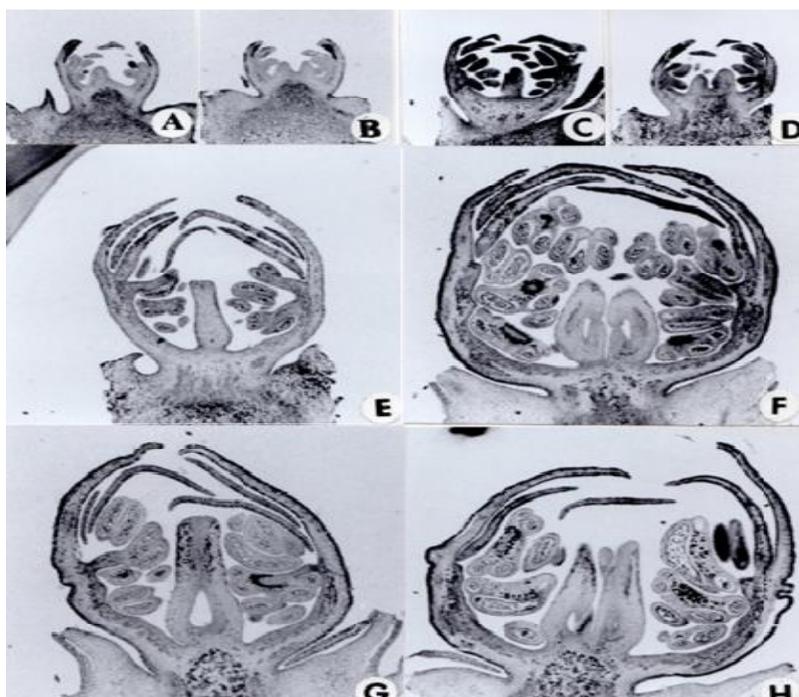


Fig. 2. Median longitudinal sections of apricot flower in buds illustrating their development of flower parts

Table 3. Stages of flower bud development in the “Royal” apricot from water stressed and control trees on different dates during 2018-2019

| Date | Treatment ^z | | | | | |
|-------------------------|---|-----|-----|-----|-----|-----|
| | I | II | III | IV | V | VI |
| 07/16/2018 | 1 | 1 | 1 | 1 | 1,2 | 1,2 |
| 08/3/2018 | 1 | 1 | 2 | 2 | 2 | 2 |
| 09/13/2018 | 2 | 1 | 2 | 2 | 3 | 3,4 |
| 10/4/2018 | 3 | 2,3 | 3 | 3 | 3 | 4 |
| 11/3/2018 | 3 | 3 | 3,4 | 4 | 4 | 5,6 |
| 12/1/2018 | 4 | 4 | 5 | 5 | 5 | 6 |
| 01/9/2018 | 5 | 4 | 5 | 5 | 6 | 7 |
| 02/22/2019 ^y | 8 | 8 | 8 | 5,6 | 6 | 8,9 |
| 02/25/2019 ^y | 8,9 | 8,9 | 8,9 | 8 | 8 | 10 |
| 02/27/2019 ^y | 10 | 10 | 10 | 8,9 | 8,9 | 10 |
| 03/4/2019 ^y | 10 | 10 | 10 | 10 | 10 | 10 |
| Stage of development | Description | | | | | |
| 0 | No evidence of differentiation | | | | | |
| 1 | Sepal and early petal initials evident | | | | | |
| 2 | Sepal and petal primordia more advanced than in stage 1; early stamen and pistil initials evident | | | | | |
| 3 | All floral parts readily distinguishable | | | | | |
| 4 | All floral parts larger, more advanced than in stage 3 | | | | | |
| 5 | Pistils with ovarian cavity well-formed | | | | | |
| 6 | Pistils larger, more advanced than in stage 5 | | | | | |
| 7 | Increased size of pistils | | | | | |
| 8 | Popcorn stage | | | | | |
| 9 | Open flowers | | | | | |
| 10 | Full bloom | | | | | |

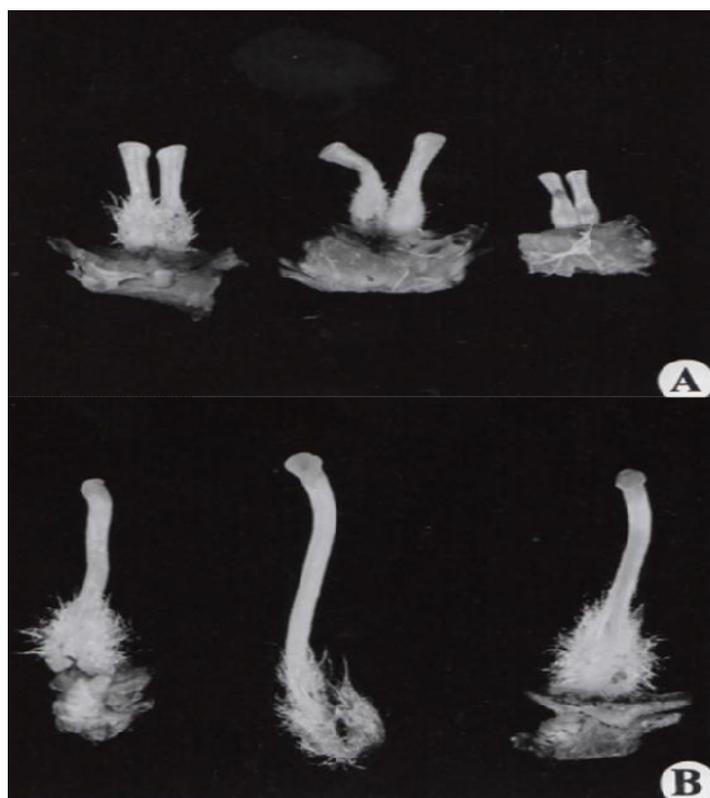
^y: Examination in the field on selected limbs;

^z: Evaluation on microscopic examination of 10 buds per treatment on each sampling date

Table 4. Effect of water stress on numbers of flower buds, good flowers, percent of flower drop and flowers with double pistils on apricot cv “Royal” in 2019

| Treatment | Water stressed In 2018 | Number of flower buds ^v Jan/26/2019 | Number of good flowers at full bloom | Percent of flower drop n.s | Percent of flowers with double pistil ^z |
|-----------|------------------------|--|--------------------------------------|----------------------------|--|
| I | April 15-May 20 | 4306 ^a | 2180 ^{wa} | 49 | 9 ^b |
| II | May 20-June 24 | 3308 ^a | 1790 ^{wa} | 45 | 15 ^b |
| III | June 24-July 29 | 3474 ^a | 1739 ^{wa} | 49 | 5 ^c |
| IV | July 29-Sept. 2 | 3321 ^a | 1575 ^{xb} | 53 | 2 ^c |
| V | Sept. 2-Oct 7 | 3914 ^a | 1957 ^{xa} | 50 | 20 ^a |
| VI | Control | 2924 ^b | 1529 ^{yb} | 49 | 6 ^c |

^{n.s} non significant; ^v mean 24 samples per treatment; ^w full bloom on Feb. 27, 2019; ^x full bloom on March 4, 2019; ^y full bloom on Feb. 25, 2019; ^z values with different letter are statistically significant between columns (Tukey $P \leq 0.05$)

**Fig. 3. “Royal” Apricot pistils in 2019**

A: Twin pistils in treatment V, collected on January, 26. B: Control pistils collected on February 22

Table 5. Maximum, minimum, and mean temperatures (°C) for 2017 and 2018 during the periods in which apricot trees were subjected to water stress

| Treatment | Temperature (°C) | | | | | | |
|-----------|------------------|---------|------|---------|------|------|------|
| | Water stress | Maximum | | Minimum | | Mean | |
| | | 2017 | 2018 | 2017 | 2018 | 2017 | 2018 |
| I | April 15-May 20 | 25 | 28 | 7 | 9 | 17 | 18 |
| II | May 20-June 24 | 31 | 31 | 11 | 12 | 21 | 22 |
| III | June 24-July 29 | 35 | 36 | 13 | 14 | 23 | 25 |
| IV | July 29-Sept. 2 | 35 | 33 | 13 | 12 | 24 | 22 |
| V | Sept. 2-Oct. 7 | 28 | 28 | 10 | 11 | 19 | 20 |

The number of flowers buds and good flowers present at full bloom was higher in most of water stressed apricot trees (Table 4). This effect has also been seen by Dejampour et al. [19] and by Septar et al. [3] in apricot and by Goldhamer et al. in almond trees [10]. The promotion of flower bud formation in deciduous fruit trees such as apricot and apple as seen in this study, has been related to a reduction in vegetative growth induced by water stress (Pérez-Pastor et al. [6]. It has been reported that this condition allows more carbohydrates and flowering promoting cytokinins flux to be translocated into the meristematic bud where both chemical components contribute to flower induction in that tissue [9,21]. One of the main effects of water stress in fruit trees is expected to be an increase in flower drop the following year [3,22]. Therefore, the degree of drop in the spring in this research was to be used to evaluate the detrimental effect of water stress applied at different periods in the previous summer. However, the counts showed no significant differences in flower drop among the water stressed treatments compared with the control (Table 4). Perhaps the water stress period at some time between April to October in those trees growing in containers was not long enough to induce flower drop the following spring [6,19] or the water stress could not be maintained sufficiently high and uniform throughout each of those periods to cause bud drop [3,20,22]. It seems that further studies on causes of 1) delay in flower bud development, 2) delay in bloom and 3) flower malformations in the apricot will probably furnish an opportunity to learn more about the phase of bud development at which water stress and other conditions affect the formation of flowers. Such a study gives promise of being important to the growers who are interested in both the time that flower development may be affected and how loss from malformations may be prevented.

4. CONCLUSIONS

Seven-year-old apricot trees growing in containers subjected to a 4- to 5-week period of water stress during the growing season, resulted on:

The water status of the leaves was severely affected to a level as low as -33 bars.

Leaf water potential in water stressed trees was constantly low through-out the entire day.

Water stressed early in the season provoked a delay in bud development during late summer and fall.

Water stress late in the season did not appreciably affect the rate of bud development. Full bloom was delayed when water stress was applied in late summer and fall.

Water stress, together with high temperatures, may have induced flowers with double pistils when they occurred during flower initiation (May – June) or pistil differentiation (July – September). Water stress for short periods of time from April through October did not induce flower drop significantly.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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