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Long-term effect of dry conditions and drought on fruit trees yield in dryland areas of Tunisia

M. Ghrab*, K. Gargouri* and M. Ben Mimoun**
*Laboratoire d'Amélioration de la Productivité de l'Olivier et des Arbres Fruitiers, Institut de l'Olivier, BP 1087, Sfax 3000, Tunisia
**Institut National Agronomique de Tunisie,
Av. Charles Nicole, 34, Cité Mahrajène, 1082 Tunis, Tunisia

SUMMARY – Research has been developed on tree species and genotypes presenting adaptive mechanisms to drought. Almond and pistachio were considered as very drought tolerant crops. The ability to endure high water deficits was related to efficiency in valorising marginal soils under conditions of high evaporative demand and chronic water shortages. In the arid regions of Tunisia, severe drought threatening the survival of the trees was frequent. Almond and pistachio productivity trees were investigated under limited water supply conditions. The yield of different cultivars was determined for several years as well as climatic data of the orchards. Important yearly fluctuations in rainfall were observed. The result revealed a relationship between these factors and yield. In fact a correlation was found between the amount of rainfall and yield. Thus autumnal rain seems to be an important physiological consideration for water relations in almond and pistachio grown in arid zones. Almond cultivars appeared to be more affected by cyclic severe drought.

Key words: Dryland, drought, almond, pistachio, cultivar, yield.

RESUME – *"Effet à long terme du déficit pluviométrique et de la sécheresse sur le rendement des arbres fruitiers dans les zones arides de Tunisie". La valorisation des zones marginales a eu recours à des espèces végétales capables de survivre et de produire sous conditions difficiles. En Tunisie, des espèces fruitières telles que l'amandier et le pistachier ont été largement plantées en raison de leur capacité d'adaptation. L'effet d'un déficit pluviométrique sur le rendement de plusieurs variétés de ces deux espèces a été évalué sur une longue période (plus de 10 ans). Durant la période d'étude, une fluctuation importante de la pluviométrie a été enregistrée avec une sécheresse cyclique qui s'est produite plus de trois fois. Sous ces conditions, les productions des variétés d'amandier et de pistachier se trouvent affectées. Les sécheresses sévères qui ont touché la zone ont affecté la survie de la plupart des variétés d'amandier. Toutefois, les variétés de pistachier ont montré une grande tolérance et un rétablissement dès que les conditions se sont améliorées pour donner des rendements satisfaisants.*

Mots-clés : *Régions arides, sécheresse, amandier, pistachier, variété, rendement.*

Introduction

Changes in seasonality may be one of the most difficult aspects of climate. Theses changes can have profound impacts on vegetative and crop success (Damour *et al*., 2007). In Mediterranean region, strongest seasonal climates were found with cool and wet winter and hot and dry summer. However, considerable special heterogeneity exists for both temperature and rainfall more specifically for season pattern of rainfall changes (Stevens *et al*., 2006). Under current water scarcity conditions, the limited available water should be used more efficiently (Bessembinder *et al*., 2005) and viable ways of crops and water management must be explored which may help to mitigate the impact of drought.

Drought is the most significant environmental stress in agriculture and many efforts have been made to improve crop productivity under water restriction (Cattivelli *et al*., 2008). Minimizing yield gap and increasing yield stability with different stress conditions are of strategic importance. In perennial cropping systems, almond (*Prunus dulcis*) and pistachio (*Pistacia vera*) are among the most important fruit trees in the world used to valorise dryland (Jacquy, 1973; El Gharbi *et al*., 1989). In Tunisia, theses species are almost grown in the Centre and South regions and often cultivated in rainfed under arid and semi arid conditions.

Under these conditions, yields were affected and trees showed strong tendency toward alternate bearing (Ghrab *et al.*, 2002, 2005). An experiment was achieved with theses two species to investigate their behaviour under dry conditions of Tunisia. This paper analyse the long-term effects of dry conditions on almond and pistachio cultivars.

Material and methods

The experiments were carried out at the experimental station "Taous" of Olive Tree Institute of Sfax in the South of Tunisia during 1972-2003. The region was characterized by Mediterranean climate with annual rainfall of 202 mm and a sandy soil. Two experimental orchards of almond and pistachio planted in 1969 were trained in rainfed conditions and gathering respectively 68 and 11 cultivars. Almond trees of 18 local cultivars and 50 foreign cultivars from USA, France, Italy and Spain were planted at 12 x 12 m apart and grafted on bitter almond. For pistachio, tree density was 14 x 14 m apart. The yield of the followed almond and pistachio cultivars was investigated in report to precipitations.

Results and discussion

During the period of the survey (1972-2003) the average of annual rainfall was of 202 mm. However a high yearly fluctuation was observed with extremes values of 68 and 593 mm. Moreover, cyclic severe droughts affected the study region (Fig. 1). Punctual rigorous rainfall deficits were observed during 1970/71 and 1977/78. Whereas, prolonged droughts were recorded during 1981-83, 1991-95 and 2000-02 periods. Thus, 21 years presented rainfall deficit on a total of 32 years of survey.

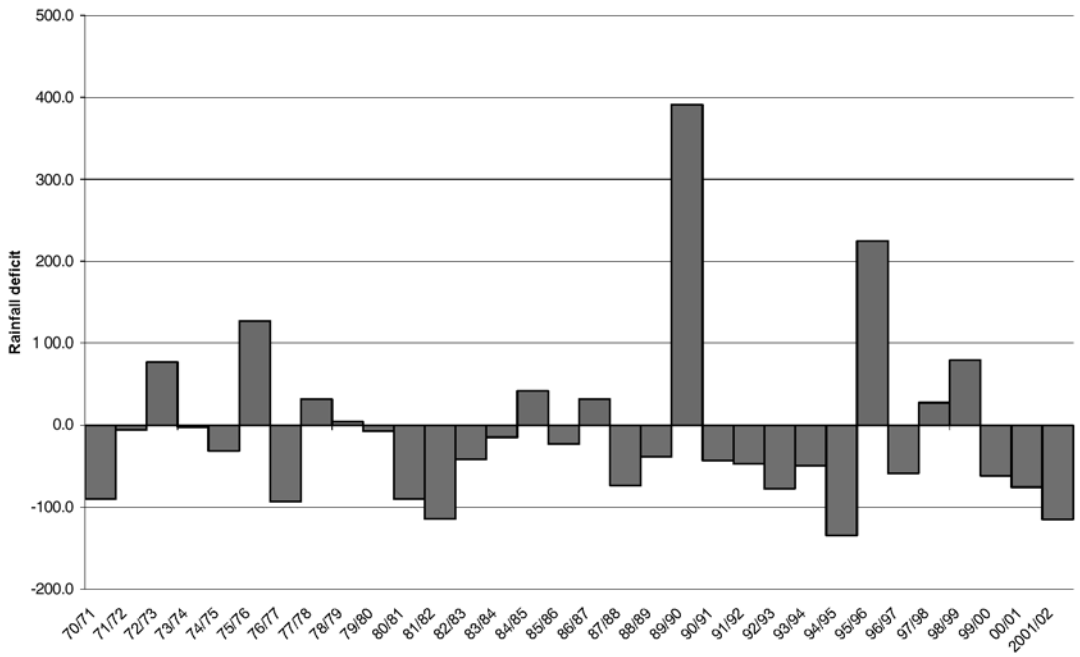

Fig. 1. Rainfall deficit compared to average determined for the period of study (1972-2003).

Almond is characterized as drought resistant (De Herralde *et al.*, 2003; Rouhi *et al.*, 2007). It is able to withstand frequent periods of low soil moisture accompanied by high evaporative demand and high temperature during growing season. Almond production and survive were affected by the occurrence of cyclic and severe droughts. In fact, 18% of cultivars did not survive after two successive drought periods, i.e. 1981-83 and 1986-87. On the other hand, local cultivars gave low productions with a total yield ranged between 44 and 199 kg/tree in 32 years. A width range of total production was observed for foreign cultivars. It was comprised between 3.5 and 274 kg/tree. For all cultivars, yearly yield variation was observed and was related in part to rainfall irregularity (Figs. 2 and 3). It was explained sometimes by the fact that trees have been severely pruned after important production or during drought.

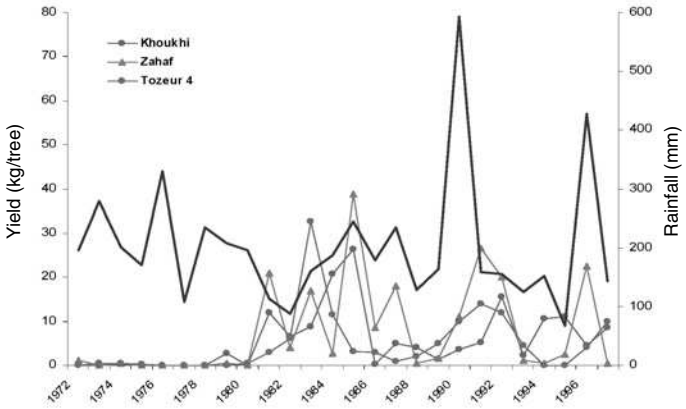

Fig. 2. Yield pattern of local almond cultivars with rainfall changes.

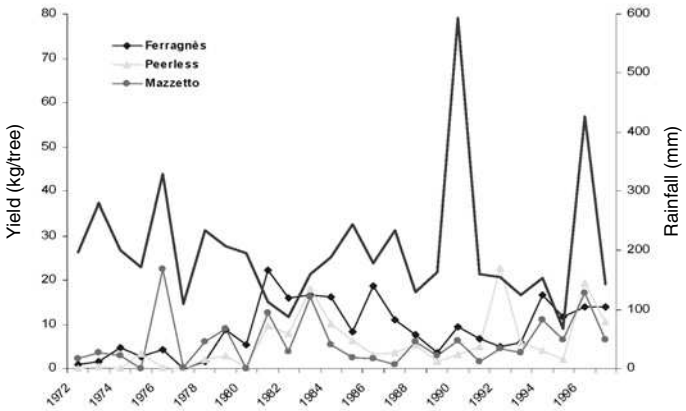

Fig. 3. Yield pattern of foreign almond cultivars with rainfall changes.

Some cultivars seemed to be adapted to the semi-arid and arid weather of Tunisia and water scarcity. These cultivars were tolerant to successive drought periods and performed good yields such as Khoukhi, Mazzetto, Fasciuneddu, and Ferragnes. The yield of some of them was strongly correlated with the amount of rainfall of a year before production and quasi independent from the rainfall of the producing year. It was the case especially of French cultivars. Then autumnal rainfall had a great benefit effect on yield which seemed to be an important physiological trait for water relations in almond grown under water limitation. Late blooming cultivars, including Ferragnes and Ferraduel were of considerable interest because they escape to the danger of frost injury, and they expressed good performances under semi arid conditions (Mahhou and Dennis, 1992; Grasselly and Duval, 1997; Ghrab *et al*., 2002). Blooming date, temperature and pollination can affect almond cultivars production. In arid zones, early bloom can be desirable because in this case the initial fruit development could be happen before the period of severe drought (Socias i Company *et al*., 1997). Local cultivars are early blooming ones and their yield is less affected by rainfall variation (Fig. 2). However, their first production is delayed in comparison with other cultivars (Fig. 3).

Yearly yield variations were observed for different cultivars of pistachio (Fig. 4). However, an enhancement of nut production was recorded along the experimental period. Yield was more affected with drought duration which was pronounced in 1995.

The yield of pistachio cultivars during the period of study varied annually (Fig. 4). These cultivars showed an important alternate bearing. Depending on the year, the yield was ranged between 31 kg/tree and no production reflecting the variability and the bearing characteristics of pistachio (Johnson and Weinbaum, 1987). On the other hand, during some successive years, low productions were recorded out of "On" and "Off" year's cycle. This raises the fact that the yield variation is closely related to annual rainfall in addition to bearing cycle. The same tendency was observed for the yield of two pistachio

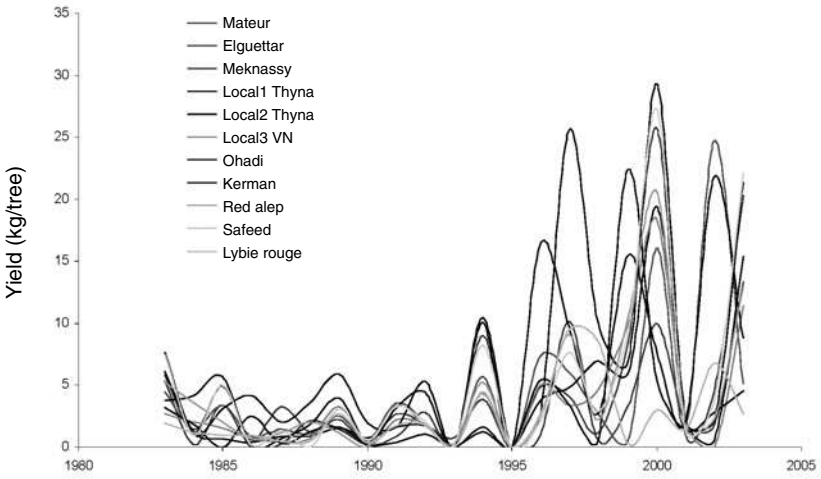

Fig. 4. Yield of pistachio cultivars recorded during 1983-2003.

cultivars in the region of Sfax (Ghrab *et al*., 2005). The water is a limiting factor in our conditions, thus low production levels were observed. However, successive drought periods didn't affect pistachio survival. The observed yield for the studied cultivars was weak compared to results shown by other authors and in different sites of experimentation (Oukabli, 1995; Maggs, 1973; Vargas *et al*., 1997; Rouskas, 2002) which can be related to water shortage, high evaporative demand and frequent drought periods.

Conclusion

In this study the responses of yields of two perennial crops to changes in precipitation were analyzed. In order to evaluate the potential impact of these climate changes on perennial crop production, we considered two valuable perennial food crops in Tunisia: almond and pistachio. Each of these crops is typically planted only once every 25 or more years. Therefore, adoption of new varieties occurs much more slowly than annual crops. Results obtained revealed differential species tolerance level to successive drought periods. Pistachio yield presented similar pattern along years as precipitation. However, almond cultivars had variable behaviour and some of them were lost in consequence of successive drought periods. Data obtained for a perennial cropping system with long period of survey in relation to climate change have a great value for the assessments of yield responses to projected changes in temperature and precipitations (Lobell *et al*., 2006).

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