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# Pistachio industry in Tunisia: Opportunities of improvement

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**Abstract.** Pistachio is an important nut crop well extended in the centre and the south of Tunisia. An important increase of growing area occurred during the last forty years using almost only one variety 'Mateur', selected in the North of the country. However, the productivity is still very weak under low annual precipitation, warm climate and deficient cultural practices. These limiting factors for pistachio yield increased also the alternate bearing phenomena. Consequently, efforts are being made to improve the productivity of pistachio. The effect of main endogenous and environmental factors and their interactions on yield and alternate bearing was analyzed. The chilling and heat requirement of the main cultivar 'Mateur' were estimated to determine the best growing zone for its cultivation. This paper presents the main endogenous and environmental factors associated to alternate bearing and discuss possible approaches to be used to improve productivity and reduce alternate bearing of pistachio.

**Keywords.** *Pistacia vera* – Warm climate – Productivity – Alternate bearing – Chilling requirement.

## **Industrie du pistachier en Tunisie : Opportunités d'amélioration de la productivité**

**Résumé.** Le pistachier est une culture très importante, répartie essentiellement au centre et au sud de la Tunisie. Au cours des quarante dernières années, la superficie a subi une nette augmentation avec une nette dominance de la variété 'Mateur' qui a été sélectionnée au nord du pays. Cependant, la productivité demeure toujours très faible due aux basses précipitations annuelles, à un climat relativement chaud et aux déficiences des techniques culturales. Ces facteurs, limitant pour le rendement, ont aussi accentué le phénomène d'alternance. Des efforts sont fournis pour l'amélioration de la productivité à travers l'étude de l'effet des principaux facteurs endogènes et exogènes et de leurs interactions sur le rendement et l'alternance de production. Les besoins en froid et en chaleur de la principale variété cultivée 'Mateur' ont été estimés pour déterminer la meilleure zone de croissance pour sa culture. Ce papier présente les principaux facteurs endogènes et exogènes et associés à l'alternance de la production et discute les approches qui pourraient être utilisées pour améliorer la productivité et minimiser le phénomène d'alternance chez le pistachier.

**Mots-clés.** *Pistacia atlantica* – Hiver doux – Productivité – Alternance – Besoin en froid.

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## **I – Introduction**

Pistachio (*Pistacia vera* L.) is a dioecious species, widely cultivated in the Mediterranean basin. Pistachio is wide spread in Tunisian arid land, and is considered as the most interesting drought tolerant species. During the period of the seventies, some development projects, supported by international organizations like FAO, were carried out. The growing area, localized mainly in the center and the south of the country, has been extended from less than 50 ha sixty years ago to more than 35,000 ha nowadays. During the period between 1985 and 1995, many technical problems related to crop multiplication were resolved and the pistachio production has increased greatly. This is probably due to the entering of young plantations to productive cycle and the increased attention given to orchard management (pruning, pollination technique, fertilization...). Despite these efforts and the relatively large land occupation, productivity was low and highly variable under harmful climatic conditions and rainfall scarcity with an average yield of 2.5 kg tree<sup>-1</sup> (Ghrab *et al.*, 2008).

The female trees strongly alternate bears (Wolpert and Ferguson, 1990). The fundamental hypothesis underlying alternate bearing is that yield in the current year affects yield in the following year (Rosenstock *et al.*, 2010). Two competing hypotheses for the irregular production are suggested: endogenous and environmental factors. Endogenous factors suggest that reproduction is carbon-limited and the individual plant alternates carbohydrate allocation between reproductive and vegetative structures (Nzima *et al.*, 1997; Spann *et al.*, 2008). In contrast, environmental factor hypothesis contends that annual variability in nut production is produced by the climatic variations of precipitation and temperature (Elloumi *et al.*, 2013). The objective of this work was to present the main endogenous and environmental factors and their interactions associated to alternate bearing and to review approaches that may be used to attenuate this phenomenon.

## II – Methodology

The responses of pistachio female trees cv. 'Mateur' to severe climatic conditions were investigated in the centre of Tunisia (34°94', 10°60'). Nut yield was monitored for a long period and related to precipitation and winter chill. Winter chill was estimated as chilling hours (CH) according to Crossa-Raynaud model (Elloumi *et al.*, 2013).

Under warm climate, fruit trees are affected by lack of chilling which amplifies the alternate bearing. An experiment was conducted to mitigate the harmful effect of warm winter on flowering and fruiting of pistachio trees. The hydrogen cyanamide (Dormex) was applied at concentrations of 2 and 4% and sprayed 40 days before the estimated bud break. The effect of these applications on bud break, shoot growth and yield of pistachio trees was evaluated. The main endogenous factors involved in pistachio alternate bearing were studied. Disbudding treatments consisting of flower buds removal were applied. In reference to untreated trees as control (T0), three treatments were applied as (i) removal of all flower buds for one year (T1); (ii) removal of all flower buds for two successive years (T2); and (iii) removal of 50% of flower buds for each year (T3). The storage and the mobilization of starch, dry matter and nutrients were evaluated in fruiting and non-fruiting branches.

## III – Results and discussion

Flowering and yield of pistachio trees cv. 'Mateur' were analyzed under semi-arid climate during 1997-2014. This long period was characterized by strongly variable annual winter chill accumulation and precipitation (Table 1). Yield correlated poorly with precipitation and showed a moderate alternate bearing index of 0.63. However, flowering and nut yield of pistachio trees was a function of chill accumulation computed as chilling hours (CH) as previously reported (Elloumi *et al.*, 2013). 'Mateur' cultivar was suggested to have low chilling requirements. Previous reports indicated that this cultivar vegetated and grew under warmer conditions in the south of Tunisia (Jacquy, 1973). However, Salhi *et al.* (2014) found that this cultivar had a minimum of 600 CH of chilling requirement. The obtained result explains in part the low productivity of this cultivar in the centre and the south of Tunisia, where the average of chilling accumulation is less than 300 CH.

With the climate change, warm winters are projected to become more frequent in Tunisia. The lack of chilling resulted in abnormal patterns of bud-break and development of pistachio trees cv. 'Mateur' with delayed flowering date and an extended flowering period. For this reason, hydrogen cyanamide was evaluated on pistachio trees to compensate for the lack of chilling. Results showed that hydrogen cyanamide treatments at 2-4% advanced floral bud break and the flowering period and increased the percentage of floral bud break compared to the untreated control trees (Ghrab and Ben Mimoun, 2013; Elloumi *et al.*, 2013). If it is economically feasible, winter oil application could be a solution to improve pistachio production in low winter chill areas. This practice is commonly used in most fruit tree orchards but growers need a prediction of chill accumulation to decide whether to apply oil or not.

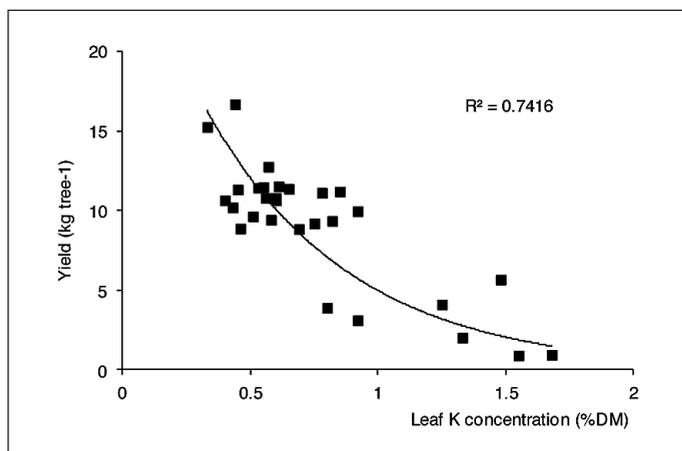
**Table 1. Winter chill, precipitation, flowering date and yield monitored during the experimental period (1997-2014)**

	Winter chill (CH)	Precipitation (mm)	Flowering date (DOY <sup>†</sup> )	Yield (kg tree <sup>-1</sup> )	Flowering vs CH (r <sup>††</sup> )	Yield vs CH (r)
Min	72	79	84	0.0	–	–
Max	346	405	118	26.4	–	–
Mean	221	202	99	6.5	0.77	0.65

<sup>†</sup> DOY: day of year; <sup>††</sup> r: correlation coefficient.

Pistachio trees are an assemblage of carbohydrate sinks including fruit, stems, leaves and floral buds. In arid zone, under scarce rainfall conditions, the processes of partitioning among these different organs are of interest. The balance of vegetative and reproductive growth has important consequences for tree morphology and productivity. Results showed that once pistachio nuts start developing in July, they become major sinks that draw resources from individual vegetative organs (Elloumi *et al.*, 2014a; Elloumi *et al.*, 2014b). Disbudded trees permitted an estimation of vegetative growth potential of cv. 'Mateur' pistachio tree. These findings revealed the importance of individual one-year-old wood in source-sink relationships and in the regulation of the carbohydrates distribution within isolated branches. Pistachio appears to have a specific pattern of annual carbohydrate storage and mobilization. In fact, results showed a mobilization of carbohydrates from current-season and one-year old stem wood of On-trees during kernel fill period that corresponded with the period of flower bud abscission. Thus the alternate bearing of Mateur pistachio cultivar may be associated to mid-season mobilization of stored carbohydrates in current season stems.

Besides, alternate bearing influences directly the nitrogen, phosphorus, and potassium dynamics of the pistachio isolated branches (Elloumi *et al.*, 2014c). In Off year, different sink organs store an important quantity of macronutrients, and mobilize it during the subsequent On-year to support initial spring growth. However, mobilized quantity does not seem to be enough to satisfy the nutrients demand of the tree. Macronutrients, accumulate in the same season must be also mobilized. Leaf K concentration explained 75% of yield variation (Fig. 1). Leaf K concentration decreased with the increase of nut production.



**Fig. 1. Relationship nut yield (kg tree<sup>-1</sup>) vs leaf K concentrations (%DM) determined in late July.**

Yearly removal of 50% of flower buds showed a beneficial result. It leads to an earlier and regular accumulation of dry matter and starch in fruiting and non-fruiting branches. It induces less variation of leaf K concentrations with regular nut yield and a significant improvement of the cumulated production compared to bi-annual On-Off cycle. The induced better and stable inter-annual tree K status could be helpful for applying adequate potassium fertilization to improve the nutritional status of pistachio trees. Moreover, under rain-fed conditions, annual hand-pruning could be used to prevent or to minimize alternate bearing of pistachios.

## IV – Conclusions

According to this study, the productivity of pistachio may be improved and alternate bearing may be reduced in dry and warm area Tunisian climate. Results showed that: (i) the annual pruning could be applied to improve the tree carbon status, to regularize the nut production and to significantly increase the cumulated production; (ii) the application of hydrogen cyanamide could be used to improve pistachio production in low winter chill regions. It will be interesting to consider the important genetic diversity of pistachio species to mitigate the harmful effect of environmental factors and to valorise tolerant wild species as rootstocks.

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