Available online at www.elixirpublishers.com (Elixir International Journal)

Agriculture

Elixir Agriculture 96 (2016) 41450-41454

ISSN: 2229-712X

Agro-ecological requirements for growing pistachio trees: A Literature Review

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ARTICLE INFO

Article history:

Received: 23 May 2016;

Received in revised form: 29 June 2016;

Accepted: 2 July 2016;

Keywords

Arid climates,
Land suitability,
Land use requirements,
Pistachio Vera,
Crop yield.

ABSTRACT

Pistachio is one of the most important export and strategic agricultural product in the word and comprehensive study on its agro-ecological requirements can lead to find out the suitable areas for producing pistachio as well as addressing the best management practices to achieve the sustainability. This paper tries to review agro-ecological requirements (climate, soil and site) for pistachio after describing the role and the limitation levels of the climatic, landscape and soil properties that influencing on the yield and quality of the pistachio trees and their nuts, respectively.

Introduction

Pistachio (*Pistacia Vera*) which is a sub-tropical plant belongs to the Anacardiaceae family, is one of the most important product in Middle Eastern (e.g. Iran, Turkey, Syria, and Greece), some European (e.g. Italy) and American (e.g. U.S) countries (Ozden and Alayunt, 2006). It covers an area about more than 5000 km2 of the world surface with average yield of 1.3 ton/ha (Janick and Paull, 2008). Although many studies have been conducted to determine the role of different soil nutrients (Hosseinifard et al., 2010; Shahriaripour et al., 2010; Shahriaripour et al., 2011), water stress (Sepaskhah and Karimi-Goghari, 2005; Saadatmand et al., 2007) and individual land properties on pistachio yield and ecology (Goldhamer, 2005; Ferguson et al., 2005a; Ferguson et al., 2005b), few attempts have been done to prepare all required agro-ecological needs for pistachio growth. In the other hand, the high tolerance of pistachio tree to the soil moisture tension and salinity (Ferguson, 2003; Sanden et al., 2004; Goldhamer, 2005; Ferguson et al., 2005a; Ferguson et al., 2005b) and the economic importance of its yield cause growing of this crop to be spread in many arid and semi-arid lands all over the world. According to the existence of various soil limitations like high amounts of soluble salts, gypsum and lime in arid and semi-arid lands (Fanning and Fanning, 1989; Schaetzl and Anderson, 2005; Buol et al., 2011) which increase the probability of land degradation when these lands being irrigated, the need for knowing accurate land requirements and specifying the limitation levels of each land characteristic in respect to the expected pistachio yield is increasingly highlighted nowadays. Thus, the aims of this paper are 1) to compile the most effective land qualities and characteristics on pistachio trees growth and yield, 2) to propose a rational basis for assessing the land suitability for pistachio to both selecting the best areas suitable for growing pistachio orchards and suggesting the optimum management practices to improve the pistachio production in currently planted regions.

1. The role of the climatic factors on pistachio yield

Climatic evaluation for agricultural purposes, by matching the climatic conditions of a certain area with the climatic requirements of desired crops, is an essential part of land suitability studies (Dent and Young, 1981; De la Rosa et al., 2004). Assessment of the climatic conditions prior to perform a project may decrease the occurrence of unfavorable events. Following climatic properties are necessary to be considered through land suitability evaluation for pistachio.

1.1. Precipitation

Although pistachio trees can grow and survive in a wide range of soil moisture regimes (Goldhamer, 2005) but optimum production and the high quality nuts are only reached under suitable soil water contents (Sepaskhah and Karimi-Goghari, 2005; Saadatmand et al., 2007). Pistachio trees are known as drought tolerant plants that are able to survive and even produce fairly yield with very little water (Ferguson et al., 2002; Ferguson, 2003; Sanden et al., 2004; Goldhamer, 2005; Ferguson et al., 2005a; Ferguson et al., 2005b). Actually, their roots may grow up to depth 2.5 m to reach the moist soil layers during dry seasons (Goldhamer, 2005). Furthermore, with the extreme drought when available soil water content declines below the permanent wilting point, roots may completely stop their activities for 4 to 5 weeks in all soil layers (Spiegel- Roy et al., 1977; Kanber et al., 1993). Despite of being drought tolerant, pistachio trees require adequate water for optimal performance (Goldhamer, 2005; Ferguson et al., 2005a; Ferguson et al., 2005b). In the other hand, high humidity or poor to very poorly drained soils that lead to prolonged wet conditions during the growing season are not accepted conditions for pistachio (Goldhamer, 2005). An annual rainfall of at least 300 to 450 mm has been reported as the optimum amount of precipitation for this tree (Goldhamer, 2005). Pistachio trees are not generally irrigated in semi-arid regions like Syria and Turkey, but in Iran and USA, all the trees are irrigated (Goldhamer, 2005).

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In the both cases, consideration of pistachio water requirement is in high importance for the land suitability evaluation of pistachio.

1.2. Chilling requirement

A minimum period of low temperatures which is required by pistachio trees to their fruit set be successful called as the chilling requirement (Beede et al., 2005). The ranges of chilling requirement for pistachio trees are between 500 to 1000 cumulative hours below 7.2 °C depending on the trees' age, location and even cultivars (Küden et al., 1994; Beede et al., 2005). If the climate at the selected region does not fulfill optimal accumulation of chilling hours, yields will be negatively affected (Küden et al., 1994). Some researchers have reported inadequate cumulative chilling hours as a constant problem to produce pistachio in Kerman provinces during considered years (Javanshah et al., 2005). Elevation above the sea level is one of the main factors to receive enough chilling hours for pistachio. The elevations between 1000 to 3000 m above sea level are suitable for regions with mild climates (Faust, 1989). Another important factor effects on the chilling requirement for pistachio is the latitude of the allocated area. The less the latitude of that region is, the more elevations will be needed. In areas with lower latitudes, trees do not go through complete dormancy (Faust, 1989). Furthermore, the occurrence of shadow or foggy weathers causes the dormancy of the blossoms to break sooner, especially blossoms of plants with higher chilling requirement. It is probable that in shadowy or foggy weathers, the chilling requirement is fulfilled better because of the lower temperature (Erez, 2000).

1.3. Radiation

Radiation influences, together with temperature, on the rate of photosynthesis. The photosynthesis process provides plants with assimilated substances that are necessary for its growth (Sys et al., 1991). All plants, however, do not need sunshine to the same extent. Some of them require minimum and some need maximum rates of sunshine. In terms of sensitivity to sunshine, pistachio is categorized as a sun plant (Javanshah et al., 2005).

1.4. Temperature

Temperature generally determines the rate of plant growth (Sys et al., 1991). Plants are different in the optimum ranges of temperature they tolerant to various winter and summer air temperatures as well. Cold winters and hot dry summers with 2200 to 2800 heat units are required by pistachio (Ferguson et al., 2005a; Ferguson et al., 2005b). However, spring frost can kill flowers and young leaves. Although pistachio can easily tolerate the temperature as low as -20 °C in winter and as high as about 45 °C in summer (Javanshah et al., 2005), both extreme (low and high) temperatures, and low annual rainfalls, were considered as the two major constraints to pistachio growth in Turkey (Sykes, 1975). The optimum temperature for pistachio has been reported between 25 and 35 °C (Ferguson, 2003; Ferguson et al., 2005a; Ferguson et al., 2005b).

2. The role of landscape and soil factors on pistachio yield

Landscape and soil are the other main parameters influencing on agricultural land utilization types. Slope, drainage and flooding play important roles on success or failure of a specific land uses.

Slope determines directly the irrigation system (i.e. surface or sprinkler) and land management practices (i.e. mechanized or traditional) to be applied in desired land utilization types (Sys et al., 1991). For instance, the surface and sprinkler irrigation systems are not applicable in slopes more than 6 to 8 and 25 percent, respectively (Dent and Young, 1981; Sys et al., 1991; Soil Survey Staff, 1993). Moreover, the use of machinery to manage agricultural land uses is not possible in slopes more than 12 percent without land tracing because of the difficulty of tillage practices (Dent and Young, 1981; Sys et al., 1991; Soil Survey Staff, 1993). It also indirectly effects on land properties like vegetation, air temperature and depth to water table (Buol et al., 2011).

Good and perfect soil drainage classes tougher with the deep water table (i.e. locating deeper than 1.5 m from the soil surface) are essential land qualities for almost all perennial plants to reach the optimum yield with high quality (Dent and Young, 1981; Sys et al., 1985; Sys et al., 1991; Soil Survey Staff, 1993). Flooding is also one of the land qualities associated to land form that certifies the consistency of the crop planted in a certain land and the settled infrastructures instruments (Sys et al., 1985).

Although various plant types show different tolerance to characteristics related to the landscape, many researchers (Storie, 1933; Sys and Verheye, 1974; Dent and Young, 1981; Sys et al., 1985; Sys et al., 1991; Soil Survey Staff, 1993) have suggested the same limitation levels for most of the fruit trees in respect to the impact of the landscape factors. These limitations have similar effects on the growth and management of pistachio trees as well.

Among soil characteristics, the percentage of coarse fragments has similar effect on crop production and farm management in the most of the fruit trees like pistachio trees since the coarse fragments make tillage problems and decrease the water and nutrient retention capacity (Storie, 1933; Sys and Verheye, 1974; Dent and Young, 1981; Sys et al., 1985; Sys et al., 1991; Soil Survey Staff, 1993). Hence, no specific limitation level is necessary to be considered for assessing the influence of coarse fragments on the pistachio yield. The other important soil characteristics for pistachio production, has been described as follow.

2.1. Soil texture

Soil texture is one of the most important factors to determine land suitability for almost all crops (Storie, 1933; Sys and Verheye, 1974; Dent and Young, 1981; Sys et al., 1985; Sys et al., 1991; Soil Survey Staff, 1993). This soil property influences on availability of water and nutrient in soil as well as soil management practices. Fine texture soils are often preferred for allocating to agricultural lands because of their high cation exchange and water holding capacity (Brady and Weil, 2007). However, these soils encounter generally with the decrease in infiltration of water into the soil. In severe conditions water ponding occurs around the roots and causes aeration problems for plants (Hillel, 1998, 2003). Moreover, high water holding capacity in these soils increases the probability of fungal diseases invasion to the pistachio roots (Jaime-Garcia and Cotty, 2006). Another problem in soils with heavy texture is the volatilization of the N-fertilizers (Power and Prasad, 1997; Havlin et al., 2005). High clay contents as a major limiting factor in soil of the pistachio orchards in some parts of Kerman province, south east Iran have reported by some researchers (Hosseinifard et al., 2005; Hosseinifard et al., 2010). In the other hand, the low cation exchange and water holding capacity in coarse texture soils are the main problems of such soils that lead to leaching of essential nutrients as well as drought stress (Brady and Weil, 2007). Nevertheless, different soil textures are required by various plants. Pistachio trees like any other crops can survive in wide ranges of soil texture (Ferguson et al., 2002; Ferguson, 2003; Goldhamer, 2005; Ferguson et al., 2005a; Ferguson et al., 2005b). However, sandy loam is preferred by

them for high quality yield production (Ferguson et al., 2002; Ferguson, 2003; Goldhamer, 2005; Ferguson et al., 2005a; Ferguson et al., 2005b).

2.2. Soil salinity and sodicity

Salinity is mainly considered as an important soil limitation because of its inverse effects on the plant growth and yield quality. Such problems occur as results of the soil osmotic pressure induced water stress and specific ion toxicity that endangered the plants life (Zhu, 2001; Lee et al., 2004; Kao et al., 2006). Despite pistachio is a common crop of arid and semi-arid regions with saline soils, many researchers have been illustrated that salt stress has an inhibiting effect on its growth and development because of the reduction in photosynthesis, respiration, protein synthesis and consequently decrease of biomass production especially in sensitive species (Boyer, 1982; McKell, 1994; Ungar, 1996; Khan et al., 2000a, 2000b; Pal et al., 2004; Mehari et al., 2005). Pistachio trees, however, are able to tolerate higher amounts of soil salinity than the other similar fruit trees. As laboratory and farmlands researches (Ferguson, 2003; Sanden et al., 2004) have been shown, pistachio trees can be irrigated by water with 8 dS/m electrical conductivity without any remarkable decrease in the yield. Moreover, Sanden et al. (2004) have pointed out that soil electrical conductivities up to 6 dS/m exert no limitation to the pistachio growth, but raising the soil electrical conductivity to 8 dS/m declines about 50 percent of the pistachio yield.

Beside the soil salinity, high amounts of sodium ions in soil solution that is lead to high exchangeable sodium percentage (ESP) or sodium adsorption ratio (SAR) cause soil infiltration problems because of the destroying the soil structure (Ferguson et al., 2005a; Ferguson et al., 2005b). Although many literatures (Soil Survey Staff, 1993; Brady and Weil, 2007; Buol et al., 2011) has considered 15 percent as marginal value for ESP in which soil structural deterioration and sodium toxicity start damaging the plants. Fregusen et al. (2005a) reported ESP up to 25 percent as non-limiting level for pistachio trees. They also stated that ESP more than 45 percent is not suitable for these trees. High amounts of SAR in soil have been reported by Hosseinifard et al. (2005) as a main limiting factor on pistachio growth in Kerman province, south east Iran.

2.3. Calcium carbonate and gypsum status

The effect of calcium carbonate on pistachio yield like other crops depends on both the amount and size of lime in soil (Sys et al., 1991). Generally, presence of lime in soils of arid and semi-arid regions, especially in particles less than 20 microns, develops structural consistency of these soils that is very useful factor in air and water movement into the soil (Verheye and Boyadgiev, 1997). High concentrations of soil calcium carbonate particularly in very fine fractions, however, increase the possibility of lime-induced nutrient deficiency (Ellis and Foth, 1996; Power and Prasad, 1997; Havlin et al., 2005). Furthermore, the high amounts of lime in soils have been illustrated to change the physical properties of soils through irrigation and make them impermeable to the roots (Beek and Bennema, 1974; Sys et al., 1991).

Gypsum is more soluble than lime (more than 100 times), hence it has more effects on soil properties in fewer concentrations than calcium carbonate. It is evident that calcium ions release from soil gypsum concentrations less than 2 percent could ameliorate the soil structure and provides calcium requirements of many common plants as well as pistachio (Mashali, 1996). Van Alphen and de los Rios Romero (1971) pointed out that up to 2 percent gypsum in the soil is fair for plant growth, between 2 and 25 percent has little or no adverse effect if exists in powdery form, but more than 25 percent can reduce yields, substantially. Indeed, the increased concentrations of gypsum in soil more than 5 percent, decreases the water holding capacity and its movement in soils to the extent that a layer in soil with more than 25 percent gypsum is considered as an impermeable layer for roots (Hesse, 1976; Verheye and Boyadgiev, 1997). Generally, low gypsum contents present in pistachio orchard which are frequently irrigated for long period of times, but Hosseinifard et al. (2005) observed gypsum as one of the limiting factors in some pistachio orchards in Kerman province, south east Iran.

2.4. Soil pH

Soil pH is one of the most important factors to assess the fertility quality of soils in the arid and semi-arid regions (Sys et al., 1991; Verdoodt and Van Ranst, 2003). It influences on solubility of the elements in soil, and also soil microbial processes (Brady and Weil, 2007). Therefore, soil pH has a significant effect on nutrient availability. Higher soil pH than neutral conditions, greatly limits the solubility of micronutrients (i.e. Zn, Cu, Mn, Fe), while acidic soil pH can lead to deficiencies of P or Ca and toxicities of Al, Fe or Mn (Ellis and Foth, 1996; Power and Prasad, 1997; Havlin et al., 2005). The range of 6.5 to 7.5 is reported by many researchers as the best soil pH for almost all plants including pistachio (Ellis and Foth, 1996; Power and Prasad, 1997; Havlin et al., 2005; Brady and Weil, 2007).

2.5. Organic carbon

Soil organic carbon content is often a good criterion for intrinsically soil fertility together with cation exchange capacity (Beek and Bennema, 1974; Sys and Verheye, 1974). Sys et al. (1991) state that this parameter is particularly important for appraisal of soil fertility in highly weathered tropical soils, with low activity clays where the organic carbon is the only source for plant nutrients. They also suggested that it is not necessary to evaluate soil characteristics such as organic carbon content in the arid regions while clay activity rate usually exceeds the plant requirement for nutrients; thus, only the assessment of soil pH would be sufficient for evaluation of the soil fertility.

Conclusions

The absence of the comprehensive agro-ecological requirements for pistachio has been the most challenging issue to assess the land suitability for pistachio as a basis for allocating the best sites for this tree as well as planning the proper management practices to sustain the pistachio production, in spite of the numerous studies about the effects of land properties on the pistachio growth. The aims of this study was to open a new horizon to the land suitability studies and settle a useful step towards the site-specific and consequently, sustainable management of lands under pistachio cultivation. This study tried to achieve these goals by the means of compiling the effective land characteristics on pistachio trees growth as well as determining the limitation levels of those properties on yield and quality of pistachio nut.

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