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Investigation of characteristics and rating of saline-sodic soils and effect of important parameters on pistachio yield in Kerman province

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Abstract. Kerman Province, located in southeastern Iran, is the global center of pistachio production. Excessive development of pistachio cultivation over the province due to use of land with low or insufficient potentials, resulting in reduced yield. The main objective of this study is defining the characteristics of saline and alkaline soils and their effect on pistachio yield. For this purpose, 88 orchards were selected in important pistachio plain with diversity in soil and crop, then drilling and sampling of a profile was done at any point and questionnaires were prepared for the functional management. In this study, regression analyses were used to study the effects of different land characteristics on the yield of pistachios. Results of study in the 6 areas showed that the salinity average was about 4 to more than 50 and SAR also varies from about 8 to 70. Average total salinity and SAR was 22.5 dS m^{-1} and 22, respectively in studied profiles. Threshold limit of salinity and SAR for pistachio was 9 dS m^{-1} and 12 respectively and their break-even yield (marginal yield) was 28 dS m^{-1} and 30 respectively. Comparison of salinity and SAR of studied soils with their critical and economy level showed that about 80% of the land under cultivation has been adversely affected of salinity and alkalinity and in about 35% of this land, salinity and SAR were more than break-even yield level. Investigation of regression equations revealed that correlation coefficient for salinity and SAR with yield was 63 and 57 dS m^{-1} respectively, so that these parameters have a significant effect on yield of pistachio. Apart from these parameters, properties such as gypsum, organic carbon, soil texture, structure and gravel are also limiting yield of pistachio. Due to the adverse effects of soil salinity on pistachio yield, soil management and desalinization is essential for the optimal use of resources. As well as is recommended the mapping and monitoring of the soil salinity and alkalinity and removing gardens with the low yield.
Key Words: SAR, soil properties, soil salinty, threshold limit.

Introduction. Soil formation is the result of many natural processes that gradually and steadily change in place and time. Nowadays, study of characteristics of various soils and their qualitative and statistical description are very important in planning their optimal use and in applying suitable management for them (Mohammadi 2006). Identification of the constituents of a soil makes it possible to interpret its physical and chemical processes and to maintain the potential for soil formation (Buol et al 2003).

Knowledge of the various conditions in the soil such as physical and chemical parameters and fertility in relation to agriculture and natural resources is essential for optimal management of lands and for achieving maximum economic productivity (Wander et al 2002). Soil potential, also called soil quality index, can be determined by using soil physical, chemical, and biological characteristics (Shukla et al 2006). Soil physical and chemical characteristics and fertility are strongly influenced by soil type. Soil physical properties are more important in assessing its quality. Soil aggregate stability, organic matter content, and percent clay are considered among the main factors in evaluating qualitative properties of soil (Six et al 2004). Soil organic matter is one of the important properties of soils in evaluating their quality, and changes in soil organic carbon greatly affect soil conditions (Wang et al 2010). Ability of soils in maintaining and storing organic carbon and nutrients depends on preserving and increasing soil organic materials (Martin et al 2006).

A major portion of soil resources in the world is destroyed and turned into affected soil under the influence of secondary salinity, which results mainly from irrigation (Qadir et al 2008). Since improvement of soil that has turned saline due to human activities is very costly, preventing this condition seems to be more desirable. Saline and alkaline soils constitute a large part of the lands in the world (FAO 1990). Salts in soil, of whatever origin they are, have many adverse effects on growth and yield of various plants (Ould Ahmed et al 2007), and this can be observed in pistachio (*Pistachio vera* L.) gardens of Kerman Province including those in the Anar, Sirjan, Shahr-e-Babak, Rafsanjan and Rabat Plains (Golzari 2011).

Overuse of pistachio cultivation in most regions of Kerman Province has led to utilization of lands with low potential, or unsuitable for, pistachio production, resulting in reduced yield, land degradation, and a waste of production resources and capital (Malekshahi 2005). Moreover, in some areas pistachio gardens did not have optimum yields, hence, were not economically profitable, and were abandoned (Iranian Pistachio Research Institute 2011).

Pistachio species have almost similar crowns and different root systems. Therefore, pistachio tree bed (soil characteristics) is the main factor that must be studied to specify the relationship between the various characteristics of the soils and growth and production of pistachio nuts (Ferguson 2005).

Pistachio is one of the most important horticultural crops in the country and is grown in 21 Provinces (the Ministry of Jihad-e-Agriculture 2013). Countries with the largest acreage under pistachio cultivation, which are also the main producers of pistachios, are Iran, the United States, Turkey, Syria, and China, respectively, but the highest yield per unit area does not belong to Iran. According to statistics published by FAO (2011), pistachio yield per unit area in the United States is more than three times that of Iran.

Pistachio is important for Iran from the viewpoints of social conditions, job creation, the environment, the economy, and foreign exchange earnings. The acreage under pistachio cultivation in Kerman Province is about 300,000 hectares (the Ministry of Jihad-e-Agriculture 2013).

Research has shown pistachio is very resistant to soil and water salinity. It has been stated in studies that soil salinity of up to 8 dS^{-1} m has no effect on this plant and electrical conductivity (EC) of up to 12 can be recommended for growing this crop, but at EC of about 17 yield is severely curtailed (Samadi 2001; Shahriarpour et al 2011).

Abu-Sharar (1994) studied effects of salinity on pistachio cultivars Ashouri and Atlantica, and reported that pistachio was resistant to salinity, with the salinity threshold of 10 dS/m.

Field studies conducted by Sanden et al (2004) in western United States showed that salinity thresholds for irrigation water and soil were 8 and 12 dS m^{-1}, respectively, for the pistachio cultivar Kerman.

Farahbakhsh (2012) studied a transect of soils on various physiographic units in the pistachio gardens of the Zangiabad region of Kerman. In some locations, very high salinity and alkalinity levels had severely reduced yield. These soils had very low organic matter contents.

Olaleye et al (2010) studied four rice cultivars in different climatic regions of Nigeria to evaluate the relationship between soil characteristics and rice yield. Before planting, soil samples were taken from various depths and analyzed. Yield and other special information related to the selected fields were recorded. Table of ANOVA showed there was a significant relationship with a high correlation coefficient between rice yield and soil characteristics in the various climatic regions. Study of regression equations indicated there were correlations between the three characteristics of acidity, available phosphorous and percent sand in all climates with rice yield, with the correlation coefficients varying from 36.5 to 63%. Moreover, the yield curve against each of the three characteristic was drawn and the line slopes for various rice cultivars varied from 0.5 to 0.89. The main purpose of this research is to study the salinity severity of selected profiles of pistachio orchards in Kerman province and investigate the role of these parameters on pistachio yield.

Material and Method. Considering the prevailing conditions in pistachio production in Kerman Province at october 2013 , this research was conducted to study characteristics of saline and sodic soils, to rating the important parameters in fruit bearing pistachio trees, and to investigate the adverse effects of these soil characteristics on pistachio yield. Soil maps, satellite images of various regions, collected information, and field observation to the Plains where pistachios are grown were used to select orchards and six soil transect in the Plains of Sirjan-Kaffeh Moor, Rabat, Shahr-e-Babak, Anar, Kashkouiyeh Rafsanjan, and Mahan Kerman (Figure 1). The transectes were perpendicular to the orientations of the Plains so that they included all physiographic units. Considering the percentage under pistachio cultivation in each physiographic unit of the total area of the Plains, the study areas were scattered along the sequences and included a wide spectrum of soils with respect to physical and chemical characteristics and fertility.

Figure 1. Position of transects in study area-kerman province.

The profiles in pistachio orchards of average quality management were drilled between rows of 15-18 year old trees of the Ohadi or Akbari cultivars. In all, 88 profiles were drilled and analyzed. Soil samples were sent to the soil laboratory (Center of Agricultural Research in Kerman Province) to be analyzed (Olsen & Sommers 1982). For each orchard, performance management questionnaires were prepared and, considering variable costs and yield (revenue-costs), the minimum economic yield (the breakeven yield) was determined. Given the laboratory results, the physico-chemical characteristics EC, pH, soil texture, gypsum, calcium carbonate, cations and anions, macro elements fertility (OC) of the pedons were studied in the horizons.

In this study, regression relationships were used to study the effects of various characteristics of the lands on pistachio yield, to investigate the roles of the important parameters (EC, SAR), and to determine the threshold limits. One of the characteristics of the land was considered the independent variable, and yield was the dependent variable in all equations (Zare Chahooki 2010). Regression analysis the possibility of studying changes in the dependent variable is predicted, and the share of each variable in explaining the dependent variable is determined (Ghiasvand 2013).

Finally, considering the results of the research, soil characteristics were studied and the most important parameters influencing pistachio yield were determined and analyzed.

Results and Discussion. In general, the selected soil transects were perpendicular to the orientations of the Plains, and it was found their characteristics varied greatly from the boundaries to the middle part of the Plains. Slopes varied from about 5 to 8 percent in gravelly collu-alluvial fans physiographies to less than one percent in low lands.

Studies indicate in some places signs of salinity and alkalinity are observed in the physiographies of flood plains and low lands of Rabat, Sirjan, and Rafsanjan Plains (Ebrahimi 2009).

In dry regions, the formed soils exhibit little development, or are undeveloped, compared to soils in other climates, and are mainly saline, gypsum, and calcareous soils (Buol et al 2003), and soils under pistachio cultivation in Kerman Province exhibit the same characteristics as those in dry regions.

Results of laboratory studies on pedons indicate the position and slope of each profile along the studied sequence are important and affect the physico-chemical characteristics. In these soils, soil salinity and SAR differ depending on position, parent material, groundwater level and quality, irrigation, and evaporation and, therefore, soil characteristics differ, too (Farahbakhsh 2012).

Research by Golzari (2011), Salehi et al (2009), and Naghavi (1996) determined soil salinity and alkalinity as the main parameters limiting pistachio yield in Sirjan and Anar Plains. Irrigating pistachio gardens has caused salinity and alkalinity in some regions due to the quality of irrigation water (Rezaeinezhad 2009). Considering the effects the quality of irrigation water has on solubility, transfer, and accumulation of soluble salts in pistachio gardens, the trend of changes in salinity in each physiography may be irregular, but the general trend of changes along the transects from alluviums and gravelly collu- alluvial fans containing gravel to the low lands is almost an increasing and regular one. Electrical conductivity in the surface layer varies from about 2.8 to more than 50 dS m^{-1}, and confirms the increasing trend from the boundaries to the centers and the ends of the Plains, and a relatively greater increase in the physiography of flood plains and low lands. Moreover, the trend of changes in salinity in the lower layers is usually greater compared to the surface layers and varies from about 3 to 70 dS m^{-1}. Changes in salinity in the various profiles show an increasing trend from the surface layers to depth, which indicates that salts are washed down by irrigation water and precipitation and, hence, the maximum accumulation of salts takes place in the second layer (25 to 60 centimeter) and third layer (60 to 95 centimeter). Study of results concerning the profiles at the end of the physiography of flood plains and low lands shows that salinity in the surface layer is greater compared to upper layers. Moreover, there is a decreasing trend from the surface to the depth of the soil, the most important factors contributing to which being the high groundwater level and the intense evaporation from pistachio orchards, which cause accumulation of salts in the surface layer and crusting in some regions (Buol et al 2003). Figure 2 shows the trend of changes in mean salinity of the various physiographies.

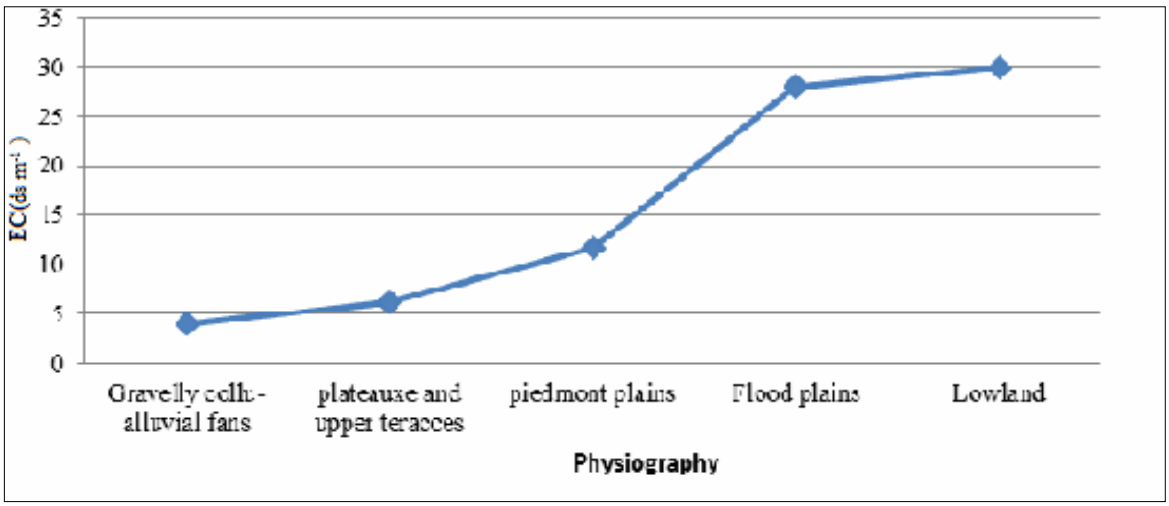

Figure 2. Trend of mean salinity changes in various physiographies.

Studies indicate changes in sodium adsorption ratio (SAR) along transects are almost similar to the trend of changes in electrical conductivity of soil saturation extract. Furthermore, changes in SAR in the various layers of a profile are also almost similar to changes in soil salinity. This parameter varies from about 8.5 in the surface layer to more than 70. In flood plains and low lands, SAR is more influenced by the quality of irrigation water and groundwater. Figure 3 shows the trend of changes in mean SAR along the sequences. In soils of arid and semi-arid regions, salinity and presence of gypsum are more affected by the geological structure of the region (Buol et al 2003).

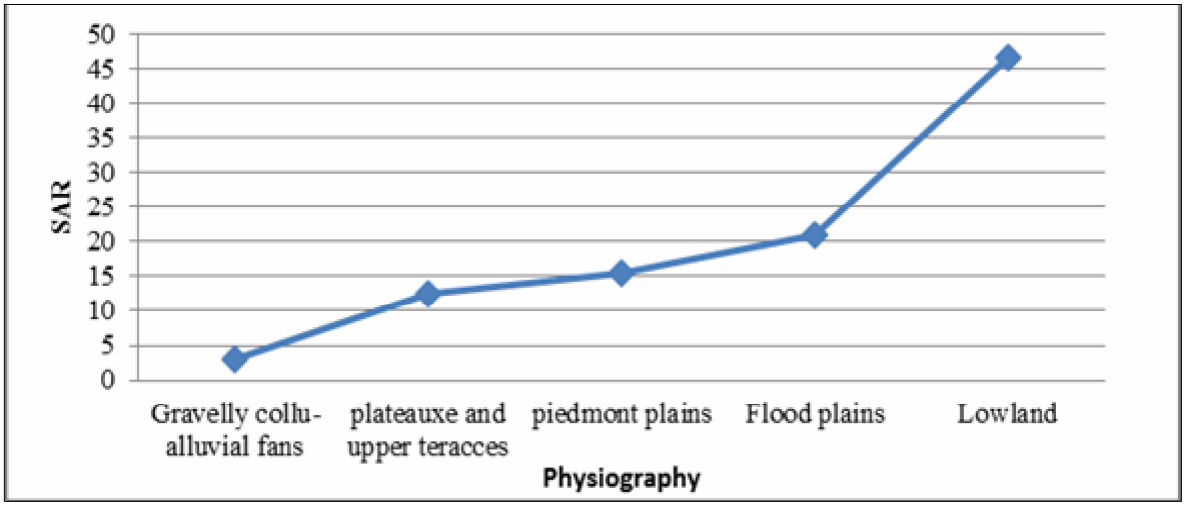

Figure 3. Trend of SAR changes in various physiographies.

Overuse pistachio cultivation in unsuitable lands, and irrigating pistachio orchards with unsuitable water in the past three decades have been very influential in salinization of lands, and have caused expanded salinity and accumulation of salts in some orchards (Rezaeinezhad 2009). Uncontrolled use of groundwater makes irrigation water undesirable (the Ministry of Energy 2012), and use of such water not only does not lead to leaching of salts but increases salts and their accumulation in all layers of soils. Table 1 shows the threshold levels of soil salinity and SAR for pistachio trees.

Table 1

The threshold levels of soil salinity and SAR for pistachio trees

Land characteristics	*unit*	**Threshold limit*	***Marginal yield (break-even production)*
EC	ds m^{-1}	9	28
SAR	-	12	30

*Threshold limit: the limit for a parameter, and if the parameter exceeds this limit, it will cause reduction in plant growth or yield (Homaei 2001); **Marginal yield (break-even production): is crop yield benefit a value equal to the variable costs of a year.

Results indicate the overall mean salinity of the soils and the SAR are 22.5 and 22 dSm^{-1}, respectively, which exceed the permissible levels for these parameters in pistachio orchards. Therefore, salinity and alkalinity play an important role in reducing pistachio yield. Comparison of the results shows more than 80% of the profiles have salinity levels exceeding the threshold levels, of which about 35% exceed the limit for marginal (break-even yield) production. This indicates conditions are not suitable for pistachio production in some orchards of Kerman Province. Research indicates pistachio trees are sensitive to gypsum but tolerance to salinity (FAO 1990). Moreover, high levels of groundwater is also a limiting factor, and pistachio is among crops sensitive to ponding and high water table levels (Ferguson 1995).

In this stage, in order to study the relationships between characteristics having higher degrees of correlation with yield, the related simple (two-variable) equation, and its curve, was determined (Figures 4 and 5).

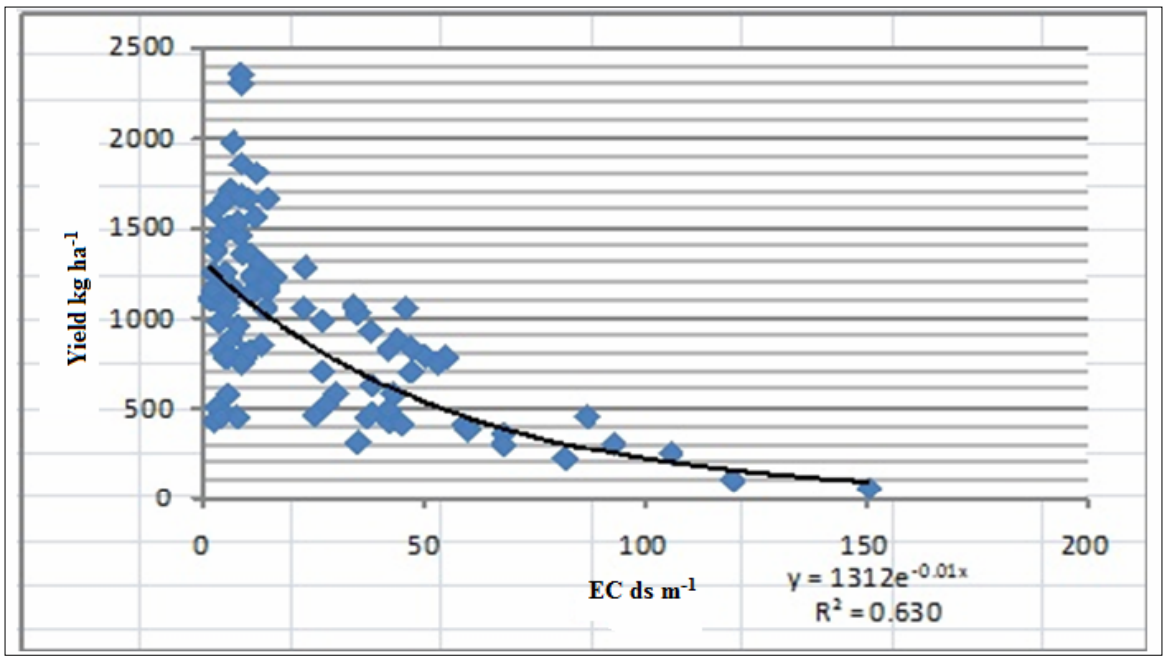

Figure 4. Relationship between soil salinity and variation of pistachio yield.

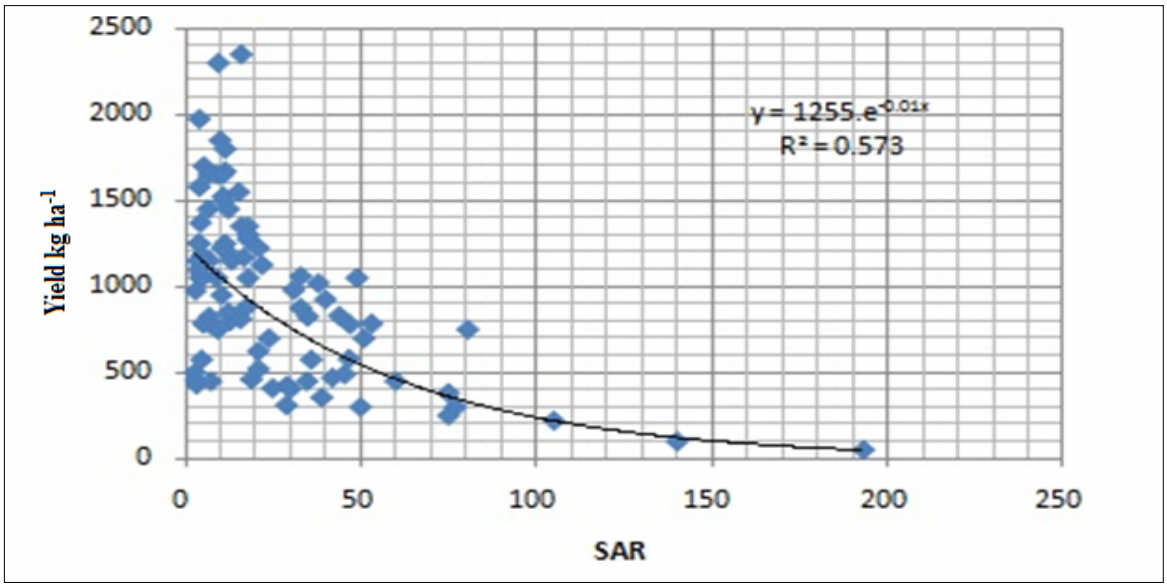

Figure 5. Relationship between SAR and variation of pistachio yield.

Based on the equation of each variable with yield, it is possible to predict the yield in various soils. Salinity and alkalinity of soils control a greater percentage of changes in the dependent variable (yield) considering their relatively high determination coefficient (R2, salinity 63, SAR 57). Regression equations indicate that yield decreases with increases in salinity and alkalinity, but clay and available potassium and phosphorous positively influence yield. Coefficients of yield reducing variables are higher and more important compared to those of yield increasing parameters.

Acidity of saturation extracts of the studied soils shows pH values in the surface layer varies from about 7.3 to 8.2, and in lower layers from 7.4 to 8.4. Results of chemical analyses of soils indicate pH decreases in the second layer of most profiles but exhibits an increasing trend again. Essentially, changes in soil acidity of the various layers are not regular, and pH varies according to the type, and the characteristics of the sediments in each layer.

Changes in lime content have the greatest effect on soil acidity in the studied pedons, and lime content does not increase with increases in sodium adsorption ratio considering soil acidity does not increase with increased salinity (Buol et al 2003). Mean lime content in the studied pedons varies from 20 to 50%, the changes are not regular, and lime content increases in the profiles with increases in depth to the third layer (depth of 50-80 centimeters).

Soil texture is also very variable in the pedons and changes from sand to clay. Soil texture becomes irregularly heavier with decreases in slope and erosion. Results indicate soil texture in the lower layers, especially the second and third layers, is usually heavy (clay, sandy clay, clay loam, sandy clay loam), and in most profiles soil texture in the surface layer is lighter compared to the lower horizons. In these pedons, gravel is observed in the surface layer and in deep layers in debris and fan-shaped alluviums, but not in other profiles. Mean available phosphorous in all profiles is less than 15 mg kg^{-1} and it decreases with increases in depth.

Organic carbon content in all pedons is less than 1%, and it decreases sharply with increases in soil depth. The high organic matter on the soil surface is due to organic fertilizers used and because of the presence of pistachio trees. However, this organic matter content is much lower than the critical limit of the soil (Samadi 2001).

Considering the dry climate of the pistachio growing regions, and because of the extremely low organic matter content of the soils, the organic matter content of the soils in the plains where pistachio grows is negligible and inconsiderable (Ebrahimi 2009). However, factors such as type of management and use of various sources of organic matter influence the quantity of this parameter. Organic matter content in all layers is less than 1%, and varies from 0.05 to 0.7%. Results of laboratory analysis show the organic matter content in the first and second layers are greater compared to the lower layers but then changes in organic matter content becomes regular. The reasons for the increase of organic matter in the upper layers are the plant cover and the use of organic fertilizers. The important thing is to make optimal use of soil resources and of various inputs such as macro and micro chemical fertilizers and irrigation water, to modify soil pH, and to increase its organic matter content.

Along transects, lime content varies in the different layers and profiles, from small in the east to large in the west. In the surface layer, the lime content varies from 25 to 35%, and in the lower layers from about 22 to 45%. In some profiles, the increased lime content of the lower layers may be due to the quantity of lime deposits (FAO 1990).

In the studied profiles, unlike the lime content, secondary gypsum is observed in almost all pedons and in some lower layers. Gypsum content increases along transects from the boundaries to the centers, and its accumulation in the center and end part of the Plains is much greater compared to its boundaries. These pedons contain up to 35% gypsum.

In large parts of the studied soils, especially in Sirjan, Rabat, and Anar, the salinity and alkalinity problem is more serious. The salinization and alkalization process is more intense in pedons located in flood plains, and low lands (Golzari 2011). In the studied soils, those in low lands generally contain large quantities of salts and gypsum, but the depth at which salts and gypsum accumulate depends on the physical characteristics of the soils (Abdolazimi 2003).

Laboratory results indicate groundwater in some of the studied Plains has very high electrical conductivity (the Ministry of Energy 2012). Therefore, the main reasons for salinization and alkalinization of these soils in some regions are capillary rise and accumulation of salts in soil profile due to water evaporation and irrigation of pistachio orchards with saline water. Moreover, these salts are washed from the surface layers during the rainy season and irrigation and accumulate in the lower horizons (Abadeh 2004). Accumulation of large quantities of salts and gypsum in the lower horizons has had adverse effects on yield and growth of pistachio in the orchards of the region (Ebrahimi 2009).

Conclusions. Laboratory analysis of soil samples from selected pedons show the degree of salinity in the surface and lower layers increases irregularly from the physiographies of

gravelly collu- alluvial fans to the centers of the Plains, but the highest degrees of salinity are related to the physiographies of flood plains and low lands. In most profiles, soil salinity increases with depth due to leaching. The trend of changes in SAR along the transects and in the various layers is almost similar to that of salinity. In the various profiles, salinity increases from the surface layer to lower layers, and this shows salts are washed by rainfalls and irrigation water and accumulate mostly in the second and third layers.

Along soil sequences, slopes and erosion decrease from the boundaries to the centers of the Plains and the degree of salinity and alkalinity depends on the location of the selected points.

In soils under pistachio cultivation also, salinity, gypsum, and lime contents are similar to those of soils in dry regions, but their formation and development vary in the different Plains.

The main reasons for salinity and alkalinization in these soils in some regions are that capillary rise and accumulation of salts in soil profiles, and that these salts are washed from the surface layer during the rainy season and irrigation and accumulate in the lower layers. Moreover, agricultural operations, especially gravity irrigation, have had various effects depending on the quality of irrigation water and position of the studied pedons.

Based on our research, we offer the following suggestions for optimal use of soil resources in pistachio orchards:

- soil survey in the areas under pistachio cultivation be prepared and the information they include be monitored at specified intervals;
- thematic soil maps be prepared, especially in saline areas, and the trend of changes in them be studied in the whole region;
- suitable management be applied by considering factors limiting soil resources such as salinity, gypsum, and extreme deficiency of organic matter;
- orchards with uneconomical and unprofitable yields be eliminated;
- new lands be selected in the country for growing pistachio by using studies conducted on soils and on land evaluation.

Therefore, a more comprehensive study of limiting factors in regions under pistachio cultivation, application of suitable management, and improvement of parameters, especially salinity and alkalinity, are essential for increasing yield and for sustainable production.

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