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Morphological Attributes of Root Systems and Seedling Growth in Three Species of *Pistacia*

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Abstract. Iran is one of the most important growing centers for wild and domesticated species/varieties of pistachio. Because of the adaptability of wild pistachio species to severe environmental conditions and resistance to drought and some pest and diseases, these can be used as rootstock for pistachio cultivars and in breeding programs for rootstock improvement. The present study aims to evaluate the seedling behavior of *Pistacia vera, P. mutica* and *P. khinjuk* at the inter-specific level. The results showed significant differences among species for most of the measured traits indicating high genetic variability among these species. *P. vera* showed highest stem height, stem diameter, shoot and root fresh and dry weights. *P. vera* also produced more leaves, more number and longer roots per seedling than the other two species. The correlation between various morphological traits showed that many of the associations between morphological traits of shoot and root vary between these three species. However, only leaf number was found to be common and important morphological trait for these three species to evaluate stem diameter of *Pistacia* species before their nursery test.
Key words: Morphological characters; *Pistacia vera; P. mutica; P. khinjuk*

Atributos Morfológicos dos Sistemas Radiculares e do Crescimento de Plântulas de Três Espécies de *Pistacia*

Sumário. O Irão é um dos mais importantes centros de produção de espécies/variedades selvagens e cultivadas de pistácio. A facilidade de adaptação de espécies selvagens de pistácio a condições ambientais severas e a sua resistência à seca e a algumas pragas e doenças, permitem a sua utilização quer como porta-enxertos para cultivares de pistácio quer em programas de melhoramento destes. O presente trabalho visa avaliar o comportamento interespecífico de plântulas de *Pistacia vera*, *P. mutica* e *P. khinjuk.* Os resultados mostraram diferenças significativas para a maioria dos parâmetros medidos, indicando alta variabilidade genética entre estas espécies. *P. vera* apresentou caules mais altos e de maior diâmetro, maior peso seco e fresco de lançamentos e raízes. *P. vera* produziu igualmente mais folhas, raízes mais longas e em maior número, por plântula, que as outras duas espécies. A correlação entre associações de vários aspectos morfológicos de lançamentos e raízes demonstrou diferenças entre estas três espécies. No entanto, verificou-se que apenas o número de folhas era um importante traço morfológico comum a estas três espécies, para avaliar o diâmetro do caule das espécies de

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Pistacia antes dos testes de viveiro.
Palavras-chave: Caracteres morfológicos; *Pistacia vera*; *P. mutica*; *P. khinjuk*

Attributs Morphologiques des Systèmes Racinaires et de la Croissance de Plantules pour Trois Espèces de *Pistacia*

Résumé. L'Iran est un des plus importants centres de croissance d'espèces/variétés sauvages et cultivées de pistachier. En raison de l'adaptabilité des espèces sauvages de pistachier aux conditions environnementales et leur résistance à la sécheresse, aux parasites et maladies, ceux--ci peuvent être utilisés comme porte-greffe de pistachier cultivars et dans des programmes de reproduction de portes-greffes améliorés. L'étude vise à évaluer le comportement de semis *Pistacia vera*, *P. mutica* et *P. khinjuk* à l'inter niveau précis. Les résultats ont révélé des différences importantes pour la plupart des espèces mesurées et indiquant une haute variabilité génétique entre ces espèces. *P. vera* a montré des tiges plus hautes, et de diamètre supérieur, et poids sec et frais des pousses et racines supérieur. *P. vera* également produit plus de feuilles, plus de racines et plus longues que les deux autres espèces. La corrélation entre divers traits morphologiques du rameau et racines varient entre ces trois espèces. Toutefois, seul le nombre de feuilles était une caractéristique morphologique importante et commune aux trois espèces, pour évaluer le diamètre de la tige des espèces de *Pistacia* avant leurs tests en pépinière.
Mots clés: Caractères morphologiques, *Pistacia vera*, *P. mutica*, *P. khinjuk*

Introduction

Pistacia vera L., the pistachio, is a dioecious tree species cultivated widely in the Mediterranean regions of Europe, North Africa, Middle East, China and California (ONAY *et al.*, 2004). The monographical study by ZOHARY (1952) indicates that genus *Pistacia* include 11 species: *P. atlantica*, *P. cabulica*, *P. chinensis*, *P. falcata, P. integerrima, P. vera, P. kurdica, P. mutica, P. palestine, P. terebinthus and P. khinjuk.* Among these only *P. vera* had edible nuts and considerable commercial importance. The nuts of the other species are used for local consumption, oil and soap production (Kafkas, 1995), however, their main economic importance derives from using their seeds as rootstock for *P. vera*. Iran ranks first in the world in terms of both pistachio production and harvested area (FAO, 2005). *P. mutica* F. & M. and *P. khinjuk* Stocks are two wild species naturally distributed in an area of more than 2.5-3 million hectares in many parts of Iran (SHEIBANI, 1987). They grow in rocky mountain areas and on clay soils (THAKUR and RATHORE, 1991). Because of their adaptability to severe environmental conditions and their resistance to some pests and diseases, they can be used in forest of semi-desert areas to control soil erosion and as rootstocks for pistachio cultivars.

For rootstock production, reliable seed materials with fast seedling growth are of economical importance required in the nursery management. Since Iran is extremely rich in *Pistacia* trees, finding such seed materials should not be difficult. That seeds can be used not only in Iran but also in the world pistachio production after testing their effects on the scion productivity, nut quality and their tolerance to soil-borne diseases. The material trees can also be used in worldwide pistachio rootstock breeding programs (KAFKAS *et al.*, 2002).

There are several studies that characterize seed and seedling characteristics of *Pistacia* species at the

nursery stage comparing at the inter specific level (CRANE and FORDE, 1974; NIKPEYMA and KASKA, 1995; KAFKAS *et al.,* 2002) that may not give satisfactory information for a species. There is no study in the literature demonstrating seedling characteristics of Iranian wild pistachio species. Therefore, this study aims to evaluate seedling behavior of *P.vera*, *P.mutica* and *P.khinjuk* at the inter-specific level.

Materials and methods

Sound nuts of *P. mutica* and *P. khinjuk* were scarified by immersing them in concentrated H_2SO_4 for 90 and 20 min respectively. Nuts were then washed for 24 h in running water (BANINASAB and RAHEMI, 2001). Naturally split *P. vera* hulled seeds were soaked in tap water for 24 h. The nuts of all species were then mixed with moist peat- moss [3:1, peat-moss: seed (V/V)] and stratified by keeping them at 5±1°C for 20 d. After stratification period, nuts were sown directly in 5 kg black plastic bags filled with a 1:1:1 (V/V) mixture of fine sand, leafmould and soil. The bags were then transferred to the glasshouse, with an average temperature of 27 ± 5°C under natural photoperiod for three months before being moved to an outdoor nursery area.

The experiment was arranged in a completely randomized design with four replications and four plants per replication. Fifteen months after sowing, seedlings were removed from the containers and the root systems was carefully washed for the removal of media and following observations were recorded. The number, length and diameter of the roots were measured using the Delta-T SCAN image analysis system (Windias software). Shoot length, shoot diameter, leaf number and fresh and dry weights of the roots and shoots were determined. Dry weights were determined after 72 h of drying plant material at 70°C.

The data were statically analyzed and the means were compared using Duncan's Multiple Range Test (DMRT). Correlation coefficients among morphological traits of the seedling characteristics of each species were calculated using the SAS package program.

Results and discussion

The analysis of variance showed significant differences among species for most of the traits were measured which indicate high genetic variability among these species. This genetic variability can be used either in rootstock selection or rootstock breeding programs.

The results showed that *P.vera* seedlings had more, longer, thicker roots with greater fresh and dry weights (98.5, 1574 mm, 1.3 mm, 2.35 g and 0.84 g, respectively) than the other two species (Table 1). There is no report in the literature on the root system of *Pistacia* species, however our study showed that there is a large variation among these species regarding measured important traits.

The shoot length was significantly different between three species. At the end of the study, *P. vera* had the tallest (25.8 cm) and *P. mutica* the shortest stem (6.9 cm) (Table 1). These results are in agreement with those reported by KAFKAS and KASKA (1997) who found that the seedlings of *P. vera* grow faster than the wild species they tested. This is generally accepted that wild species grow slower and have smaller vigor (WOODROOF, 1982).

Stem diameter, which is important to allow early budding and transplanting to orchard was observed to be different among the species following 15 months of seed planting (Table 1). *P. mutica* and *P. khinjuk* had thinner average stem diameters (2.8 and 2.6 mm, respectively), whereas *P.vera* (4.6 mm) produced the thickest one (Table 1). These results were similar with those reported by Rahemi and Baninasab (2000) who found that the low seedlings vigor of *P. mutica* and *P. khinjuk* have been a major problem in using them as rootstocks for pistachio cultivars.

Seed emergence time may affect seedling growth (KAFKAS *et al.*, 2002). In this experiment, we observed emergence in *P.vera* was earliest than the other species (data not included). Such a difference might partially explain the reason for better shoot height and diameter of *P.vera* than the other species. The differences in traits such as stem height and diameter might be controlling mainly by genetical factors responsible for seedling growth. However, there is no report in the literature on the stem diameter of these species.

The shoot fresh and dry weights were similar for *P. mutica* and *P. khinjuk*, whereas both showed significant differences with *P. vera* (Table 1). However, both shoot fresh and dry weights were greatest in *P.vera*.

P.vera had more leaves (14.4) followed by *P. mutica* and *P. khinjuk* (Table 1). As a conclusion, having more leaves per plant, it may provide greater photosynthate and consequently better seedling growth which is shown in Table 1.

The correlations between traits are shown separately for each species in Tables 2, 3 and 4. In *P.vera*, shoot length and diameter were significantly correlated with leaf number and root number (Table 2). This might be due to the role of the leaf in carbohydrate synthesis and root in the absorption of water and mineral salts. In *P.mutica*, shoot diameter was significantly correlated with shoot length, shoot fresh and dry weights and also leaf number (Table 3). In *P.khinjuk*, shoot diameter was also significantly correlated with root number, root length, shoot dry weight and leaf number (Table 4).

Table 1 - Comparison of means of root and shoot traits measured in *Pistacia* species

Trait	*P. vera*	*P. mutica*	*P. khinjuk*
Root number	98.5a ∗	62.6b	47.5c
Root length (mm)	1574a	1055b	793c
Root diameter (mm)	1.3a	1.1ab	0.9b
Root fresh weight (g)	2.35a	1.41b	0.48c
Root dry weight (g)	0.84a	0.49b	0.14c
Shoot length (cm)	25.8a	6.9c	8.5b
Shoot diameter (mm)	4.6a	2.8b	2.6b
Shoot fresh weight (g)	3.20a	0.66b	0.52b
Shoot dry weight (g)	1.53a	0.28b	0.23b
Leaf number	14.4a	8.2b	6.8c

∗ In each row means followed with the similar letters are not significantly different at 5% level of probability using DMRT

Table 2 - Correlation between measured traits of *P.vera*

Traits	Root Number	Root Length	Root Diameter	Root Fresh Weight	Root Dry Weight	Shoot Length	Shoot Diameter	Shoot Fresh Weight	Shoot Dry Weight	Leaf Number
Root number	1	0.929**	0.513	0.959**	0.957**	0.803*	0.737*	0.865**	0.646	0.733*
Root length		1	0.589	0.953**	0.922**	0.858**	0.419	0.860**	0.698	0.924**
Root diameter			1	0.651	0.680	0.812*	0.084	0.522	0.401	0.504
Root fresh weight				1	0.992**	0.832**	0.557	0.938**	0.784*	0.777*
Root dry weight					1	0.818*	0.530	0.912**	0.741*	0.715*
Shoot length						1	0.136	0.723*	0.521	0.800*
Shoot diameter							1	0.760*	0.815*	0.711*
Shoot fresh weight								1	0.938**	0.690
Shoot dry weight									1	0.580
Leaf number										1

*, ** Significant at the 5% and 1% level of probability respectively

Table 3 - Correlation between measured traits of *P. mutica*

Traits	Root Number	Root Length	Root Diameter	Root Fresh Weight	Root Dry Weight	Shoot Length	Shoot Diameter	Shoot Fresh Weight	Shoot Dry Weight	Leaf Number
Root number	1	0.943**	-0.732*	0.994**	0.992**	0.668	0.536	0.232	0.519	0.467
Root length		1	-0.774*	0.957**	0.955**	0.469	0.448	0.178	0.402	0.490
Root diameter			1	0.756*	0.757*	0.572	0.585	0.463	0.583	0.246
Root fresh weight				1	0.999**	0.684*	0.578	0.277	0.553	0.545
Root dry weight					1	0.690*	0.575	0.272	0.551	0.552
Shoot length						1	0.840**	0.646	0.868**	0.561
Shoot diameter							1	0.931**	0.993**	0.771*
Shoot fresh weight								1	0.931**	0.495
Shoot dry weight									1	0.601
Leaf number										1

*, ** Significant at the 5% and 1% level of probability respectively

Table 4 - Correlation between measured traits of *P. khinjuk*

Traits	Root Number	Root Length	Root Diameter	Root Fresh Weight	Root Dry Weight	Shoot Length	Shoot Diameter	Shoot Fresh Weight	Shoot Dry Weight	Leaf Number
Root number	1	0.900*	-0.644	0.966**	0.965**	0.741*	0.687*	0.384	0.483	0.351
Root length		1	-0.562	0.980**	0.976**	0.561	0.793**	0.426	0.431	0.299
Root diameter			1	0.620	0.632	0.085	0.079	0.209	0.199	0.054
Root fresh weight				1	0.999**	0.635*	0.288	0.403	0.433	0.329
Root dry weight					1	0.615	0.305	0.412	0.417	0.353
Shoot length						1	0.180	0.336	0.659*	0.386
Shoot diameter							1	0.483	0.707*	0.653*
Shoot fresh weight								1	0.827**	0.816**
Shoot dry weight									1	0.537
Leaf number										1

*, ** Significant at the 5% and 1% level of probability respectively

These correlations suggest that many of the associations between morphological traits of shoot and root vary between these three species (Tables 1, 2 and 3). However, only leaf number was found to be common and important morphological trait for three species to evaluate seedling stem diameter which is essential to allow early budding of *Pistacia* genotype before nursery test.

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