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Investigation on mechanisms of adaptation of *Ammodendron persicum* to desert sand dune habitat in arid region

Hossein Tavakoli
Agriculture and Natural Resources Research Center of Khorasan Razavi. Mashhad, I.R. Iran
Tavakoli_res@yahoo.com

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Abstract
Sand dune habitats in desert regions have harsh conditions for plant establishment and survival. *Ammodendron persicum,* an psamophyte shrub plant belongs to Leguminosae family, which grows over the desert sand dunes of Zirkohgaen, Gezik and Khash along east part of Iran. Recognizing the adaptive features of the plant species may help towards its conservation and introducing to other sand dune habitats. Therefore, the morphological characteristics of root and shoot, root distribution and forms of regeneration of the species were studied. Observations revealed that each individual plant has a deep taproot along with lateral roots which penetrate in different layers of sand, therefore benefit moisture from top to deeper layers of sand. It has white-grey stems, silver colored and spiny leaf, divided into leaflets. Plant regenerates both through vegetative and reproductive systems. Different mechanisms of adaptation enable the species to adapt in harsh conditions.

Key words: *Ammodendron persicum*; Morphological characteristics; Root; Shoot; Regeneration; Adaptation mechanisms

Introduction
Ammodendron persicum is a psamophyte, C3, long vegetating and tall shrub plant belong to the Leguminosae family. The species grows only over three sand dune habitats in Iran, named Zirkoh Ghaen, Gezik and Khash in east part of the country (Tavakoli, 2004).
Sand dunes in the desert areas have harsh conditions for plant growth and persistence due to low rainfall, moving sands, low soil fertility, strong winds, active air turbulence, low relative humidity, high light intensity due to the reflective sand, and high temperature during day time, wide temperature fluctuation, and low organic matter in soils. Therefore, only a few species with special adaptation capability can establish and grow well in such harsh dune environment (Dech and Anwar Maun, 2006). For example, *Aristida pungens* and *Rhanterium sauveolens* showed resistance to sand accumulation and deflation by formation of adventitious roots and development of new aerial structures at a level corresponding to the new soil surface (Bendali *et al.* 1989). Where sand displacement occur by winds, *Haloxylon salicornicum, H. persicum* and *Calligonum comosum* have capability to create sand hillocks (Danin, 1991; Brown and Prorembski, 1997). In *Zygophllum quarense* leaf defoliation happens as dry season progresses (Sayed, 1966). *Stipagrostis scoparia* produces adventitious roots from stem nodes and plagiotropic rhizomes by which grow into the sand and produce new aerial sprout after being covered with sand (Danin, 1991).
Because *A. persicum* grows only in a few sand dune habitats as an endemic species (Jalili and Jamzad, 1999) and it seems to has potential for green planting due to its aesthetic view and also introducing to other sand dune habitats, the aim of this study was to obtain information on some characteristics which are important for survival of *A. persicum* in such harsh conditions for its conservation and vegetation propagation to other ecosystems.

Material and methods
Study site
Zirkoh Ghaen is a sand dune habitat located in east of Iran. The sand dune area is about 134Km^2. This habitat has divers vegetation in

which *Ammodendron persicum* grows over sand dunes mainly as one of two dominant species. Climatically, the area has arid conditions with mean annual rainfall of 150 mm. The weather in summer is hot and winter is cool. Seasonal winds blow very fast during summer time (Tavakoli, 2004).

Measurements

Nineteen adult plants were selected as a representative of a *Ammodendron persicum* population. First the height of each individual plant was measured and then sand surrounding of roots of plant removed. After digging the root zone, the length of the tap-root (main root), the longest lateral root of each plant and in some plants the length of all lateral roots were measured by using meter in centimeter precision. Number of lateral roots were also counted per plant. Vertical or horizontal direction of root movement were recorded. Soil moisture depth also was considered as a promotion agent of the direction of root movement.

To understand more about mechanism of plant establishment over sand dune, 34 seedlings were randomly selected at the end of summer time of the first growing season and then the length of root and shoot of all seedlings and direction of root development were recorded.

Morphological characteristics of stems, branches, leaves and seeds were recorded and described as mechanisms by which may have important role in terms of wind, drought, solar radiation and herbivore resistance and for plant regeneration.

Forms of natural plant regeneration and rejuvenation were considered in different ways; seed born plants as reproductive regeneration by counting seedlings into 5 quadrates of 50 by 2 meters for two years. Also, if an adult plant had only one stem, it was considered as seed born plant and if it had more than one main stems, plant has responded to disturbances (by cutting, wind breaking or grazing, through rejuvenation by vegetative organs. It was considered as coppice stand. Rejuvenation was also tested by cutting 11 individual plants just close to collar and measured for regrowth after 16 month. In another experiment, 100 cuttings of branches and 100 sections of roots were planted in sand in the nursery. The response was recorded in terms of ability of sprouting and rooting after one month.

Seed germination percentage was tested with and without scarification on wet paper filter in Petri dish in the laboratory as well sowing directly in the sand dune of the habitat and in the nursery. Seed germination percentage and annual growth of seedlings were recorded for one growing season. To have estimation on growth potential of the species, annual growth of at least 30 twigs of different individual plants growing in the natural habitat, in a well watered conditions were recorded.

To provide more information on efficient method of plant establishment, different plant parts including scarified seeds, bare root and potted plants were planted at different sites. Number of established plant were recorded at the end of the growing season.

Results

Root system and development

Each individual plant had a tap-root with different number of lateral roots originated from the tap-root. The tap-roots penetrated vertically down to the depth of moist layer and then extended horizontally through the moist layer. The lateral roots were extended horizontally in different depths of the soil. The lateral roots observed from near surface layer to the depth of about 150 cm from the soil surface. In some places, surface roots were exposed to the air.

The length and number of lateral roots of 19 individual plants have been is shown in Table1. Lateral roots extended radically from 60 to 430 cm from the tap-root. Maximum length of tap-root of the studied plants was about 542 cm in which 200 cm developed vertically and then directed horizontally through moist layers of sand. Number of lateral roots were counted between 1-14 with an average of 6.9 roots per plant. Each individual plant had about 256 cm tap-root and 182 cm lateral root on average. The fine roots were less on both tap-root and lateral roots. Of 34 excavated seedlings at the end of growing season, the mean, maximum and minimum shoot length were 4, 13 and 1.4 cm respectively. Each seedling had only one root in which vertically penetrated into the soil. The length of measured roots were between 15 to 90 cm with an average of 34 cm.

Table 1- Height, root length and number in 19 individual plants of *A. persicum*

Plant number	Height (cm)	Tap-root length (cm)	Length of the longest lateral root (cm)	Number of lateral roots/plant
1	150	160	280	-
2	180	210	190	2
3	209	208	116	5
4	140	542	254	3
5	223	250	178	10
6	195	200	60	3
7	160	200	140	3
8	165	210	115	1
9	140	300	320	2
10	202	385	150	4
11	185	450	430	4
12	133	270	-	12
13	159	155	-	10
14	110	145	-	9
15	233	352	-	14
16	190	190	-	11
17	250	250	130	11
18	250	220	90	10
19	235	170	90	10
Mean	185	256	182	7

Shoot characteristics

About 96 percent of adult plants in the studied site had more than one stem the collar base. Each plant had 15 lateral stems on average. Height of measured plants are shown in Table1. Average plant height was about 185 cm. Stems have spines of up to 5 mm long. Stem color was grey-white.

Leaf forms leaflets along a spindle. Of 100 measured leave, each leaf had between 3 to 6 leaflets with an average of 4.58 leaflets per leaf. Each leaflet was 36 cm in length, 1.3 cm in width with an average of 2.7 cm^2. Average length of leaf spine was about 27 mm. The mean specific leaf area of 6.91 square millimeter per milligram (mm^2/mg) and specific leaf weight of 0.144 mg/mm^2 were obtained for the species. Leaflets color was silver covered with trichomes.

Regeneration

The studied habitat, *A. persicum* first regenerates by seed and then rejuvenate by sprouting propagules of stem and roots. Numbers of seedling were 575 and 430 per hectare in the two successive years but during drought years, seeds failed to germinate or produce seedling. Rejuvenation by sprouting propaguls from collar point and from root surfaces consisted about 95 percent of *A. percicum* population in the studied habitat. Less than one percent of exposed roots produced shoot. This kind of shoots is connected to mother plant through lateral roots. Therefore, if the connection is cut, the shoot may act as an independent plant.

Table 2- Comparing plant height in 11 individual plants before and 16 months after cutting (cm)

Plant number	Before cutting	After cutting
1	50	55
2	170	120
3	120	30
4	80	66
5	40	34
6	90	75
7	110	60
8	60	65
9	80	60
10	50	70
11	90	107
Mean	85	67

Sprouting and rooting from planted cuttings was about 5 percent and nil for root cuttings. All cut plants grown to on average height of 67 cm after about two growing seasons (Table 2). Intact seeds failed to germinate without scarification, but germination percentage of scarified seeds were 4, 65 and 40 percent on the habitat soil, on wet filter paper in Petri dish and on soil nursery, respectively.

Table 3 shows the results of some planted seed and seedlings in the different sites. In general, the success of direct seed sowing was less than 4 percent. Plants established by pot planting better than bare root planting. Supplementary irrigation increased the percentage of plant establishment.

Herbivory

A. persicum was not consumed by goat, sheep and camel before seed maturity. Its leaves were consumed by *Heliothis armigera* larve from Noktoideh family. Ants were the major consumers of the released seed in the nature.

Table 3- Number of plants established by seed sowing and transplanting of *A. persicum* in different sites

Planting site	Sown seed	Established seedling	Planted seedling	Established seedling	Soil and treatment
Zirkoh	260	8	141	106	sand dune
Passkoh	-	-	50	25	sand dune
Gonabad1	200	3	90	42	sand dune
Gonabad2	-	-	140	100	sand dune 3 time irrigation
Bajestan	100	0	32	16	loamy-sand 3 time irrigation
Saraian	200	0	60	24	sand dune
Nehbandan	-	-	10	6	sand dune 6 time irrigation
Birjand	-	-	160	113	sand dune
Sabzevar- Dolatabad	200	0	-	-	sand dune
Sabzevar- Haresabad	200	5	-	-	sand dune
Sabzevar- Abkhan	-	-	31	24	Sand 10 time irrigation
Sabzevar-Hosseinabad	-	-	43	60	sandy- loam

Discussion

Total area covered by sand dunes in the country is approximately 3.5 million ha, or 2.1% of the total land territory (Mahmodi, 2002). Sand dunes are the main sources of sand movement by wind without proper management. Control of sand dune movement accounted as a major tasks of the authorities. So far, the best and more sustainable control of sand movement was to maintaining present vegetation of the area or establishing suitable plant species over the sand dunes and wind erosion critical areas.

According to the results, *A. persicum* as psamophyte species has the ability to withstand well in the harsh conditions. The plant has a special root system with horizontal and vertical branches from top to deep moist layers of sandy soil in which gives it a flexibility to take advantage of using water from all moist depths.

Leaves of the plant species is divided into small leaflets by which leaf area of whole plant is decreased. Leaflets are thick, silver like and covered by trichomes. Stems are gry-white by which the species reduces heat absorption. Results of other studies indicated that trichomes and bright color may increase reflectance (Ehleringer 1976), reduce heat load through convective cooling (Givnish,1987and Noblel, 2005) and less leaf area and higher trichome densities may result in higher water use efficiency in plants (Picotte *et al.* 2007). Duidley (1996b) and Ehleringer (1982) pointed out that these characteristics observed in the plants species growing in seasonally arid habitats in response to increasing drought, and consequently increased plant fitness. Ability to produce multi-stem from basal area resulted in decreasing in height and increasing wind resistance and wind erosion capability control.

Findings of the study show that *A. persicum* regenerates first by seed and then rejuvenate by sprouting of vegetative organs after being cut by men, breaking by wind or grazed by animals. Both ways of regenerating by seed

and rejuvenation by sprouting from basal area may increase plant longevity and plant population ununiformity. In general plants with both vegetative and reproductive strategies of regeneration have superiority in stress conditions (Grime, 1976).

One of the threats of surviving of the plant species in sand dune areas is overgrazing by wild and domestic animals. *A. persicum* has spiny leaves and stems or has alkaloid and low palatability relative to other plant community. Therefore, the plant species is not grazed by sheep, goat and camel until seed maturity and leaf falling. These characteristics provide opportunity for complete its phonological development. Consuming of other plant species may be benefit for *A. persicum* in terms of reducing competition for absorbing available underground waters and nutrients. The spines on stems and alkaloids in leaves are accounted as grazing avoidance mechanism in the plant species (Levitt, 1972).

In conclusion, plants with the root system may be able to take benefit of the available moisture in the top surface and deeper layers. Small and thick leaves with bright color of stem and leaves of the plant species increased water use efficiency in drought conditions. Spines on the stems and leaves prevent overgrazing. Regeneration by seed as well as rejuvenation by sporting from collar point of the plant species or from root surface, all are adapted features enabling *A. persicum* to grow and survive in the harsh ecosystem.

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