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The Possibility of Ameliorating the Regeneration of Juniper Trees in the Natural Forests of Saudi Arabia

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Abstract: This study was carried out in Ridah Reserve in the southwestern region of Saudi Arabia through surveying the forest cover, describing the growth of trees, investigating seed bank and regeneration capacity of *Juniperus procera* trees. Qualitative characteristics of cones and seeds of juniper trees such as shape and colour of cones and seeds after ripeness were defined. Quantitative characteristics such as the diameter of cone, the dimensions of seed, number of seeds within the cone, number of cones and seeds in unit weight, percentage of viable seeds and, moisture content of cones and seeds were also defined. Number of juniper seedlings was counted and seed bank was investigated. Seedlings, whole cones and seeds of juniper were planted in forest ground and their growth was evaluated. The results showed that the number of naturally grown juniper seedlings in Ridah Reserve is limited despite the existence of a high percentage of cones and seeds in the soil. Slow relative growth rate of green shoots of juniper trees was noticed. Relative height growth rate of the seedlings that were planted in the forest was significantly lower than that of those grown naturally, but both had almost similar diameter relative growth rates.

Key words: *Juniperus procera*; regeneration; cones; seeds; seedlings, growth

INTRODUCTION

Juniperus *procera* trees comprise about 95% of the tree species in the natural forests in the southwestern region of Saudi Arabia, they dominated the high elevations while other species such as *Olea europaea ssp.* forma *dulcis Olea europaea L. ssp. africana (Burm. f) T. S. Green* and *Acacia origena Acacia origena A. Hunde* are found in the lower ones[1]. These forests were important source of woods for construction, cocking and hotness over ages but they subjected to over exploitation, heavy grazing and fires; with absence of any care in terms of silivicultural practicing[2,3].

The main problems that are facing these forests in the present are the loss of environmental equilibrium as a result of changes made in the natural streams caused by building roads, declining biodiversity due to use the forests as parks that forced many of the forest animals to escape and others (like monkeys) to increase with increasing the wastes and, finally decreasing the area of these forests as a result of the random expanding in constructional and agricultural activities and, fires[4]. The features of the deterioration of the juniper forests can be seen in large areas lost their trees and other areas stricken by die-back where many of their trees are partly or completely dead[5]. In addition, these forests suffer from low capacity of the natural regeneration that some researchers attributed it to biological stresses caused by specific insets infecting juniper cones[12]. While Gardner and Fisher[11] suggest climate changes, human interferences and pressure of grazing as responsible factors of the low capacity of natural regeneration in juniper forests. The present work aims at studying the possibility of improving the regeneration of *Juniperus procera* trees in the natural forests of the southwestern region of Saudi Arabia through investigating the growth of trees,

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the characteristics of cones and seeds, seed and seedling bank, planting whole cones, extracted seeds and seedlings in the forest and evaluating their germination and growth.

MATERIALS AND METHODS

Site Description: A field experiment to study the problem of decreasing the capacity of natural regeneration in the juniper forests in the southwestern region of Saudi Arabia was carried out in Ridah Reserve. The Reserve occupied an area of nine Km^2 and located about 20 km west of Abha, at 18^o 12' N, 42^o 24' E. The altitude at the plantation site ranges from 2,551 m to 2,821 m, and the slope varies between 19 and 35%.

Field Experiment: In March 2004, five sampling plots of 400 m^2 were randomly chosen in an area of 12.5 ha within Ridah Reserve (Table 1). These five plots were considered as the blocks of a complete randomized block statistical design adopted for carrying out the study. The forest cover of these five blocks was investigated by means of the tree species structure, characteristics of the growth of *Juniperus procera* Hochst. ex Endl. trees and the capacity of natural regeneration in terms of the existence of cones and seeds in the soil and, the number of naturally grown seedlings. Cones from juniper trees were collected and subjected to a study included their characteristics as well as the seeds. Improving the regeneration of *Juniperus procera* trees in the natural forest was studied through planting their cones, seeds and seedlings in the experiment blocks.

Investigation of the Forest Cover: Tree species structure was studied through a survey of the forest cover in which the species were counted. Total stem height of *Juniperus procera* trees was measured using a telescopic aluminum hypsometer to the nearest one cm. While their diameters at breast height (1.35 m) were measured using a tree caliper. Longitudinal growth of green branchlets of juniper trees was determined by choosing three trees randomly in each block and measuring eight branchlets in each tree; onse after six months of the beginning of the experiment and the other by the end of the experiment. Height growth increment was calculated. Relative longitudinal growth rate of the branchlets was also calculated using the following equation[10]:

$$RGRL = Log_e L_2 - Log_e L_1 / t_2 - t_1$$

Where: RGRL = relative growth rate of branchlet length

- Log_e = the natural logarithm
- L_1 = mean length of the branchlet at t1
- L_2 = mean length of the branchlet at t2
- $t_2 - t_1$ = the period between the two measures (6 months)

To study the capacity of natural regeneration, the number of naturally grown seedlings and the trees bearing cones in each block was counted. In this regard, seed bank was also investigated. This was carried out by choosing three sites randomly of one square meter each in each block and three samples were taken from the upper 10 cm of the soil. The samples were investigated for their contents of juniper cones and seeds and the seeds of the other plant species using three sieves with different opining sizes. The number of each component was counted and its percentage was calculated.

Planting Juniper Seedlings in the Forest: 50 seedlings of 14 month-old produced from seeds in Ridah Reserve were planted in the five blocks of the experiment in March 2004 at a rate of 10 seedlings for each block The seedlings were planted randomly in each block with avoiding water streams, dense plant cover and rocky ground in order to facilitate proper conditions for their growth. They were watered once biweekly between rainfalls. Stem height and diameter of the planted seedlings were measured three times; at the beginning of the experiment, after five months and after 11 months of planting day. In addition, 7 naturally grown juniper seedlings grown in one of the five blocks and had an age almost similar to that of the planted juniper seedlings were subjected to the same measurements as the planted ones.

Height Relative Growth Rate of Both Planted and Naturally Grown Seedlings:

$$HRGR = Log_e H_2 - Log_e H_1 / t_2 - t_1$$

Where: RGRH = relative growth rate of height

- Log_e = the natural logarithm
- H_1 = mean height of the seedlings at t1
- H_2 = mean height of the seedlings at t2
- $t_2 - t_1$ = the period between the two measures (6 months)

Table 1: Characteristics of the field experiment blocks in Ridah Reserve

Block	Elevation (m above sea water level)	Slope	Coordinates					
			N			E		
			D	M	S	D	M	S
B 1	2756	25º	18	12	16.1	42	24	35.8
B 2	2743	35º	18	12	13.6	42	24	38.7
B 3	2644	30º	18	12	14.6	42	24	30.9
B 4	2551	26º	18	11	59.4	42	24	34.2
B 5	2821	19º	18	12	18.0	42	24	40.8

Diameter Relative Growth Rate of Both Planted and Naturally Grown Seedlings:

$DRGR = Log_e D_2 – Log_e D_1 / t_2 - t_1$

Where: RGRD = relative growth rate of diameter

- Log_e = the natural logarithm
- D_1 = mean diameter of the seedlings at t1
- D_2 = mean diameter of the seedlings at t2
- $t_2 - t_1$ = the period between the two measures (6 months)

Planting Juniper Cones and Seeds in the Forest Ground: 50 whole juniper cones of *Juniperus procera* trees were planted in the blocks of the field experiment at a rate of 10 cones for each block. In addition, 150 newly extracted juniper seeds were planted at a rate of 30 seeds for each block distributed into 10 pits. The planted cones and seeds received watering as with the seedlings. Relative growth rate of stem height (HRGR) and diameter (DRGR) of both planted and the naturally grown seedlings were calculated using the Evan's equation mentioned above.

Studying the Characteristics of Juniper Cones and Seeds: The characteristics of juniper cons collected from trees grown in Ridah Reserve as well as extracted seeds were subjected to detailed study.

Determining the Proportion of Ripening Cones: 100 cones of the collected batches were assorted according to changes in their colour, shape, moisture content, odor, hardness degree of the outer coat and, the viscosity of internal fleshy tissues.

Determining the Moisture Content of Cones and Seeds: 100 fresh cone and 100 newly extracted seed were weighed using a digital balance then, placed in an oven at 60°C for 72h and their oven-dry weights were determined. Moisture content was calculated as the following: MC% = (fresh weight – dry weight/ dry weight) ×100

Defining the Number of Cones and Seeds per Unit Weight: After drying the cones and seeds in the oven, the numbers of cones in five weights of 10 grams each were counted then the average was taken as the number of cones per 10 grams. The number of cones per kilogram was calculated by multiplying the number times 100. The number of seeds per kilogram was determined by the same way.

Determining the Proportion of the Viable Seeds: The proportion of viable seeds was determined through two methods included immersing seeds in water and count the proportion of floating seeds which will be unviable and, soaking the seeds in 1% 2,3,5,-triphenyl tetrazoliam chloride then counting the proportion of viable seeds indicated by red coloured embryos.

Defining the Colour and Shape of the Cones and Seeds: The colour of the seeds and cones were defined in comparison with a colour index. The shape of the seed was defined by making a longitudinal section in the seed and related the produced shape to the nearest well-known geometric shape.

Determining the Dimensions of the Cones and Seeds: The average diameter of the cone was determined through measuring the diameters of 100 cones using a digital micrometer. The seed length was measured at a point between the middle of its wide end and the middle of other end, while its width was measured at a point in the middle of the length line. These measurements were made on a 100 seeds using a digital micrometer.

Table 2: Tree species grown in Ridah Reserve and tree density of the forest cover

Species	N	proportion of total	Tree density (tree ha-1)
Juniperus procera	98	96.07	510
Acacia origena	3	2.94	
Rhamnus lycioides ssp. Oleoides	1	0.98	
Total	102	100	

RESULTS AND DESCUSSION

Results:

Investigation of the Forest Cover: Structure of forest cover in Ridah Reserve: Surveying the forest cover in the five blocks of the field experiment in Ridah Reserve showed that there are three tree species which are *Juniperus procera, Acacia origena* and *Rhamnus lycioides* L. ssp. *oleoides* L. *Jahand & Maire* distributed as 96, 3 and 1%, respectively. The tree density of the forest cover in Ridah Reserve was accounted as the number of trees per unit area (Table 2). Because *Juniperus procera* trees represent the majority of the forest species in the Reserve, thus the ongoing research works were devoted only to this species.

Trees Bearing Cones: Surveying the trees that were bear cones in March 2004 in the Reserve showed that they represent only 2.04% of the total number of trees in the five blocks of the field experiment. However, this percentage increased substantially by the following spring.

Status of the Trees in Ridah Reserve: Investigation the status of the trees grown in the five blocks of the field experiment in Ridah Reserve showed that 59% of the trees are healthy intact, 7% irregular (clad, slotted, fork, slantwise), 2% deteriorated (partially cut, scalded, broken, destroyed). While the rest of the trees which represent 32% are suffering from dieback (Table 3).

Growth of the Trees in Ridah Reserve: Measuring the dimensions of juniper trees in Ridah Reserve showed that their stem diameters ranged between 1.5 and 70 cm tree^{-1} and their stem heights ranged between 1.2 and 8.24 m tree^{-1} (table 4).

Longitudinal Growth of Juniper Trees Branchlets: Measuring the length of the green branchlets of juniper trees through a period of six months showed that the calculated annual height increment was 0.162 cm year^{-1}. This means that the branchlets had a relative longitudinal growth rate accounted for 0.00134 cm cm^{-1} month^{-1} (table 5).

Table 3: The status of trees grown in the field experiment blocks in Ridah Reserve

Status of tree	Number of trees	Per cent
intact	60	58.82
irregular	7	6.86
deteriorated	2	1.96
died-back	33	32.35
Completely dead	0	0
Total	102	100

Characteristics of Juniper Cones and Seeds: Investigation the collected cones of juniper trees in Ridah Reserve showed that the proportion of ripening cones accounted for 72%. The shape of the cone of *Juniperus procera* tree is almost globular and it is light green before ripening changes to violet to brown colour coated with a white film of wax after ripening. On the other hand, the seed of *Juniperus procera* tree almost looks like an irregular prism and its colour is a light yellow.

The diameter of the cone ranged between 5.56 and 10.04 mm with a mean of 7.35 mm. The dimensions of the seeds are 4.25, 2.69 and 2.25 mm for length, width and thickness, respectively. These ranged between 2.4 – 5.5, 1.5 – 3.9 and 1.3 – 3.8 mm, respectively. Moisture content of the cones accounted for 4.85% while that of the seeds was 6.36%.

The proportion of viable seeds using immersion in water was 83.42%, while determining this trait by soaking the seeds in 1% 2,3,5,-triphenyl tetrazoliam chloride showed that the proportion of viable seeds was 69%.

The number of cones of *Juniperus procera* tree per kilogram accounted for 6556.5, while there were 65 659.88 seed per kilogram.

Seed Bank: Investigation the seed bank in the soil of Ridah Reserve showed that the cones and seeds of *Juniperus procera* tree represent 18.7 and 65.7% of the total number of fruits and seeds found in the soil samples, respectively. The rest was seeds of other plant species (table 6). The number of naturally grown seedlings of *Juniperus procera* found in the Reserve at the time of survey was very limited.

Evaluation of Planting the Seedlings in the Forest: Evaluation of planting the seedlings in Ridah Reserve

Table 4: Mean ± Standard error of stem diameter and height of juniper trees grown in the field experiment in Ridah Reserve

Trait	Mean ± Standard error	Range
Stem diameter at breast height (cm tree^{-1})	4.47±1.39	1.2-8.24
Stem height (m tree^{-1})	14.41± 9.22	1.5-70

Table 5: Longitudinal growth of juniper trees branchlets

Growth of branchlet in length	Mean ± SD
Branchlet length at the beginning of the measurement (cm branchlet^{-1})	9.44±2.81
Branchlet length after six months of the first measurement (cm branchlet^{-1})	9.63±2.83
The increase in branchlet length over six months (cm branchlet^{-1})	0.19±0.137
Relative longitudinal growth rate of branchlet (cm cm-1 month^{-1})	0.0035±0.0026

Table 6: Seed bank in the soil of Ridah Reserve

Species	Per cent
Cones of *Juniperus procera*	18.7
Seeds of *Juniperus procera*	65.7
Seeds of other plant species	15.6

Table 7: Relative growth rate of stem diameter (mm mm-1 month-1) of the planted and the naturally grown seedlings in the field experiment in Ridah Reserve

Period of measurement	Seedlings type	N	Relative growth rate (mm mm-1 month-1)
The first 5 months of the experiment	planted	41	0.034a
	naturally grown	7	0.030a
The following 6 months of the experiment	planted	41	0.01a
	naturally grown	7	0.011a
Over the course of the experiment	planted	41	0.021a
	naturally grown	7	0.020a

Table 8: Relative growth rate of stem height (cm cm-1 month-1) of the planted and the naturally grown seedlings in the field experiment in Ridah Reserve

Period of measurement	Seedlings type	N	Relative growth rate (cm cm-1 month-1)
By the end of the first 5 months of starting the experiment	planted	41	10.029b
	naturally grown	7	0.046a
After 6 months from The first measurement	planted	41	0.006a
	naturally grown	7	0.005a
Over the course of the experiment	planted	41	0.017b
	naturally grown	7	0.024a

1Means followed by different superscripted letters in every two consecutive vertical boxes are significantly different at probability level ≤0.05 according to Duncan's Range test.

was carried out by means of calculating the survival percentage by the end of the experiment which was 82%.

Growth of the Planted and Naturally Grown Seedlings in Ridah Reserve: Analysis of variance procedure for diameter relative growth rates of the planted and naturally grown seedlings in the field experiment in Ridah Reserve showed that there were no significant differences between the two types of the seedlings in this trait by the end of the experiment (table 7).

On the other hand, mean relative growth rate of the height of the naturally grown seedlings was significantly greater than that of the planted ones in the first period (5 months) since planting date (P<0.05) and by the end of the experiment (11 months) since planting date (P<0.05) (table 8).

Evaluation of Planting Juniper Cones and Seeds in the Forest: Planting the whole cones and the newly extracted seeds of juniper trees in the forest ground in Ridah Reserve did not result in any germination in spite of the availability of the growth factors.

Discussion: In the present study, surveying the forest cover in Ridah Reserve which is located in Asir region showed that it has 96% *Juniperus procera*

trees. This concurs with the statement of Abo Hassan *et al.*[1] that "Asir region has a forest cover of 95% *Juniperus procera*. The existence of irregular and deteriorated trees in the Reserve may attributed to various factors such as the mechanical effects of wind, soil erosion, competition between trees, animal grazing and others. Barth and Horst[6] found that more than 50% of *Juniperus procera* trees in Assoudah National Park are damaged and most of their branches are dead. Aref and El-Juhany[5] asserted that causes of this deterioration in *Juniperus procera* trees may attributed to extensive forest clearing for cultivation, over-grazing, and exploitation of forests for fuel-wood and construction materials without replanting.

Die-back of *Juniperus procera* trees is a phenomenon occurred since about 30 years in the in the natural forests in the the southwestern region of southwestern forests of Saudi Arabia and affecting other tree species, however, yet there is no single reason can be the accused in this problem.

Tree density in Ridah Reserve accounted for by 510 tree ha^{-1} and it considers scattered according to Abo Hassan *et al.*[1] who defined tree density of < 100 tree $dounum^{-1}$ as scattered tree cover (one dounum = 1/100 ha) and they found that the tree density of Assoudah forest near Ridah Reserve is scattered.

Measuring diameter and height of *J. procera* trees showed that they have 14.4 cm and 8.24 m as averages, respectively. This result is in agreement with the finding of Chaudhary[8] who mentioned that the height of *Juniperus procera* trees grown in the natural forests of the southwest region of Saudi Arabia exceeds eight meters.

Growing the branchlets of *J. procera* trees in Ridah Reserve by relative growth rate of 0.00134 cm cm^{-1} $year^{-1}$ is lower than that of *J. procera* seedlings which were planted in Baha forests in the southwest region of Saudi Arabia and was 0.246 cm cm^{-1} $year^{-1}$[5]. In another study with the same species in Yemen Republic, Herzog[13] asserted that juniper seedlings are growing very slowly, a few centimeters a year only.

The lower percentage of the juniper trees bearing cones in Ridah Reserve is a result of doing the survey at an early episode of ripening in which the fruits may still too small. *Juniperus procera* trees produce flowers by the end of April until the end of May then fruits start to appear from the end of May until September and start to ripen from late September to the end of winter.

In the present study, the investigation of the juniper cones showed that the shape of the cone is globular. This result concurs with the finding of Borota[7].

Regarding the colour of the cone of *Juniperus procera* trees, it is light green before ripening changes to violet to brown colour coated with a white film of wax after ripening. Chaudhary[8] described the colour of the cone as it is bluish to purple blackish when repine.

The shape of the seeds of *Juniperus procera* trees can be described as locks like an irregular prism and their colour tends to light yellow. This differs from the seeds of Rocky Mountain juniper which is black[9].

The diameter of the cones of *Juniperus procera* trees ranged between 5.56 and 10.04 mm with an average of 7.35 mm. Chaudhary[8] mentioned that the length of the ripen cone of the same species ranged between 3 and 7 mm, while[17] found that the diameter of Rocky Mountain juniper ranged between 5 and 8 mm.

The number of the seeds in the single cone is between 2 and 13. It was found that with increasing the number of seeds in the cone, the majority of them are none-ripen or imperfect in growth. In a study with the same species, Chaudhary[8] asserted that the cone contains between 2 and 4 seeds. It seems that the different juniper species vary in the number of seeds within the cone and may vary from scientist to another.[17] found this number ranges between 1 and 2 seeds in the cone of *J. scopulorum* Sarg trees while Daniel[9] found 2 to 3 seeds in the cone of the same species.

The average dimensions of the seed of *Juniperus procera* tree was 4.25, 2.69 and 2.25 mm for length, width and thickness, respectively. Daniel[9] found that the length and height of the seed of *J. scopulorum* Sarg tree was 5 and 3 mm, respectively.

Counting the number of cones and seeds in the unit weight showed that there are 6556.5 cone kg-1 and 65 659.8 seed kg^{-1}. In comparison, Scianna[17] found that there are 60 000 seed kg^{-1} as an average of 39 000 and 93 000 seed kg^{-1} of *J. scopulorum* Sarg.

The percentage of the viable seeds of *Juniperus procera* trees ranged between 69 and 83.4%. Memon[15] in his study on the same species in Ziarat forest in Pakistan asserted that about 90% of the produced seeds are unviable.

In the present study, the depth of the top soil of Ridah Reserve was found to be ranged between 1.3 and 3.7cm. In a similar study in Ethiopia, Yirdaw[20] found that the depth of the litter under *Juniperus procera* tree was 1.5 cm. Investigation of seed bank in the soil samples taken from the forest soil of Ridah Reserve showed that 66% of the seeds found belong to *Juniperus procera* tree. Owens and Schliesing[16] concluded that 80% of the seeds of *Juniperus ashei are* found under canopy. In the present study, there was a limited number of *Juniperus procera* seedlings in the forest floor despite of the existence of a quite high percentage of seeds in the soil. This in addition to the failure of the germination of the whole cones

and seeds planted in the forest may a result of the lake of the environmental factors favorable to seed germination that needs further studies.

In his study on the effects of different methods of preparing forest land for planting seedlings of *Juniperus procera* in Ethiopia, Sharew[18] found that about 25% of the naturally grown seedlings were found in the ground that was cleared from trees while no seedlings at all were grown naturally in those plots that have their trees uncut. He also found that the success of germination of juniper seeds was better on the soil disturbed either by fire or mechanical preparation. Scianna[17] found that the germination percentage of the seeds of *J. scopulorum* Sarg in nature was 22%. Teketay and Granström[19] suggest distributing the seeds of *Juniperus procera* to long periods in which they restoring their germination ability successfully in the soil within four years under natural conditions. However, Laurent and Chamshama[14] asserted that the expiry of the seeds of *Juniperus procera* is from 6 to 12 month only and they suffer from dormancy due to the hardness of the seed coat. After 11 months of planting the seedlings of *Juniperus procera* in Ridah Reserve, their mean relative growth rate of height was 0.016 cm cm^{-1} $month^{-1}$ comparing with 0.024 cm cm^{-1} $month^{-1}$ for the naturally grown seedlings in the Reserve. The greater height relative growth rate of the naturally grown seedlings in the Reserve may a result of the settlement of those seedlings as they were existed in the site before the planted ones and their roots might extended and became able to exploit the under ground resources more efficiently. The result of the present study more or less concurs with that found for *Juniperus procera* seedlings (average relative growth rate of height = 0.0205 cm cm-1 month-1) after two years of planting in the natural forests of Baha in the south western region of Saudi Arabia by Aref and El-Juhany[5].

Survival percentage of the *Juniperus procera* seedlings that were found growing naturally in Ridah Reserve in the present study was 100% while that of the planted ones was 82%. This seems lower than the survival percentage reported by Aref and El-Juhany[5] for the seedling of the same species planted in Baha forests which was 98%.

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