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Research and Full Length Article:

Effects of Pruning on *Haloxylon aphyllum* L. Dimensions and its Application in Biological Reclamation of Desert Regions in Yazd Province

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Abstract. Knowledge of the Saxaul dimensions used in sand dunes stabilization is considered essential for designing live windbreak in desert regions. This research aimed to collect and analysis data and was performed on the pruned and control shrubs of *Haloxylon aphyllum* L. in Yazd province, Iran in the last two decades. Our review clearly showed the superiority of shrubs pruned at the height of 35 cm in comparison with the other treatments as well as the superiority of soil surface height pruning with shoot thinning in the first year as compared with the other years. In the present study, data of canopy diameter and height of *Haloxylon aphyllum* L. from three treatments including "35 cm height pruned method", "shoot thinning method" and "control" were collected and analyzed using a completely randomized block design with three replications over 7 years (1995 to 2000 and 2005). Results of this study showed that the maximum canopy diameter of shrubs was obtained in the 35 cm height pruned method and soil surface pruning plus shoot thinning method with the average values of 261 and 240 cm, respectively with no significant differences. In addition, no significant difference was found for their heights (164 and 174 cm) and the dimension of pruned shrubs never reached to the height that was obtained before pruning. It was concluded that in designing the live windbreak with *Haloxylon aphyllum* L., considering the normal dimension of 35 cm height pruned shrubs at the executive levels as a practical pruning method is of high importance.

Keywords: Saxaul, Afforested areas, Pruning, Plant dimension, Wind break, Yazd

Introduction

Nearly 13 millions ha of sand dunes are distributed throughout Iran of which more than 5 millions ha are active and semi-active sand dunes (Ekhtesasi, *et al.*, 1996). Sand storm and the movement of flowing sands have been always considered as one of the main problems in these regions and its surrounding (adjacent) lands. In order to control this dilemma of Iranian desert regions, biological stabilization with Saxaul has started since 1959 (Jariani and Nateghi, 2003). Although the Saxaul is known as one of the unique compatible shrubs, the first wilting phenomenon in the afforested Saxaul areas has been reported in Hares Abad region of Sabzevar, Iran after 5-6 years of establishment and then, it spread across the country (Iran) with a greater extent (Amani and Parvizi, 1996).

Several factors have been reported to affect the dieback of Saxaul shrubs. For example, Rahbar (1988) stated that high density could affect the dieback and growth reduction of the afforested Saxaul shrubs. Kebin (1989) investigated the growth of Saxaul within the planted forests of Minqin desert region of China with the densities of 350 to 5000 shrubs per ha. According to the obtained results, high density and excessive consumption of water in the soil were reported to be effective in the reduced healthy growth of them. Baghestani Maybodi *et al.* (2004) investigated the effects of density on the growth and vigor of *Haloxylon aphyllum* L. shrubs in Ashkezar region of Yazd province, Iran. They concluded that a density up to 250 trees per ha was ineffective in the plant growth and suggested to conduct further investigations for higher density stands.

In order to recover the increased longevity, vigor and growth stimulation of Saxaul shrubs, pruning operations had been considered in the past years. Soil surface height pruning method had been reported as a growth-stimulating factor in Saxaul shrubs (Alizadeh, 1981; Baghestani Maybodi, 1992; Arabzadeh, 1995; Amani and Parvizi, 1996). Arabzadeh *et al.* (2009) investigated the impact of pruning on the growth and vigor of haloxylon trees in Kerman, Iran and showed that the intensive pruning could increase the growth, vigor and freshness of haloxylon. According to Perry and Gardener (2008) and Sellmer *et al.* (2004), pruning is among the operations being effective in removing the dying status and wilting conditions of haloxylon trees. Elfadi and Luukkanen (2003) studied the effects of pruning on *Prosopis juliflora* and showed that heavily pruned trees yielded larger usable wood volume more than six times and produced 60% more leaf biomass than the control. Annie DesRochers and Tremblay (2009) in a study on the effects of shoot pruning on the early growth of hybrid poplars concluded that shoot pruning is a useful management option to reduce the planting stress of hybrid poplars. Albert *et al.* (2010) investigated the effects of pruning on the vegetative growth and yield of the half-high blueberry and showed that the yield was increased for 4 years after pruning. They concluded that severe pruning was more suitable for half-high blueberry fruiting plants in northern climate conditions. Jones *et al.* (1998) investigated the effects of crown pruning in semi-arid agroforestry and showed that tree species selection and management will be key factors in determining the feasibility of dryland agroforestry systems.

Baghestani Maybodi *et al.* (2008b) reported that the most massive shrubs were obtained in shoot thinning method by reducing the shoots to 1 to 2 branches during the first year after soil surface height pruning. Pruning at a height above basal area has been also studied in silvicultural operations, but the soil surface height pruning method has been generally considered in these studies. The results of three methods including soil surface height pruning method and 35 cm

and 70 cm height pruning methods with control treatment (no pruning) investigated on 12-year shrubs of *Haloxylon aphyllum* L. indicate that the growth, viability, vitality and forage quality of the 35 cm height pruned shrubs were preferable (Baghestani Maybodi, 2008; Baghestani Maybodi and Rahbar, 2009; Baghestani Maybodi *et al.*, 2006). Boggess (1950) studied the effects of repeated pruning on the diameter and height growth of Slash Pine and concluded that pruning to tree height, and pruning to 3/4 tree height significantly reduced the diameter and height growth.

A number of reports also are available on the effects of Saxaul utilization in natural and afforested areas abroad. According to Ivakhov and Dash (1992), one to two times rotation grazing in the growing season has been recommended to improve the cover and production of *Haloxylon ammodendron* planted in Mongolia. The adverse impact of clearing a number of *Haloxylon aphyllum* L. shrubs on Saxaul communities has been reported by Shubenkina (1990) in Turkmenistan. He further stated that after 30 years, re-vegetation was not enough in this area.

In conclusion, pruning operations as a silvi-cultural method stimulate the growth of Saxaul shrubs and its application seems necessary for the sustainable management of afforested Saxaul shrubs in the desert areas. However, using this species as live windbreaks, the dimension changes in the pruned and control shrubs should be taken into consideration. In this research, the dimension changes of Saxaul shrubs pruned at 35 cm height and at soil surface height with shoot thinning have been studied in Ashkezar region of Yazd province as a model of the afforested Saxaul area in the desert regions.

Materials and Methods

Study area

This research was conducted in the afforested Saxaul area which was 12 years old with a density of 250 shrubs per ha in 1994 (Figs. 1 and 2). The seeds of Saxaul were sown in the pots and seedlings were transferred to the field after 6 months in the fall of 1982. The seedlings were irrigated until two years after the transfer. The shrubs were pruned at the age of 12. The study area is a plain located in 31°57′ 33″ Northern latitude and 54° 13′ 57″ Eastern longitude with the slopes less than 2% covered with flowing sands with an altitude of 1140 m above sea level. The mean rainfall in the past thirty years is 61.7 mm. The mean annual temperature is 18.1°C and maximum and minimum temperatures are +46.5°C and -15.5°C, respectively. This area has a cold and dry climate according to Emberger climate classification and according to the Demarton classification, its climate is ultra-dry cold (Dashtakian and Abolghasemi, 2003). In terms of natural vegetation, the study area is considered as an area without vegetation although some single plants of *Salsola tomentosa*, *Anabasis setifera*, *Artemisia sieberi*, *Stipagrostis plumosa* and *Launaea acanthodes* are observed on the path of channels.

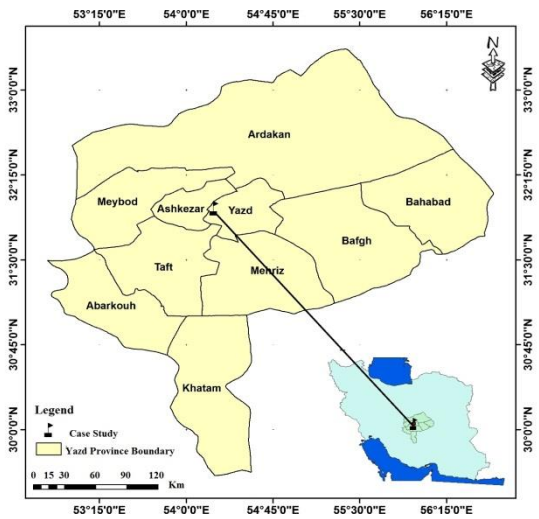

Fig. 1. Location of the study area in Yazd province, Iran

Fig. 2. A view of the study area in research project (before pruning in fall of 1994)

Research method

In present study, a field with an area of about 3 ha was selected within the afforested Saxaul area in the studied region. Shrubs in this area were examined by different pruning methods including soil surface height, 35 and 70 cm height pruning methods and control treatment (no pruning). The obtained results reported in this research indicate that the growth, viability, vitality and forage quality of the 35 cm height pruned shrubs were preferable (Baghestani Maybodi, 2008; Baghestani Maybodi and Rahbar, 2009; Baghestani Maybodi *et al.*, 2006) by the end of 2000. After five years in 2005, data were collected on the same treatments for canopy diameter and canopy height (Baghestani Maybodi *et al.*, 2008a).

The effects of soil surface height pruning with shoot thinning in the first year method on the diameter and height growth of Saxaul shrubs were studied in an area of approximately 3500 m^2 in the vicinity of the 3 ha region. The shrubs in this area were cut by a chainsaw in the fall of 1994 and this area was protected as an exclosure until 2000. The results of this research indicate the preference of soil surface height pruning with shoot thinning in the first year as compared with the other years (Baghestani Maybodi *et al.*, 2008b). According to the data of two experiments and the canopy height and diameter of shrubs for the years 1995-2000 and 2005, the between years analysis of variance was made using a completely randomized block design with three replications for each of these three methods i.e., 35 cm height pruning, soil surface height pruning with shoot thinning shrub and control. The between methods analysis of variance also was made in each year. Means comparisons were made using Duncan test. Data were analyzed in the SAS Software (SAS Institute, 1996).

Results

The results of between years analysis of variance concerning the canopy diameter and height of *Haloxylon aphyllum* L. shrubs for each of the treatments from 1995 to 2005 are shown in Table 1. The results of the means comparison of data are presented in Table 2. According to the results, the diameter and height of control shrubs did not show a significant decreasing trend until 1999 (coinciding with the age of 17 years old). However, the reduction of variations started from the age of 18 years (2000) and under the influence of drying and weathering of branches, the shrub dimensions reduced steadily. The results of ANOVA of height and their means comparison for 3 studied treatments in each year are shown in Tables 3 and 4, respectively. The height of the shrubs pruned with the mentioned shoot thinning method generally showed no significant differences as compared to the 35 cm height pruned shrubs. The analyses of canopy diameter data are shown in Tables 5 and 6. The diameter of the shrubs pruned with the mentioned shoot thinning method was shorter until 4 years after pruning and after that, no significant differences were recorded as compared to the 35 cm height pruned shrubs.

Table 1. Summary of ANOVA results of Saxaul shrubs canopy diameter and height in studied treatments during the experiment in afforested areas of Ashkezr region of Yazd province

Sources	df	MS					
		Control		35 cm Height Pruning		Soil Surface Pruning	
		Height	Diameter	Height	Diameter	Height	Diameter
Years	6	1622.87**	2047.44**	1340.22**	5212.61**	3630.82**	17546.83**
Block	2	136.71	2987.09	720.49	1273.33	18.03	677.44
Error	12	109.44	124.93	13.12	63.23	55.84	145.09
C.V. %		3.90	2.90	2.30	3.50	4.90	6.80

** indicates significant difference among treatments at the P < 0.01 level

Table 2. Mean comparisons of Saxaul shrubs canopy diameter and height (cm) in studied treatments during the experiment in afforested areas of Ashkezr region of Yazd province

Years	Control		35 cm Height Pruning		Soil Surface Pruning + Shoot Thinning	
	Height	Diameter	Height	Diameter	Height	Diameter
1995	280 ± 3.4 ^{a}	381 ± 22.7 ^{ab}	111 ± 4.4 ^{a}	143 ± 7.3 ^{d}	86 ± 1.3 ^{c}	17 ± 1.1 ^{c}
1996	270 ± 6.4 ^{ab}	402 ± 11.1 ^{a}	150 ± 4.9^{c}	208 ± 6.1 ^{c}	134 ± 2.4 ^{d}	172 ± 5.6 ^{b}
1997	272 ± 4.7 ^{ab}	392 ± 10.3 ^{a}	164 ± 5.8 ^{b}	233 ± 4.9 ^{b}	153 ± 1.9 ^{c}	170 ± 8.2 ^{b}
1998	277 ± 2.1 ^{ab}	389 ± 7.9 ^{a}	167 ± 6.1 ^{ab}	231 ± 4.9^{b}	164 ± 4.2 ^{bc}	185 ± 10.8^{b}
1999	267 ± 1.9 ^{ab}	399 ± 9.3 ^{a}	172 ± 7.8 ^{a}	258 ± 12.1^{a}	190 ± 7.9 ^{a}	233 ± 13.8^{a}
2000	259 ± 9.9 ^{b}	364 ± 12.5 ^{b}	168 ± 7.5 ^{ab}	257 ± 9.7 ^{a}	176 ± 2.0 ^{b}	226 ± 7.8 ^{a}
2005	212 ± 9.2 ^{c}	327 ± 14.1 ^{c}	164 ± 5.9 ^{b}	261 ± 13.2 ^{a}	174 ± 4.7 ^{b}	240 ± 6.9 ^{a}

Similar letters in each column indicate that the means are not significantly different at the P < 0.05 level based on Duncan's multiple range tests

Table 3. Summary of ANOVA results of Saxaul shrubs canopy height in studied treatments during the experiment in afforested areas of Ashkezr region of Yazd province

Sources	DF	MS						
		1995	1996	1997	1998	1999	2000	2005
Treatments	2	33301.1**	16580.7**	12926.3**	12474.3**	7668.3**	7514.1**	1933.4**
Block	2	45.78	38.38	7.45	60.39	47.01	211.02	352.21
Error	4	25.85	86.25	85.37	58.92	168.22	131.52	36.57
C.V. %		3.2	5.0	4.7	3.8	6.2	5.7	3.3

** indicates significant difference among treatments at the P < 0.01 level

Table 4. Mean comparisons of Saxaul shrubs canopy height (cm) in studied treatments during the experiment in afforested areas of Ashkezr region of Yazd province

Treatments	1995	1996	1997	1998	1999	2000	2005
Control (no pruning)	280 ± 3.4^{a}	270 ± 6.4^{a}	272 ± 4.7^{a}	277 ± 2.1^{a}	267 ± 1.9 ^{a}	259 ± 9.9^{a}	212 ± 9.2^{a}
35cm height pruning	111 ± 4.4^{b}	150 ± 4.9^{b}	164 ± 5.8^{b}	167 ± 6.1^{b}	172 ± 7.8^{b}	168 ± 7.5^{b}	164 ± 6.0^{b}
Soil surface pruning +shoot thinning	86 ± 1.2^{c}	134 ± 2.3^{b}	153 ± 2.0^{b}	164 ± 4.3^{b}	190 ± 7.9^{b}	176 ± 2.1^{b}	174 ± 4.7^{b}

Similar letters in each column indicate that the means are not significantly different at the P < 0.05 level based on Duncan's multiple range tests

Table 5. Summary of ANOVA results of Saxaul shrubs canopy diameter in studied treatments during the experiment in afforested areas of Ashkezr region of Yazd province

Resources	Df	MS						
		1995	1996	1997	1998	1999	2000	2005
Treatments	2	102085.7**	46038.1**	39121.8**	34414.3**	24238.8**	15790.2**	6252.5**
Block	2	827.11	385.84	35.67	14.37	89.92	140.13	409.89
Error	4	442.79	96.86	277.39	292.39	587.54	394.27	425.89
C.V. %		11.7	3.8	6.2	6.4	8.2	7.0	7.5

** indicates significant difference among treatments at the P < 0.01 level

Table 6. Mean comparisons of Saxaul shrubs canopy diameter (cm) in studied treatments during the experiment in afforested areas of Ashkezr region of Yazd province

Treatments	1995	1996	1997	1998	1999	2000	2005
Control (no pruning)	381 ±22.7^{a}	402 ±11.1^{a}	392 ±10.3^{a}	389 ±7.9^{a}	399 ± 9.3^{a}	364 ±12.5^{a}	327 ±14.1^{a}
35 cm height pruning	143 ± 7.3^{b}	208 ± 6.1^{b}	233 ± 4.9^{b}	231 ± 4.5^{b}	258 ±12.1^{b}	257 ± 9.7^{b}	261 ±13.2^{b}
Soil surface pruning + shoot thinning	17 ± 1.1^{c}	172 ± 5.6^{c}	170 ± 8.2^{c}	185 ±10.8^{c}	233 ±13.8^{b}	226 ± 7.8^{b}	240 ± 6.9^{b}

Similar letters in each column indicate that the means are not significantly different at the $P < 0.05$ level

Discussion

The canopy height and diameter of the Saxaul shrubs at the age of 12 coinciding with the time of pruning operations in late November 1994 were 375 cm and 280 cm, respectively. The canopy height and diameter of this afforested area were reported as 390 and 287 cm in 2 years ago (1992), respectively (Zarezadeh *et al.*, 2002). Therefore, according to these data, the control (no pruning) shrubs reach to maximum diameter and height growth at the age of 10 or earlier. The control 23-year-old shrubs (2005) showed an approximate reduction of 74 cm in the height and 63 cm in the diameter as compared to the peak diameter and height growth (at the age of 10). The maximum height of mentioned shrubs was reported to be over 200 cm (Mozafarian *et al.*, 2000) and a height of 3-5 m was reported by Arabzadeh (1995). It is clear that the canopy diameter and height of this plant vary in different climatic and soil conditions as well as the species nature, and the results announced for the study area are extendable to the similar areas.

Pruning operations stimulate the regrowth of saxsaul shrubs (Alizadeh, 1981; Baghestani Maybodi, 1992; Arabzadeh, 1995; Amani and Parvizi, 1996). Several reports are available about the positive effects of pruning on the plant growth (Valentine, 1990; Baghestani Maybodi, 1996; Moghaddam, 2009). In the afforested areas of *Haloxylon aphyllum* L. in Ashkezr region of Yazd province, pruning to a height of 35 cm has been introduced as a superior method for silvi-cultural operations and the rejuvenation of 12-year *Haloxylon aphyllum* L. in this region and similar areas (Baghestani Maybod *et al.*, 2006; Baghestani Maybodi, 2007; Baghestani Maybodi and Rahbar, 2009). Increasing trend in the dimension of shrubs which were pruned with this method continued for 5 years after pruning. According to the obtained results in 1999 and 2005, no significant increasing changes were found for the canopy height and diameter of the shrubs which were pruned with this method during a 6-year period. Therefore, by the means of pruning, an increasing trend in the dimension of pruned shrubs will not continue for a long time, but over a period of five years, the stop in diameter growth and even a significant decline in height growth are obtained. Applying the mentioned pruning operations, the plants with open and tall branches become short and dense and therefore, their dimensions will never return to the size they had before pruning. This issue should be taken into consideration in the time of initial planting so that no problem is created in terms of soil conservation due to the reduction in plant dimension. The peak canopy height and diameter of the 35 cm height pruned shrubs reached to 261 and 172 cm, respectively. Such a height will be sufficient to prevent the movement of flowing sand because about 90% of the sand particles may rise to a height of 30 cm through creep and saltation (Ahmadi,1998) and only 1% rises over 1 m height (Rafahi, 1999). According to the investigation conducted by Ekhtesasi *et al.* (1996) on the movement of flowing sands in the study area, the amount of particles transported at a height over 1 m was reported to be 3%. Although by reducing the height of shrubs, less surface of soil is conserved in the direction of

wind, these shrubs are less fractured in dealing with severe storms.

The soil surface height pruning method with shoot thinning in the first year was introduced as a superior method among the other pruning methods (Baghestani Maybodi *et al.*, 2008b). These plants reached a maximum height of 190 cm in the period ending 1999 (five years after pruning) which is significantly higher than past years. In addition, in this year, the diameter of these shrubs was reached to the peak but it was not significant as compared to the following years. Considering these data and the conditions of the studied region and similar areas, an upward trend occurs in the height and diameter regrowth of the species pruned with this method like "35 cm height pruning method" in the first 5 years after pruning. These results are not in agreement with the findings reported by Jamzad (1992) recommending the shoot thinning in order to achieve the trees having a single, strong and long stem and in some species, they include different varieties of Salix, Tamarix, Poplar and Zelkova. It should be noted that in this study, the thinning of shoot was investigated while by subsequent operations such as cutting or shortening of secondary branches, it is likely to reach the dimensions and forms different from what was found in this study. The mentioned operation after general pruning is common for the fruit trees (Faust, 1989; Khoshkho *et al.*, 1992); however, the application of this method is not feasible for Saxaul shrubs, especially in large scale. Although the plant form of the mentioned shoot thinning shrubs returns to a normal shape but it will never return to the size they had before pruning. On the other hand, the possibility of contamination with pests and diseases is higher in shrubs pruned at soil surface height (Shamszadeh and Baghestani Maybodi, 2003). Therefore, the normal dimension of control (no pruning) and 35 cm height pruned shrubs should be taken into consideration in the sustainable management of reclamation area and designing live wind breaks with *Haloxylon aphyllum* L.

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تاثیر عملیات پرورشی بر اندازه گونه *Haloxylon aphyllum* L. و کاربرد آن در احیاء بیولوژیک مناطق بیابانی استان یزد

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چکیده. آگاهی از اندازه درختچه‌های تاغ مورد استفاده در تثبت ماسه‌های روان مناطق بیابانی به منظور طراحی بادشکن زنده در این مناطق امری ضروری محسوب می‌گردد. در این پژوهش مجموع کارهای تحقیقاتی صورت گرفته بر روی درختچه‌های هرس شده و شاهد گونه سیاه تاغ در منطقه بیابانی یزد در طول دو دهه مرور گردیده است. نتایج منتشر شده از این پژوهش‌ها بیانگر مزیت درختچه‌های هرس شده در ارتفاع ۳۵ سانتیمتری در مقایسه با دیگر ارتفاعات هرس و همچنین برتری شیوه کف‌بری با تنک جست‌ها در سال اول نسبت به سایر تیمارهای کف بری بوده است. در پژوهش حاضر داده‌های اندازه‌گیری شده قطر و ارتفاع تاج پوشش این پایه‌ها طی دوره ۱۱ ساله (۱۳۸۴-۱۳۷۳) در قالب طرح بلوک‌های کامل تصادفی با سه تکرار مورد تجزیه و تحلیل آماری قرار گرفته‌اند. تجزیه و تحلیل آماری داده‌های سه تیمار هرس از ارتفاع ۳۵ سانتیمتری، کف بری با تنک جست‌ها و شاهد در هر سال مطالعه نیز در قالب طرح بلوک‌های کامل تصادفی انجام شد. نتایج این بررسی نشان داد که در درختچه‌های هرس شده همواره از شاهد کوچکتر بوده‌اند. حداکثر قطر تاج پوشش این گونه در تیمارهای هرس از ارتفاع ۳۵ سانتیمتری و شیوه کف‌بری با تنک جست بدون تفاوت معنی دار به ترتیب برابر ۲۶۱ و ۲۴۰ سانتیمتر و اندازه ارتفاع آن‌ها نیز بدون تفاوت معنی دار به میزان ۱۶۴ و ۱۷۴ سانتیمتر می‌رسند. در طراحی بادشکن زنده با گونه سیاه تاغ توجه به اندازه طبیعی گیاهان هرس شده در ارتفاع ۳۵ سانتی‌متری که به عنوان شیوه هرس قابل انجام در سطوح اجرایی معرفی گردید.

کلمات کلیدی: تاغ، جنگل‌های دست‌کاشت، هرس کردن، اندازه گیاه، بادشکن زنده، یزد