Effects of Removing Aerial Biomass and Density on Carbon Sequestration and Weight of *Atriplex lentiformis*

1K. Mahdavi, 2A. Sanadgol, 3H. Azarnivand, 4S. Babaei Kafaki, 5M. Jafari, 6M. Maleki and 7A. Malekian

1Department of Range Science, Science and Research Branch, Islamic Azad University, Iran
2Scientific board of Forests and Rangelands Research Institute, Tehran, Iran
3Faculty of Natural Resources, University of Tehran, Karaj, Iran
4Department of Forest Science, Science and Research Branch, Islamic Azad University, Tehran, Iran
5Faculty of Natural Resources, University of Tehran, Karaj, Iran
6Department of Watershed, Khalkhal Branch, Islamic Azad University, Iran
7University of Tehran, Tehran, Iran

**Abstract:** The objective of this research was to investigate the effects of removing aerial biomass and density of *Atriplex lentiformis* plantation on carbon sequestration and biomass in a split-split plot design with three replications in Ardestan, Iran. The results revealed that the highest amount of carbon sequestration produced by treatment of 2×2 m row spacing, annual removing and control height removal. The values of carbon storage of aerial biomass, among row spacing and removal of aerial biomass treatments were significantly different (p<0.05). The highest carbon storage content was related also to 2×2 m row spacing and control with 60 cm height removing. None of the treatments was significantly different, concerning soil carbon storage (p<0.05). Moreover, the highest biomass weight was in row spacing of 2×2 m while the lowest value was recorded in 6×6 m.

**Key words:** *Atriplex lentiformis*, carbon sequestration, biomass, Ardestan

**INTRODUCTION**

CO₂ is the most abundant greenhouse gas which is responsible for more than half of the radioactive forcing associated with the greenhouse effect (Dixon et al., 1993; Moura-Costa, 1996). Increasing atmospheric carbon dioxide could have negative effect on the environment. Producing and creating bioenergy in the form of biofuels and electricity from crops is a practical approach to reducing CO₂ built up by displacing fossil fuels and sequestering carbon (Ma et al., 2000). The role of terrestrial ecosystem in mitigating the effects of climate change entails the assessment of carbon stocks in various pools. By different approaches CO₂ emissions can be reduced through carbon sequestration processes (Houghton, 1999). Although the amount of carbon sequestration per unit area in rangelands is low, their high distribution through the country, make them potential for carbon sequestration (Schuman et al., 2002). Vegetation plays two basic roles in this case. First the volume of atmosphere CO₂ may be reduced by increasing vegetation biomass. This could be potentially achieved through planting shrubs in ranges of arid and semi arid area. The second approach is to utilize vegetation as a source of raw materials for energy production, usually referred to as bioenergy, which is considered a carbon-natural energy source (Van Kooten, 2000). Iran is one of the countries that obliged to decrease greenhouse gases, and one of the suitable approaches is carbon sequestration in rangeland plants. There are about 90 million hectares rangelands in Iran with high potential for carbon sequestration. At the end of 2007, about 833×10⁶ seedling was planted in rangelands. Shrubs are known for high potential in carbon sequestration. *Atriplex lentiformis* is the most common shrub used in reclamation activities in Iran (Eskandari et al., 2008). Atriplex species are characterized by high forage production, desertification control, restoration of degraded rangelands, preventing erosion and protecting wildlife, fuel usage, tolerance to salinity and harsh environmental conditions (Foroghian and Aghdam, 1986). Despite the important role of this plant in degraded rangelands, literature review
showed that there is no study on the role of *Atriplex lentiformis* plantation in CO₂ sequestration. The objective of this research then was to monitor the effects of row spacing and removing aerial biomass on biomass production and carbon sequestration capacity in arid regions of Iran.

**MATERIALS AND METHODS**

Forest and Range Research Institute of Iran carried out a study on the effects of density, period of removing and height of removing aerial biomass of *Atriplex lentiformis* on its longevity and qualitative production during 1994 to 2006. In order to investigate the carbon sequestration in this species, sampling was done at the end of the study period. The study area is located 40 km northwest of Ardestan, between 33° 23' to 33° 59'N and 51° 27' to 52° 23'E. The area has a dry climate with a long term mean annual precipitation of 111.3 mm and mean annual air temperature of 20.2°C. The sandy loam soil is highly saline, pH and EC values are 7.96 and 65.18 dS m⁻¹, respectively (Efftekhar, 2000). *Atriplex lentiformis* was planted in a split-split plot design in three hectares area with three replications and 45 treatments in each replication over 1993. Treatments were row spacing at three levels (2×2, 4×4, 6×6 m), as main treatment, period of aerial biomass removing at three levels (annual, biennial, triennial) as sub treatments, removing the aerial biomass at five levels (control, removal from bottom, 20, 40 and 60 cm heights respectively) as sub-sub treatments. Totally 135 plant samples were cut from basal area and the fresh weight of aerial parts was determined in the field. Then, 200 g of each treatment were transferred to laboratory for dry weight as well as organic carbon percentage determination. The root and soil samples were taken from 0-30 cm depth (the depth of root penetration). The plant samples were dried in open air for determining carbon content burning at 375°C in an electric oven. The Walkly and Black method was used to determine the percentage of soil carbon content (McDicken, 1997). First, data were normalized before the analysis by the one-sample Kolmogorov-Smirnov test using SAS software. Confirming the significant difference, the Duncan comparative test was applied to indicate the difference between treatment averages.

**RESULTS**

The results of different row spacing, period and height of aerial biomass removal showed no significant differences in 95% confidence level on carbon content of the soil. While row spacing and removing aerial biomass treatments indicated significant difference in root carbon storage, aerial biomass carbon and biomass weight in 5% confidence level so the maximum and minimum values were observed in the row spacing of 2×2 m and 6×6 m, respectively (Table 1-3). In contrast, periods of aerial biomass removal had no significant difference in root carbon storage, aerial biomass carbon and biomass weight in 5% confidence level. Meanwhile the carbon storage content in aerial biomass was higher than root and soil in all treatments (Fig. 1).

**DISCUSSION**

Effect of row spacing and removing aerial biomass on carbon storage: The maximum amount of carbon sequestration was found in the lowest row spacing
(Table 1). As the carbon content of biomass is the index of biomass per unit area, then dense vegetation cover supports canopy cover and the content of aerial biomass. Dugas (1999) suggested that the higher carbon storage occurred when Leaf Area Index (LAI) and aerial biomass height increased. Fang et al. (2007) also studied the biomass production and carbon storage in Populus species and concluded that the amount of carbon storage in row spacing of 3×3 m was higher than 3×4, 4×4 and 4×5 m. They also mentioned that it is important to choose the best row spacing in order to gain the maximum productivity, biomass and carbon. Park and Ohga (2004) argued that maximum amount of carbon in Willow Planting to the row spacing of 0.3×0.9 m in comparison with those of 0.3×0.3 m and 0.6×1.1 m. This study showed that removing of aerial biomass had negative effect on the aerial biomass carbon storage and carbon sequestration and the maximum amount of carbon storage was found in the control treatment while the lowest value was obtained in the treatment removed from the bottom of plants (Table 2, 3). As no stress applied on the plants in control treatment, its sufficient growth and leaf area index increased. Andrew and Gregor (2006) have studied the effect of grazing intensity on carbon storage which revealed that the amount of soil and plant carbon will be increased by decreasing of grazing intensity, because when canopy cover grows completely, more carbon will be stored in the plant. In the other hand Su-Yong et al. (2003) concluded that avoiding vegetation harvesting will increase the carbon storage in the soil and plant. These findings support the results obtained by investigation.

The content of soil carbon: As the results indicate, the row spacing, removing biomass and removing periods treatments, had no significant effect on soil carbon storage. Park and Ohga (2004) discussed that row spacing of 1.2×1.2, 3×3 m had a little effect on soil carbon and organic material in a 25 year old pine tree (Gilmore and Rolfe, 1980). They also declared that row spacing did not show a meaningful effect on soil carbon. Ma et al. (2009) investigated soil management impacts on soil carbon sequestration in switchgrass (Panicum virgatum) and suggested that row spacing and cultivar did not change soil organic carbon in the short-term (i.e., 2-3 years) after P. virgatum establishment. Park and Ohga (2004) stated that soil carbon content was not affected by planting spacing and harvest cycle (annual and triennial). They also indicated that although aboveground biomass differences between the two cycles was considerable but only one year cycle showed significant differences in aboveground biomass production which would not provide enough additional detritus input to the soil system to be detected in soil content differences.

Aerial biomass weight
Row spacing: Significant difference at 5% confidence level was observed between the row spacing of 2×2, 4×4 and 6×6 m, respectively (Table 1). Increase of density of shrubs per unit area in 2×2 m row spacing provided more canopy cover which resulted in increased aerial biomass weight. It is similar to findings of others researches for instance (Armstrong Johns and Tubby, 1999) concluded that the maximum productivity of 13.5 t ha⁻¹ was related to the row spacing of 1×1 m in comparison with 2×2 m. Moreover, Habibian and Sanadgol (2006) showed that the most aerial biomass weight in Atriplex lentiformis is related to 2×2 m row spacing.

Biomass removal: At 5% confidence level a significant difference was observed between the control and 60 cm removing heights compared to other treatments (Table 2). Since both, treatments had more branches, even the control shrubs had no new growth in the lower parts, 60 cm treatment resulted new growth in upper branches and their weight was then meaningfully different from other treatments. Eriksson (2006) reported a similar condition that unthinned treatment had the largest standing biomass for both species (Pinus sylvestris, Picea abies), which resulted that unthinned treatment is preferred if the objective is to maximize the standing biomass and the carbon storage. Also, Stegemöller and Chappell (1991) supported the ideal that aerial biomass removing and thinning reduce growing and canopy cover in comparison with control treatment while its negative effect depends on thinning height and site quality.

CONCLUSION

The results indicated that 2×2 m row spacing had the highest carbon storage (81. 6 t ha⁻¹) and decreased to 21.3 t ha⁻¹ in row spacing 6×6 m. On the other hand, different treatments had significant difference on root, aerial biomass weight and carbon sequestration. In all treatments, carbon storage in aerial biomass (93%) was higher than the root (6.3%) and soil (0.7%). Swamy et al. (2003) showed that in Gymnema arborea tree, the most carbon storage was in aerial biomass (83%) in comparison with root (18.51%). Based on the results of this research it is recommended to decrease the spacing row to increase carbon storage. If carbon sequestration and off setting greenhouse gas emissions is the prime motive behind
planting *Atriplex* on a salt land then control treatment would be the better option of the other removing heights. Nevertheless, sequestered carbon could be a useful by-product in rangelands.

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REFERENCES


