Improving Forage Production Quantity and Quality Using Native Legume Species in Semi-arid Agrosilvopastoral System

Louhaichi, M[1*]; Slim, S[2]; Gamoun, M[1]; Hassan, S[3]; Kailene, J[4], Hamdaoui, I[5]

1* International Center for Agricultural Research in the Dry Areas (ICARDA), Tunis, Tunisia;
2 School of Higher Education in Agriculture of Mateur, University of Carthage, Tunisia;
3 International Center for Agricultural Research in the Dry Areas, Amman, Jordan;
4 General Directorate of forests, Tunisia Agriculture Ministry, Tunis, Tunisia;
5 Institut National Agronomique de Tunisie (INAT), Tunis, Tunisia

Abstract

Agrosilvopastoral systems provide a range of livelihood services, either directly through forage production or indirectly by the beneficial effects on soil conservation, nutrient cycling, pollutant filtering, and biodiversity enhancement. Hence, improved silvopastoral systems have ample scope to rehabilitate degraded pastures to sustain livestock production, which remains a strong pillar for the livelihoods of the agrosilvopastoral communities. To evaluate the impact of *Hedysarum coronarium* L. (sulla) reseeding on pasture productivity, plant cover and plant density in semi-arid silvopastoral systems, an experiment was carried out in Sbaihia Site, Zaghouan Governorate, Tunisia during 2018-2019 growing season. The experiment was laid out under a randomized complete block design having 3 treatments including reseeding sulla; protection from grazing and control (free grazing) with three replications per treatment. Preliminary results showed that there were significant differences ($p<0.05$) among the three treatments. Reseeded sulla and protected plots recorded 100% plant cover while the control plots had less than 60%. The estimated biomass for the reseeded plots was four times higher than the biomass production in the protected plots and eleven times higher than the control plots. The highest plant density was recorded in the reseeded plots (163.2 plants/m^2), followed by the protected plots (30.6 plants/m^2) while the lowest value was recorded in the control plots (29.8 plants/m^2). Based on these findings, it is concluded that reseeding well-adapted native forage species has a great potential to improve productivity of semi-arid silvopastoral systems, which would contribute towards reducing the feeding cost and, therefore, enhancing the income of the agrosilvopastoral communities.

Key words: reseeding; *Hedysarum coronarium* L.; biomass production; vegetation cover; agrosilvopastoral

Introduction

Agrosilvopastoral production systems are very important ecologically, economically, and socially. They provide various ecological services, including nutrient cycling, pollutant filtering, and biodiversity preservation (Louhaichi 2016). They also serve as a resource base for livestock production – a key source of income and urban livelihood diversification. However, these ecosystems suffer from cultivation encroachment, overgrazing, and harsh climatic conditions, particularly recurrent droughts (Ouled Belgacem and Louhaichi, 2013; Alonso 2011). For centuries, the strategy for alleviating environmental degradation and overgrazing pressure was the traditional nomadic system. However, changing to sedentary land-use resulted in overgrazing and the massive increase of subsidized feeding (Martínez-Valderrama 2018). This has led to extensive exploitation of natural resources and depletion of soil nutrient. Continuous degradation of silvopastoral systems triggers the critical need to develop appropriate management strategies that enhance the sustainable use of these ecosystems. Interduce legumes species in these systems, promote a feasible opportunity for sustainable production system through enhancing the soil organic matter and providing high quality feed. This work was designed to evaluate the impact of *Hedysarum coronarium* L. (sulla) reseeding on biomass production, vegetation cover, and density in semi-arid silvopastoral systems in Tunisia with the aim to meet the huge gap in fodder demand and supply exists in the area.

Materials and Methods

The experiment was conducted in Sbaihia site, Zaghouan Governorate in the north-eastern of Tunisia (36°27'34.86"N, 10°13'52.17"E; altitude range: 180-200 m above sea level). The site natural vegetation is characterized by very sparse individuals of *Olea europea*, *Rosmarinus officinalis* and also the spread of the invasive thorny species *Eryngium campestre*. Soils at the study site are poor and shallow the dominant soil textures is silt loam. (47% silt, 29% sand and 24% clay). The climate is semi-arid with annual rainfall ranging from 350 to 600 mm. During 2018/2019 growing seasons, the site received a rainfall of 493 mm (Figure 1) (ONAGRI 2019).

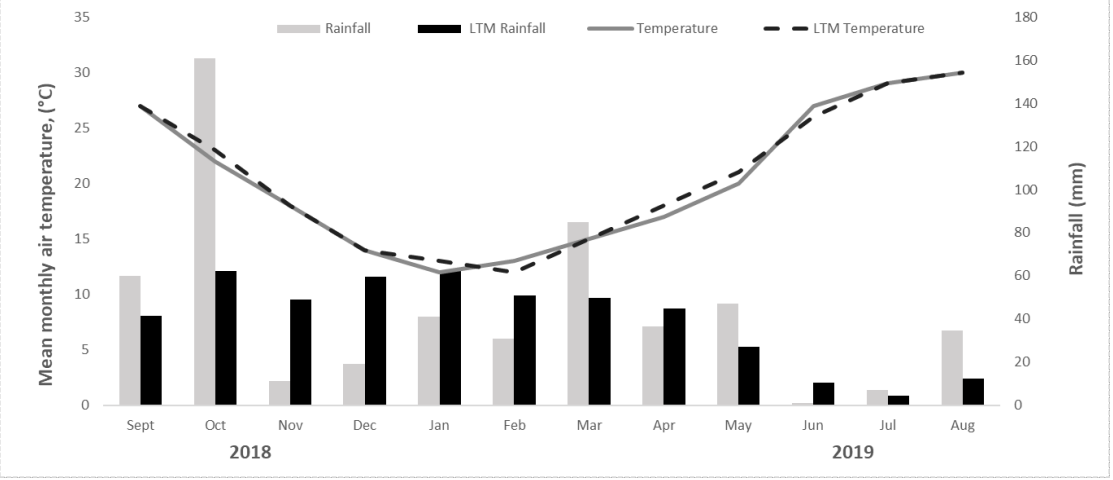

Figure 1. Monthly mean air temperature and rainfall in Zaghouan from 1 September 2018 to 31 August 2019. Long-term means (LTM) are for the period 1985-2012. The meteorological data were obtained from http://www.onagri.nat.tn/pluviometrie and https://www.historique-meteo.net (Accessed 20 June 2020).

The experimental design consisted of a randomized complete block design (RCBD) with three replications and three treatments as follows: (i) Reseeding sulla; (ii) Protection from grazing and (iii) Control (free grazing). Sulla reseeding was applied manually at a sowing rate of 40 kg ha^{-1}, on 15 October 2018, just after the commencement of the fall rainfalls followed by covering the seeds with soil using a spike tooth harrow.

The biomass production was estimated toward mid-May of 2019 at the peak of growth of the natural vegetation. Three quadrats (1×1 m) were randomly placed within each plot of the three treatments. The entire biomass inside the quadrats was clipped to a stubble height of 5 cm above ground level. Samples fresh weight were estimated using an electronic scale (Ohaus Valor 7000), while the dry matter (DM) content was determined by drying a subsample in an air-forced oven at 60°C for 72 hours. The difference in weight (before and after drying) corresponds to the loss of moisture and the residue represents the DM.

Vegetation cover was estimated using the digital vegetation charting technique developed to measure and monitor vegetation cover in different land use (Louhaichi et al. 2010 a,b). This method is reliable, fast and low-cost (Louhaichi et al. 2017). Ten vertical ground images were captured randomly in each plot, using Canon Coolpix 110 camera mounted on a monopod. The dimension of each image was 4608 × 3456 pixels, and the size was about 6.93 Mb in JPG format. The camera lens was 150 cm from the blackboard surface. One pixel in the digital image represented 0.16 mm^2 at the ground surface. The software interpreted the colours from the picture to create two meaningful classes. Bare soil and green vegetation, the total surface area of green vegetation from the image classification is calculated by summing the total area occupied by pixels classified as plant. The vegetation density is the number of individuals per unit area. To estimate plant density, three quadrates placed randomly in each treatment plots, and each individual living plant inside the quadrat was counted.

The data was analysed using the analysis of variance (ANOVA) in a randomized complete block design. Sulla reseeding, protection from grazing and control treatments were considered as fixed effects. The treatment effect was evaluated using the LSMEANS procedure. Pearson correlation analysis was used to assess the relationship between different variables. The computations were carried out using SAS v. 9.2 software (SAS Institute, Cary NC, USA). Significant differences among treatment means were compared by Fisher's protected least significant difference at P = 0.05.

Results

Biomass production and plant density were significantly higher in Sulla reseeded treatment compering to protected area and control treatments ($p < 0.05$). The biomass for the Sulla reseeded plots recorded 10.40 TDM/ha and was four times higher than the biomass production in the protected plots (2.62 TDM/ha) and

eleven times higher than the control plots (0.90 TDM/ha) (Figure 1). The highest density was recorded in the reseeded plots (163.2 plants/m2), followed by the protected plots (30.6 plants/m2), while the lowest plant density was recorded in the control plots (29.8 plants/m2). Yet, Reseeded sulla and protected treatments recorded 100% plant cover comparing to less than 60 % in the control treatment ($p < 0.05$).

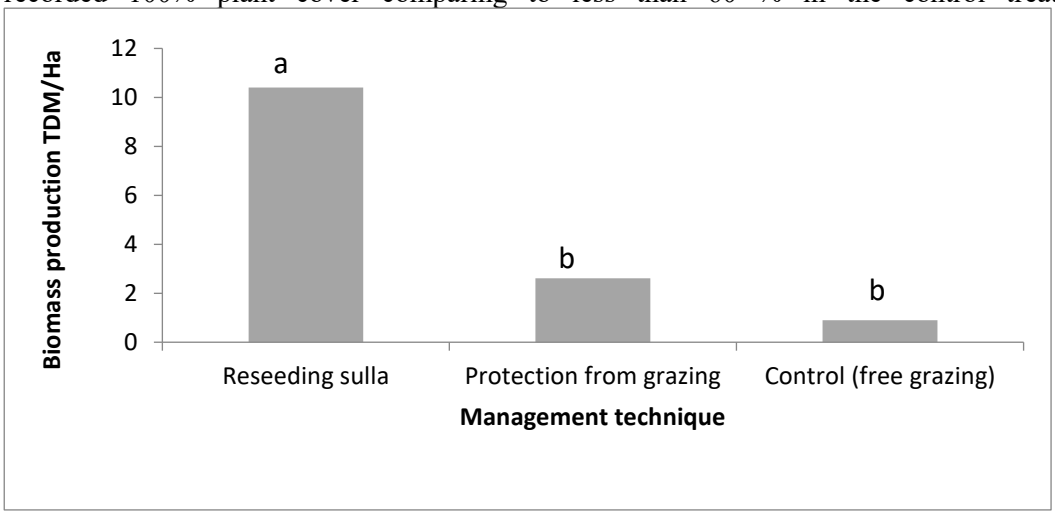

Figure 2. Biomass production of silvopasture system under three different treatments in 2018/19.

Discussion

In the current study, we evaluated the impact of reseeding a native forage legume species, *Hedysarum coronarium* L. (sulla) on biomass production, vegetation cover, and density in semi-arid silvopastoral systems, as a means of alleviating pasture degradation by providing high quality forage while diversifying the production systems. Nevertheless, the protection from grazing had a positive effect on increasing the vegetation cover by 40% as compared to the control site. The control area showed the lower values of biomass (0.90 TMS/ha), vegetation cover (60%) and density (29.8 plants/m^2) that probably due to poor seed bank and poor soil quality and less availability of nutrients (Slim and Ben Jeddi 2011; Slim et al. 2018). Sulla reseeding resulted in substantially greater biomass, vegetation cover and plant density compared to the control site (grazed area). These results support previous findings that reseeding has great potential to improve degraded natural pastures and enhance livestock production (Manyeki et al., 2015; Martiniello et al., 2000; Bouajila et al., 2013). The high biomass and vegetation density recorded in the reseeded areas could be attributed to the fact that Sulla is a forage legume species native to the Mediterranean basin, which is well adapted to the local environmental conditions of the target site (Woodgate et al., 1999).

On the other hand, sulla was the dominant species in the reseeded plots, reaching 95% of the vegetation cover. This species outcompeted other native species. If the farmer main concern is to produce quality forage, then this could be a suitable option. However, if the objective is to enhance biodiversity, then it may be important to designate only certain areas for reseeding with sulla and using these areas as forage banks or chemoscapes (Villalba et al., 2019). These findings demonstrate both the potential and the challenges of pasture rehabilitation where high evapotranspiration and erratic rainfall prevail.

Conclusion

Current practices to improve degraded agrosilvopastoral production systems are clearly unsustainable. To reverse this negative trend, alternative sustainable rangeland management practices (SRMP) must be developed. Any sound SRMP should consider significantly increasing the productivity from the same area of land while at the same time limiting negative impacts on the environment. In this regard, silvopastoral management creates an environment where trees, forage, and livestock can be developed to their full economic potential. In fact, well managed silvopasture can significantly reduce the cost of winter feeding.

This study focused on sulla reseeding as a SRMP aimed to restore degraded agrosilvopastoral systems in semi-arid Tunisia. Using well adapted native legume species has improved significantly the aboveground biomass offering enough green fodder during the lean period of the year and a very rich diet in crude protein for the livestock, which guarantees a more sustainable livelihood of the local agrosilvopastoral communities. Further

studies are needed to evaluate the impact of sulla reseeding on soil quality and other environmental impacts such as control of soil and water erosion over time. Nevertheless, these preliminary findings have demonstrated the importance of reseeding for the rehabilitation of degraded agrosilvopastoral systems across the semi-arid areas of the Mediterranean basin.

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