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Farmers' adoption of sulla (*Hedysarum coronarium* L.) cultivation as an alternative livestock feed

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Abstract
The objective of this study was to investigate farmers' adoption of sulla (*Hedysarum coronarium* L.) cultivation in northern Tunisia. Sulla adoption at farmer level and farmers' perception about the role of sulla were investigated through a survey of 216 farming households in 2017. The cultivation of sulla by farmers in the region reflected its adoption, with most farmers introducing it to their crop rotation cultivating system. The results obtained confirm the general acceptability of sulla in contributing towards farmers' livelihoods, and also that sulla is well adapted to grow in northern Tunisia.

Keywords: Fodder, Livelihood, Livestock, Perception, Rangelands, Tunisia

Introduction

Rangeland-based farming systems are of significant importance in the dry land areas, satisfying the increasing demand for animal products, increasing the economic stability of smallholders and providing animal products that have high added value (Louhaichi, 2011; Porqueddu *et al*., 2016). In Northern Africa, rangelands are mainly composed of very sparse steppe species which has been altered by various human activities (Ouled Belgacem and Louhaichi, 2013; Hudson *et al.,* 2017). A number of proven technologies including reseeding of native forage species combined with periodic resting are available and can reverse the degradation process while providing protein-rich livestock forage.

Livestock sector plays a significant economic role in most developing countries and is crucial for the food security and livelihood of the rural population (Ellis, 2000; Ellis *et al*., 2003; Pingali, 2007; Randolph *et al*., 2007). In Tunisia, the livestock sector (dominated by small ruminants), has increased from 1.3 to 3.9 million female units for sheep and from 250000 to 750000 heads for goats (Nefzaoui, 2004). Three predominant livestock production systems exist in Tunisia; the pastoral, agropastoral and intensive systems (Shideed *et al*., 2007; Nefzaoui, 2004). From these systems, the pastoral system is decreasing in importance, while the agropastoral system is increasing due to integration of palatable shrub species in intercropping practices (Louhaichi *et al*., 2016a, b). The intensive system is limited to irrigated areas, where supplementation is quite low (use of fodders and crop residues instead of concentrate feeds) (Nefzaoui, 2004). The decrease in importance of the pastoral system, due to degradation, increase in demand for cultivation land and an increase in livestock numbers, has increased the demand for supplementary feeds to sustain livestock production, not only in Tunisia, but across the arid environments of the world (Kumar *et al*., 2017; Mangalassery *et al*., 2017).

Several factors are responsible for feed nutrient deficiency, such as: livestock intensification (Jaweed *et al*., 2015), climate instability, poor management strategies and low soil nutrient status (Arab *et al*., 2009). In Tunisia, and also in most developing countries, the improvement of the production of alternative forage and fodder rich in plant proteins has become a top priority (Hernández and Sánchez, 2014). This is due to the increase in the prices of raw materials, in particular the oilseed meals, intended for feeding and supplementing small ruminants (McMichael *et al*., 2007; Dixon *et al*., 2010; Hernández and Sánchez, 2014). Hence, the main objectives of the study were to examine, via a case study in northern Tunisia, farmers' adoption and awareness about potential sulla benefits; their satisfaction with sulla cultivation, and to also recommend to them possible approaches towards improving sulla cultivation and production in their respective regions.

Materials and Methods

Study Area: The study was carried out in northern Tunisia, covering three agro - climatic zones in northern

Tunisia [North (>600 mm), NW (500 - 550 mm) and NE (<500 mm)]. The zones fall under the governorates of Bizerte and Beja, Siliana and Kef and Zaghouan and Nabeul (Fig 1). The opportunity to compare the adoption approaches from three separate regions within the northern region of Tunisia enables information obtained from this study to be used to establish how the farmer's adoption concerning sulla differ within the same land use practices. Similar biophysical and socioeconomic features also enable the study to compare to what extent the adoption and potential of sulla to contribute to farmer livelihoods varies within the northern region of Tunisia. These features include, and are not limited to; land tenure (the functioning of land tenure systems is crucial for agricultural production, and it also crucial for more diversified land use in rural areas and the dynamics of overall social transformation), social challenges, climatic conditions, the Tunisian Government's regional implementation of various incentives and regulations for the use of natural resources to sustain the economic development of the region (Mekki *et al*., 2013).

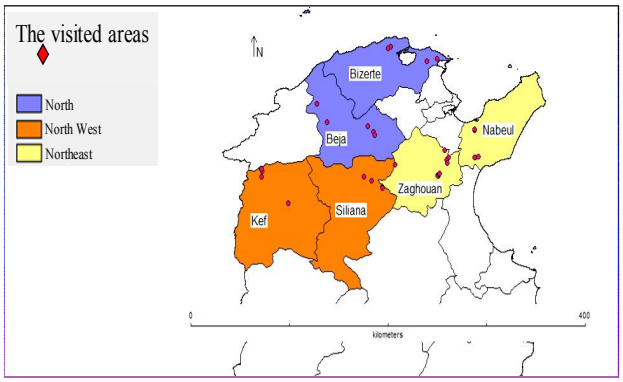

Fig 1. Geographical distribution of data collection sites in northern Tunisia

Plant material: The study species adopted was sulla (*Hedysarum coronarium* L.), a native palatable species which grows to between 110-200 cm in height and it tolerates occasional frost (Slim, 2012). *Hedysarum coronarium* L. is one of the Fabaceae forage species which is useful in contributing towards meeting a large part of the protein needs of mainly ruminants (Frame *et al*., 1998; Molle *et al*., 2003). It is a multipurpose forage species (it has potential to successfully offset the decrease in quality and quantity of the forage in arid environments), also effective for rehabilitating degraded rangelands, reducing soil erosion on sloping land, and is commonly used to enhance nitrogen supply and to maintain soil organic matter in farming systems (Jeddi, 1996; Ruisi *et al*., 2011). However, its use and adaptability in Tunisia has been low amongst smallholder farmers, with most of them relying on other alternatives, such as multipurpose shrubs (e.g. *Atriplex nummularia*) and cactus as alternative livestock supplements and feed during the dry seasons (Salem, 2010).

Data collection: In 2017, the questionnaire survey, administered across 216 households, was conducted in local language (Arabic) for a better and clearer understanding of all the elements of the questionnaire. Participating households were selected randomly using aerial photographs of each region. If household members were not at home or declined to participate in the survey, another randomly selected household was chosen to replace it and enumerators moved on to the next household on the list. The survey was done by way of an interview with a particular household member. Generally, the adults of the household were interviewed as they are most often responsible for the daily household chores and household income expenditure. In the case where there were no adults available or present, the person responsible for these tasks was interviewed, regardless of gender.

To keep the flow of information and for the convenience of the respondents, the questions were subdivided into four major parts, which included; a) Farmer's profile: region, name, age, level of education, years in farming; b) The characteristics and distribution of the household's farming area: surface area, land use; c) sulla cultivation practices (including knowledge of sulla and interest of farmers in cultivating sulla); and d) recommendations on how to improve livestock production, as well as the challenges and threats encountered while cultivating sulla. Typical questions asked included the farmers' thoughts about sulla's contributions towards improving livestock feed, and also farmers' views on the role, or potential role, of sulla in improving soil fertility.

Statistical analysis: Responses to an open ended question were coded under similar answers, with coding 1 for "affirmative response" and 0 for "no answer/ response", to speed up data entry into SPSS. Power analysis (Cohen, 1988) was used to determine the minimum sample size to ensure 95% confidence and at least 3% precision for adoption estimates. Descriptive and inferential statistics were then used to assess farmers' perception on sulla and its potential role as a livestock feed. ANOVA was performed to analyze the recorded data and the least significant difference (LSD) ($P \leq 0.05$) to separate means.

Results and Discussion

***Household description*:** Two hundred and sixteen households were interviewed to find out their knowledge on the impact of adopting sulla as an alternative livestock feed in northern Tunisia. Male respondents comprised of 85 per cent for the study (Fig 2). A higher proportion of them were above 60 years of age (72%), compared with 17 per cent from the 40-60 years' age range. Majority of them were married (97%). Households dominated by married males recorded higher (P=0.001) sulla cultivation proportions compared to female and single dominated households. A high proportion of the farmers also had a form of secondary education (53%), while a low proportion of them (11%) had higher formal education (Fig 2). The education level influenced (P<0.05) the farmers' adoption of sulla, with the few available interviewed farmers who received higher formal education appearing to cultivate sulla, compared to those who only received secondary education.

The household demographics are not surprising, considering that other studies have also found a higher participation of males in farming activities compared to females (Abule *et al.*, 2005; Solomon *et al.*, 2007; Lemma, 2010). Thus, such dynamics in livestock rearing duties reflect maintenance of cultural protocols of livestock farming more biased towards traditionally involving more males than females (Abule *et al.*, 2005). With a low number of farmer respondents having higher formal education, these results reflect the low level of involvement of professionals or highly qualified individuals in household farming activities. Such professionals or highly educated individuals are likely to engage themselves with office jobs and possible relocation to the city for employment opportunities.

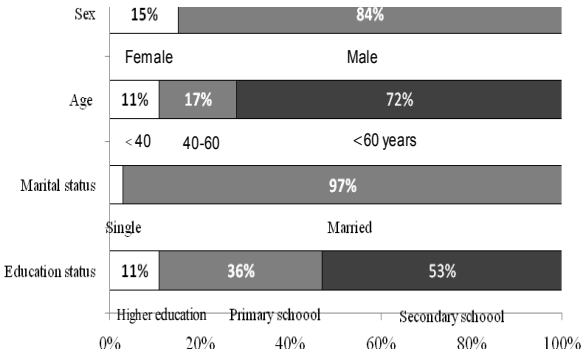

Fig 2. Descriptive classification of the farmer respondents for the household questionnaire in northern Tunisia

***Distribution of farmers based on their knowledge of the plant*:** Of the respondent farmers, 57 per cent were familiar (P<0.05) with sulla and already growing it on their farms, while a low proportion of them (4%) reported that they had not heard of sulla before (Fig 3A). At least 39 per cent of the total farmer respondents indicated that they knew sulla but were not growing it on their farms (Fig 3A). The results indicated that pasture office members (OEP) were involved in disseminating information about sulla benefits, with those who had knowledge of sulla mentioning that the role of OEP members (96%, P<0.05) (Fig 3B). A low proportion (4%) indicated that they knew sulla from other sources, such as discussions with neighbors, as well as participation in farmer information days or field days (Fig 3B). These results reflect a general acceptability of sulla cultivation by farmers in northern Tunisia, although they do not necessarily indicate for what purposes farmers are cultivating sulla for.

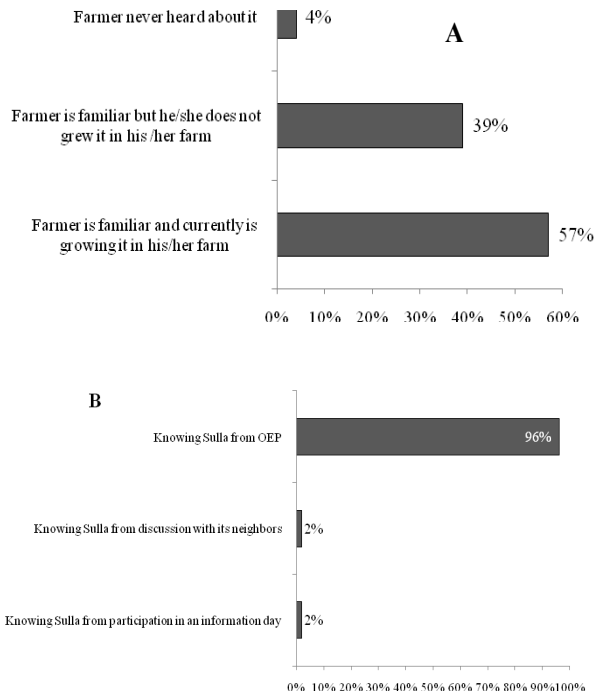

Fig 3. A) Distribution of farmers by knowledge of sulla, as well as B) farmers source of sulla knowledge in northern Tunisia

***Distribution of farmers based on available cultivation area*:** From the farmers already cultivating sulla, 44 per cent of them had been growing sulla for only a year (44%), whereas 22 per cent of them had been cultivating sulla

for three years at the time of administering the questionnaire (Fig 4). A high proportion (P<0.05) of those farmers already cultivating sulla allocated between 1-5 ha of their total cultivation area (66%), while 22 per cent allocated more than 10 ha of their total cultivation area towards growing sulla (Fig 4). A high proportion (49%, P<0.05) of the farmers had a total farming area of more than 20 ha, while 26 per cent had between 11-20 ha of farming area (Fig 4). A low proportion of farmers cultivating sulla for at least three years (22%), this suggests that farmers may still need more information regarding the potential benefits of sulla cultivation. This is supported by a low proportion of the farmers allocating more than 5 ha of their total farming area towards sulla cultivation (29%). However, the 44 per cent of the farmers cultivating sulla for at least a year, and those allocating at least 5 ha of their total farming land, suggests that there is a gradual increase in the number of farmers cultivating and dedicating more land towards sulla.

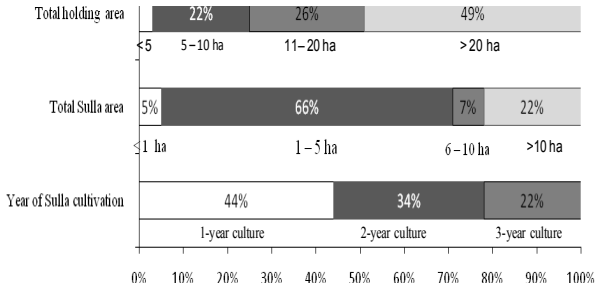

Fig 4. Distribution of farmers according to the area and the year of sulla cultivation

***Origin of sulla seeds and seeding rate*:** From the total farmer respondents cultivating sulla, 93 per cent of them purchased their seeds for planting, while only 7 per cent of them self-produced their own seeds for planting purposes (Fig 5A). From these farmers, 85 per cent of them did not conserve or store their seeds, whereas 15 per cent of them indicated that they do conserve or store their seeds after harvesting (Fig 5B). These results could reflect a few possibilities; if sulla cultivation was high in northern Tunisia, it was such that farmers found better economic benefit in selling their seed for more profit than storing their seeds or using it for their own planting. This is also reflected by the proportion of farmers not conserving their seeds after harvesting. Another possibility is that farmers did not view conserving their seeds after harvesting as profitable, due to the lack of investment in sulla cultivation activities in northern Tunisia, hence the need to sell their seeds off to generate more income.

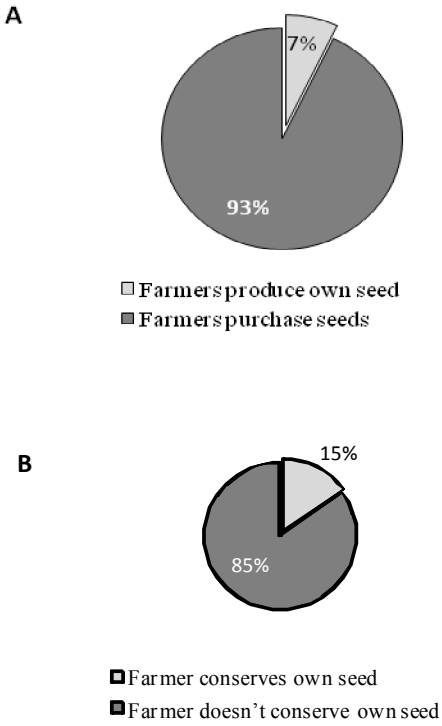

Fig 5. A) Distribution of farmers according to the origin of sulla seeds, and B) how farmers utilize sulla seeds after harvesting

***Sulla fertilization and weed treatment*:** A high proportion of the farmer respondents already cultivating sulla (68%) indicated that they did not use any form of fertilization to enhance sulla production, nor that did they use any herbicide to control problem weeds while cultivating sulla (Fig 6). These results suggest that sulla cultivation in northern Tunisia is beneficial to smallholder farmers with low income, because a low input crop would present an opportunity for farmers to save on costs, while simultaneously benefitting them through its multipurpose uses.

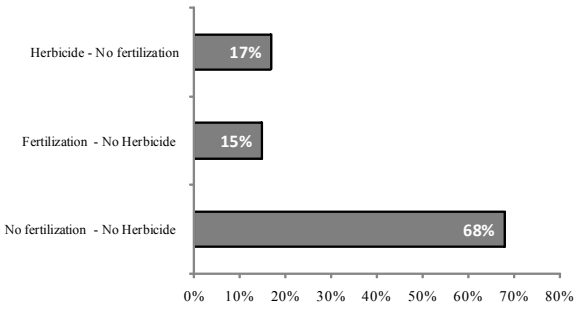

Fig 6. Distribution of farmers according to the sulla fertilization and weed treatment

Sulla adoption as a fodder species

Interest of farmers in sulla cultivation: A high proportion (P=0.036) of the farmers already cultivating sulla indicated that their main interest, which motivating them to cultivate sulla was the need to supply animals with feed in northern Tunisia (56%). The rest of farmers mixed their main reasons for cultivating sulla from animal feed, soil improvement, to animal feed and honey production (44%) (Fig 7A). From these farmers, forage production and grazing were also the main reasons for sulla cultivation, while 34% of the farmers combined the need for forage production, grazing and seed production as their reasons for cultivating sulla (Fig 7B). These results imply that livestock feeding is the dominant factor motivating farmers to cultivate sulla, so as to possibly cover the feed gap during low forage availability and production periods, such as in winter. Soil improvement and honey production came up as the second dominant reasons motivating farmers to cultivate sulla, indicating the multipurpose uses of this species.

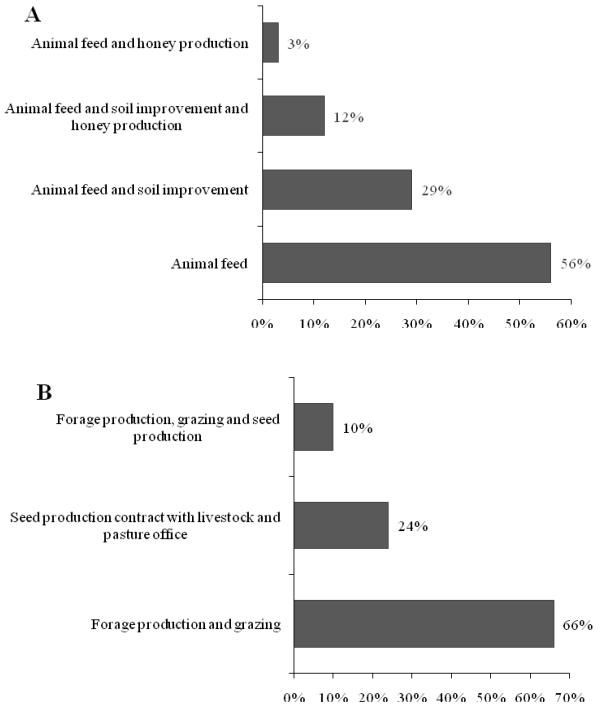

Fig 7. A) The main famers' reasons for sulla cultivation and B) the main farmer's uses for sulla in the livelihoods

Improving livestock production, feed availability and soil fertility: Farmer respondents mentioned a number of strategies they have been utilizing, which benefit them towards meeting livestock feed demands in northern Tunisia (Fig 8). A considerable proportion of farmer respondents (37%) indicated that buying of feed concentrates was ideal to meeting the feed-gap. A higher proportion (58%) of the farmers highlighted that the adoption and introduction of new high performing forage species such as sulla would likely meet the livestock feed requirements in their region (Fig 8A). Also, a considerable proportion of the farmers (at least 90% P=0.041) believed that the use of traditional transhumance practices such as rotational grazing and resting would be beneficial towards meeting livestock feed requirements (Fig 8A). A high proportion of the farmers (at least 90%, P<0.05) believed that the introduction of highly adaptable forage species such as sulla would restore and improve the soil fertility in the region (Fig 8B). The fact that farmers are aware that sulla is capable of improving and restoring soil fertility, and also that the introduction of sulla would benefit livestock in terms of meeting feed requirements, reflects the acceptability of sulla in the northern region of Tunisia. These responses also reflect the general knowledge of sulla as a multipurpose species in the northern region of Tunisia.

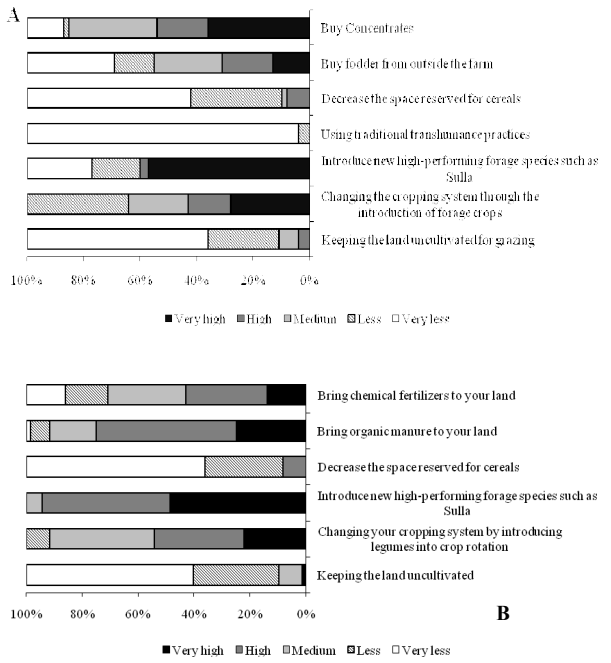

Fig 8. A) Farmer respondents towards strategies which address livestock feed demands, and B) the different strategies adopted to improve farmers' land fertility.

Major issues faced when cultivating sulla: Farmers were also asked for their views on the potential issues and challenges related to sulla cultivation (Fig 9). A high proportion of the farmers (63%) indicated that they faced no problems with sulla cultivation, whereas a small proportion (10%) mentioned that they faced challenges

in preventing livestock, such as grazing sheep, from grazing sulla (Fig 9). These can not necessarily be viewed as challenges because these views reflect how much animals utilize sulla in the northern region of Tunisia. The benefits of sulla towards livestock and the rangeland are reflected by the low views of sulla being viewed as invasive (3%) and its low expensive labor costs (4%) (Fig 9). These results suggest that farmers in northern Tunisia are obtaining ideal results from cultivating sulla, hence their views that sulla is not an invasive weed and also it does not require high or expensive inputs for its cultivation.

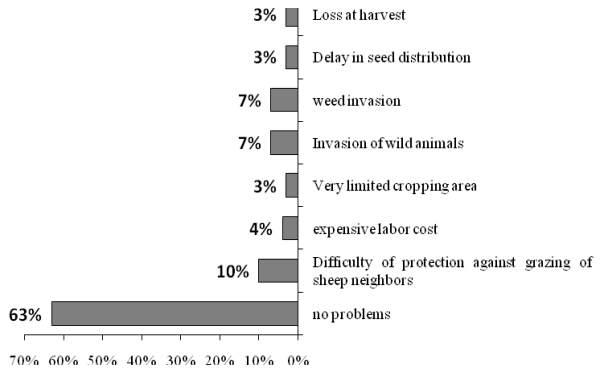

Fig 9. Distribution of farmers according to the possible problems encountered in the field in cultivating the Sulla

Conclusion

The current study investigated northern Tunisian farmers' adoption of sulla and its contributions towards improving feed availability for livestock and rangeland production. There is a strong view amongst farmers in that region that sulla is an important plant species which would be critical in improving the land's fertility. A high number of the farmers also indicated that sulla introduced to livestock would benefit them through covering the feed-gap livestock face during the dry season, or periods of low rangeland production. The positive perception of farmers about the feed value of sulla in livestock suggests a confirmation of its value for improving livestock performance in the northern region of Tunisia. Despite the appreciation to improve animal productivity, it is important to make follow-up experiments concerning the nutritive contribution of sulla towards livestock productivity in the study's region. There are also farmers who indicated not knowing anything about sulla, suggesting the need to inform farmers through extending extension services or farmer field days, which would educate farmers and share more information concerning the benefits of sulla.

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