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Opportunities to Grow Annual Forage Legume Fenugreek (*Trigonella Foenum-Graecum L.*) Under Mexican Sylvopastoral System

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Abstract
The first part of this chapter provides an introduction to Mexican livestock systems. The second part describes silvopastoral systems which are recognized as a strategy for food production, including the integration of annual, forage, legumes such as fenugreek (*Trigonella foenum-graecum* L.). The third part highlights the importance of silvopastoral systems for livestock production and how fenugreek can be integrated in to the diet of the Mexican livestock. Overall the current review discusses various agronomics aspects of intercropping with fenugreek mainly as a fodder bank for increased fodder yield and quality. Fenugreek cultivation can not only improve the local animal diet but it can also improve the soil nitrogen content. Based on this current review it can be concluded that integrating fenugreek into silvopastoral systems with livestock production could be a good sustainable solution to enhance the biodiversity of the system as well as increase the margin of profitability for the local producers and growers.

Keywords: Fenugreek, *Trigonella foenum-graecum* L., Mexico, forage, legume, silvopastoral system

Abbreviations: **CP**: Crude Protein; **DM**: dry matter; **IVDMD**: *in vitro* digestibility of dry matter

INTRODUCTION

Mexico is characterized by a physiography of different altitudes that has profound impact on the widespread climatic variations observed with respect to temperature fluctuations. Most of the arid and semiarid regions are restricted to North Mexico (48 % of land area), with dry tropical conditions along the coast (16 % of land area) and a sub-humid temperate climate characterized by a seven month long dry season in Central Mexico (23 % of land area). Southern Mexico predominately features a humid tropical climate (12 % of land area) while also incorporating both mountain chains, which have proportionately smaller regions with humid temperate climate are found. The Mexican climate is tropical with high diurnal temperature range fluctuations with respect to different altitudes. The Mexican neotropics is characterized by seasonal dry tropical forests; however, this vegetation is under risk of disappearance. Nationally, only 27 % of the original vegetation has remained undisturbed. At the regional level, approximately 60 % of the original vegetation has been destroyed and only 19 % of residual land remains as virgin forest. Remaining forests are at risk of disappearing with a calculated annual deforestation rate of 1.4 %. These remnant forests are located only in difficult-to-reach areas, and have become severely fragmented. In the dry and semi dry parts of North Mexico pastoral use of available land resources is one of the most common agricultural activities. On the other hand, pasture degradation is a significant problem throughout Mexico livestock systems and the restoration of degraded pastures is expensive [1]. However, the inclusion of leguminous trees or shrubs integrated with grass pastures and other legume species such as *Trigonella foenum-graecum* L. (fenugreek) in livestock silvopastures may contribute to sustainable production systems with low environmental impact on livestock farm producers. In this chapter, we summarized the potential of fenugreek integrated under silvopastoral systems and for livestock production in Mexico. We sincerely believe that agri-regions in Africa with similar agro-ecological conditions like Mexico will also benefit equally from the production of this multi-purpose crop.

MEXICAN LIVESTOCK PRODUCTION SYSTEMS

Cattle production is one of the most important livestock activities in major parts of rural Mexico in addition to forage and food crop production and agro-industrial by-products. In Mexico, cattle are divided into three groups: dairy, beef and dual purpose. Cattle are mainly grass fattened; most Mexicans consume grass-fed beef because it is generally leaner and less expensive [2]. Three ecological regions of Mexico define the cattle industry: the arid and semi - arid northern region that constitutes 27 % of the Mexican cattle inventory, the southern tropical region, which accounts for 42 % of the herd, and the temperate central region, which represents 31 % of Mexican cattle inventories in 1988 [3]. According to Garcia-Vega and William [3], the northern region is the most important livestock region in the country. Conditions in this region are mostly suitable for extensive but poor yielding livestock production systems characterized by low rainfall and poor

soil conditions. Production of feeder cattle is more common than production of cattle for slaughter in the northern region. The central temperate region is more oriented to crop rather than to livestock production but competition for land usage between livestock and crop production has been quite intense. An interesting feature of this area has been preference over diary production compared to beef generation and the latter is primarily produced as a by-product. Both dairy and beef production in this region are totally dependent on the local crop production. During winter cattle are grazed on fall-seeded grains and on crop residues. For the rest of the year different amounts of feed are usually supplemented [2].

On the contrary, the tropical zone in this region enjoyed the best livestock growth over the past two decades. The existing production systems are highly complex and heterogeneous in this region compared to that in the north [3]. Cattle production is more intensive and frequently involves dual purpose livestock operations (*i.e.*, milk and meat production). Such systems can be described as those that produce milk (daily milking) and meat (calf after weaning) in individual production cycle. Such facilities are restricted to the poor developing areas with low technology environment with low production output. Milk produced is predominantly used for self-consumption or sold at the local markets. The calves, at the post weaning period are also sold at local feedlots or sent for export. In this region, the cattle are mainly fed on grass; however; additional supplementation in the form of feed concentrates and traditional forages are also used, but not to their full potential [4]. The dual livestock purpose system is described as those systems aiming to produce milk and meat (weaned calves), in an individual production cycle, generally cows are milked by hand and is the dominant system production in the humid and sub-humid tropics. In this specific region, the cattle are mainly fed on grass with the system based on grazing native and sown pastures. *Cynodon* plectostachyus (K. Schum.) and *Cynodon nlemfuensis* Vanderyst are the most commonly used species. Animal production in the tropic regions are mainly affected by the low forage availability and quality especially crude protein content, particularly during the dry season. Only some farmers provide supplementary feeding particularly at the time when food resources are most deficient and limited numbers of farmers grow forages for cattle during this time.

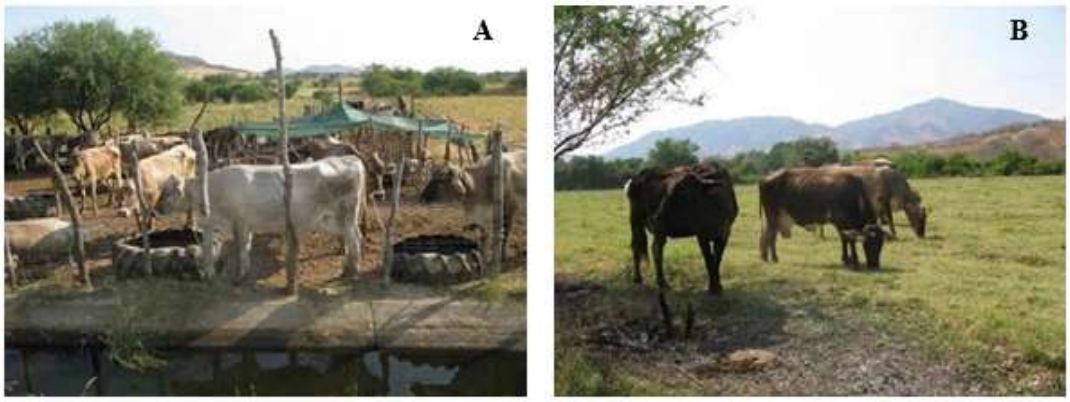

Figure 1. A) Typical dual purpose cattle in the Mexican regions; B) Dual purpose cattle based on in native or introduced grassland is the dominant systems in the Mexican tropics.

MEXICO AGROCLIMATIC CONDITIONS

Due to its location, Mexico's climate is tropical with generally high temperatures (average greater than 18 ºC) that show variation according to the altitude. Therefore, Mexico has climates that range from annual average temperatures ≥26 ºC, to areas with average of <10 ºC. However, temperatures vary from 10-26 ºC in about 93 % of the territory. Warm humid and sub-humid climates constitute 21 % of the country, while dry areas constitute 49 %. Mexican physiography is complex and includes two mountainous chain systems (The Western and The Eastern Sierra Madre) which comprise a great part of the country and create narrow plains near the coasts of the Atlantic and Pacific Oceans. This typical physiography together in addition to the geographical location initiates a wide diversity of climatic conditions with altitude having significant effect on the local temperature. The Eastern Sierra Madre obstructs the humid air circulation from the Gulf of Mexico [5]. Hence, arid to semi- arid conditions are abundant in most part of the country. These conditions establish limits to land use as previously mentioned.

Pastoral land use is common in the Northern arid and semi-arid regions of the country. According to Jiménez [6] 50 % of the territory (~98 million hectares) is dominated by vegetation adapted to animal pastures, such as natural prairie grasses, various types of brushwood, deciduous tropical forests, and conifer and oak forests. Arroyo [7] reported that ~74.5 million hectares (38 % of total land area) are being used for pastures. About 76 % of these pastures are located in the North. Considering edaphic characteristics, it is very difficult to classify soils in Mexico because of their extreme variability. Greater soil diversity has been reported near Central Mexico and coastal regions of the Gulf of Mexico. Due to high population densities in these localities there is enormous pressure on the available soil resources [5]. The use of legume crops like fenugreek in place of applying chemical fertilizers is a viable alternative both for effective cattle production and efficient soil management.

According to Darby [8], fenugreek production is optimal if the plant grows under the sun in areas with annual temperatures of 8-27 ºC, and an annual rainfall of 16-60 mm. Soils much be rich and well drained with soil with a pH range of 5.3- 8.2. In contrast, growth in low temperatures and humid soils is slow. Therefore, based on the evaluation of the fenugreek plant, it is found to be more optimal as a potential forage crop for Mexico. Nevertheless, it is important to point out that because fenugreek is an annual plant, its potential as a pasture plant is limited. However, there are suggestions for its cultivation combined with other crops, like alfalfa [12-15]. It is also important to emphasize that, when compared to other crops (like maize) fenugreek can reduce soil loss by approximately by 90 % and enhances top soil layers. This helps prevent soil erosion, which is a consistent problem for Mexican agriculture. Fenugreek also has the capacity to fix its own nitrogen and hence reduces fertilizer requirement during production [11], another advantage for introduction of the crop for silvopastoral systems of Mexico.

SILVOPASTORAL SYSTEMS AND FENUGREEK INTEGRATION

Silvopastoral systems refer to land use practices where woody perennials are integrated with crop and/or animal species. Silvopastoral systems can be classified as *simultaneous* where both trees and crops are grown together and *sequential* where either component are grown in rotation or they are grown at different time periods [9]. Integration of fenugreek into silvopastoral systems (fodder bank or cut-and-carry systems) has the potential to improve soil fertility by either enhancing nutrients levels within the rooting zone of grasses or by enriching nutrient availability to the grass root-depth by improved nutrient cycling and transformation to plant- available forms via biological nitrogen fixation [10].

Figure 2. A. Mexican silvopastoral systems associated with tree crops; B. Silvopastoral systems with legumes for animal production in Mexico and improved soil nitrogen content.

FODDER BANK WITH FENUGREEK

Mexican tropics are characterized by long dry periods with poor availability of feed and fodder. Small and medium farms allow cattle grazing in pastures or woodlands dominated by grasses and herbaceous species. During wet season the forage yield in the region is substantially high allowing stable and sustainable cattle production. However, both quantity and quality of forage is compromised in terms of nutritional level during the dry season. Rapid loss in weight and productivity are observed in cattle production system dependent on such diets. Producers usually provide their animals with agricultural sub-products such as citrus peel, maize or sorghum straw and poultry manure to supplement their cattle diet or include expensive supplements or feed concentrates. Unfortunately due to the high economic cost involved and the limited availability of such resources, quality of cattle feed is severely compromised resulting in poorly finished animals.

Establishing fodder banks or cut-and-carry fodder systems is another viable alternative. Fodder banks can be planted with high-quality fodder species like fenugreek as well as grasses. The goal of these systems is to maintain healthy, productive animals throughout the year.

Such systems can be utilized all year around, but will mostly be designed to bridge the non-availability of forages during the annual dry season. The ability of fenugreek and other leguminous shrubs in fixing atmospheric nitrogen makes them animal feed rich in proteins. In terms of nutritive value, fenugreek has been shown to be more digestible and have a higher nutrient content than other competing forages [11]. To maximize yield in the drier seasons, fodder banks should be planted as dense and nearly pure stands of forages. The total biomass yields per area will be larger at higher plant densities. The recommended agronomic planting arrangement consists of rows oriented east to west in order to provide the foliage with sun exposure and avoid light competition between grasses and legume plants or shrubs. Once the legume fenugreek crop is well-established, grasses are allowed to grow in the areas between the rows. The grasses grown in the inter-row area are of specie known to produce high-quality fodder. Competition between the different species is monitored continuously to avoid a decrease in fodder bank productivity.

The cutting height and frequency in addition to dry season management are important criteria for installing the cut-and-carry system. All these factors are influenced by the amount of precipitation, temperature, soil, species used and the inter-row spacing [12]. For better results, most cutting frequencies will be each 5-6 weeks. Longer cutting frequencies (such as 8- 10 weeks) produce greater biomass but increase the proportion of indigestible tissue or low-quality forage at the same time. In contrast, shorter cutting frequencies favor increased fodder quality. As for fertilizers, legumes have a high requirement for phosphorus. The application of phosphorus need to be monitored strictly and should only be applied if the grass component of the system dominates the legume growth. The nitrogen to phosphorus application ratio should be balanced properly to maintain healthy balance between legumes and grasses within the system.

IMPORTANCE OF FENUGREEK FOR ANIMAL PRODUCTION

Fenugreek, is an annual herb around 50 cm in height, the leaves are trifoliate, leaflets oblong to lanceolate in shape, the flowers are usually pale yellow or white and are borne at the leaf axils (Fig. 3). Pods are long, straight and flattened with distinct beak. Seeds (Fig. 3) are small, golden-brown, and oblong to rhomboidal in shape and are arranged in batches of 10-20 within the pods [13].

Earlier researcher have reported that fenugreek forage harvested at the dough stage of maturity constitute 14.4 and 13.9 % CP (Crude Protein) and IVDMD (*in vitro* digestibility of dry matter) of 58.3 and 51.2 % respectively [14, 15]. The highly digestible fenugreek hay dry matter (DM) has been found to demonstrate higher feed efficiency in comparison to early-bloom forage alfalfa cut. This could potentially decrease the requirement for extra feed supplementation and dependence on feed concentrates [16]. Fenugreek, a dryland adopted crop can produce high quantity and quality forage and do not cause bloating among cattle. It is grown as a cool season crop under both irrigated and rain fed conditions. The crop can also be grown in summer in cooler areas. Fenugreek contains animal growth-promoting substances not available in other competing forage legumes, and thus has the potential for curbing the application of artificial growth promoters

and feed concentrates. Leaves are important source of protein, mineral and vitamin C, and seeds are rich in iron, phosphorus, lysine and lipids. Whole seed and dried plants are used as insect and pest repellent for the purpose of grain storage [17]. Furthermore, fenugreek will form symbiotic relationships with nitrogen-fixing bacteria that can help replenish and maintain soil fertility on tropical agricultural lands by supplying nitrogen to the soil-plant system. Additionally fenugreek seed has been found beneficial in many diseases. Disrupted metabolism in diabetic animals can be treated by using fenugreek seed as supplement in their regular diet [18]. This legume can be used for different curative purposes; it could stimulate lactation in woman, also it is used for head lice removal, and to reduced blood sugar and blood cholesterol levels among other important medicinal uses [16].

Figure 3. A. & C. Fenugreek plants growing under dryland and irrigated field conditions, respectively; B. and E. Variations in fenugreek seed size and color representing different germplasms; D. Characteristic root nodules of fenugreek, F. Solitary terminal, self-pollinating and closed papilionaceous flower of fenugreek.

Figure 4. A. Animal foraging on fenugreek stand. B. Forage fenugreek under field conditions.

Fenugreek is palatable for livestock, and can be grown either as fodder banks system in a cut and carry systems or for direct grazing (Fig. 4). Generally, diets in the tropics for ruminant production are poor quality roughages with high neutral detergent fibers and low nitrogen/protein content. Including legumes in these animal production systems can correct some of the problems associated with low protein and high fiber diets. By including fenugreek in the animal diet, daily weight gain and high level of milk production will be achieved. The systems that include fenugreek will produce more milk per animal per hectare than a traditional system.

Nowadays, many industries are investigating fenugreek for medicinal, pharmaceutical and nutraceutical purposes. As a matter of fact, fenugreek seed is a source of many phytochemicals such as galactomannans (soluble carbohydrates), diosgenin (steroidal sapogenins) and 4-hydroxisoleucine (free amino acid) of well-known medicinal values to both humans and animals. Such renewed interest in fenugreek is triggered, in one hand, by the low cost of its production due to its adaptation to drylands, and by its impact on following crops because of its ability of fixing atmospheric nitrogen, in another hand [16]. Maximum output may, however, depend on the use of the appropriate genotype since fluctuation in both yield and quality of the crop may be influenced by environmental factors. Therefore, more efforts are needed to improve available fenugreek genotypes with respect to resistance to draught, salinity and disease, biomass and seed yields and to the levels of bioactive compounds in the seeds. The focus need to be concentrated towards developing locally adapted cultivars with higher seed and forage yield and quality.

CONCLUSION

Silvopastoral system for cattle production will be suitable for similar agro-climatic regions in both Mexico and in the African continent. Fenugreek can yield high quality and quantity of fodder and can grow as a multi-purpose crop since it can also be used as medicinal plant and a spice crop. Fenugreek forage has the potential to reduce heavy dependency of the local cattle to graze in restricted forested lands in tropical and sub-tropical

countries where shortage of fodder quality and quantity affects the livestock production. Fenugreek, like other legumes, is an important source of plant dietary protein for both animals and humans a like. Fenugreek can be efficiently applied as a cheaper green manure resource in crop rotation cycles even in marginal lands in developing and under developed countries with low input agricultural systems for improving the nitrogen quality of the soil. It is also recommended for production under rainfed agricultural systems due to the superb dryland adaptability of the crop.

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