

CHAPTER 1

SUNN HEMP (*Crotalaria juncea* L.)

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1. INTRODUCTION

Livestock farming in Türkiye encounters economic, technical, and certain cultural constraints, impeding the progress of cultivating forage crops, a crucial source for fulfilling the high-quality forage needs of farm animals. Despite the acknowledged significance of advancing forage crop cultivation and the emphasis on new research for the future of national animal husbandry, desired advancements have not been realized due to a variety of challenges. Ensuring the supply of high-quality forage stands as one of the most critical challenges for fostering healthy livestock activities within livestock operations. Given that approximately 70% of expenses in livestock farming are attributed to feed costs, coupled with the current state of meat prices in our country, the significance of producing high-quality forage becomes unmistakable.

Although there exist numerous alternative forage crops that could be cultivated in our country, the cultivation of these crops remains limited. In contrast, many other countries, especially those with advanced animal husbandry practices, employ a variety of forage crops. In regions of our country characterized by the Mediterranean climate, successful cultivation of well-known and widely used plants worldwide is feasible. Sunn hemp (*Crotalaria juncea* L.), an annual summer legume, has been identified as having promising potential in our country due to its various usage opportunities. Therefore, experiments with *Crotalaria juncea* L. have been conducted since 2016 in the fields of the Department of Field Crops at Ege University, located in Bornova/Izmir, representing the typical Mediterranean climate. The results obtained indicate the successful cultivation of this plant in our country (Demiroglu Topcu and Ozkan, 2019; Demiroglu Topcu and Ozkan, 2021; Ozkan, 2022).

2. SYSTEMATIC AND MORPHOLOGY

The genus *Crotalaria*, a member of the Genisteae tribe within the Papilionoid Legumes (Papilionoideae), encompasses a diverse array of approximately 600 species. The nomenclature “*Crotalaria*” derives from the evocative notion of “rattle” symbolizing the audible emanations produced by seeds within mature pods (White and Haun, 1965). These species exhibit a broad distribution, thriving in tropical, subtropical, and selectively temperate zones, with adaptability to regions maintaining elevations below 600 meters from sea level in temperate climates.

Crotalaria juncea L., belonging to the Fabaceae family, stands out as an annual plant with versatile applications and global cultivation. Noteworthy counterparts within the genus include *Crotalaria striata*, *Crotalaria spectabilis*, *Crotalaria intermedia*, and *Crotalaria lanceolata*. These species have been cultivated over extensive periods, particularly in the United States and various nations, serving dual roles in soil conservation and amelioration, alongside their utility as forage crops (Ahlgren, 1956).

The paramount species within the *Crotalaria* genus, recognized as *Crotalaria juncea* L. or Bengal Hemp/Bombay Hemp, is commonly acknowledged as indigenous to India. Its deployment extends to soil reclamation, fiber production, and as a forage crop. Within tropical realms, notably in Indonesia, Malaysia, Taiwan, Thailand, and China, it finds prominence as a robust green manure crop. In South Asian territories, it has sustained historical significance as a pivotal fiber crop, contributing to the production of ropes and paper (Rotar and Joy, 1983).

Systematic (Anonymous, 2023)

Kingdom Plantae	: Plants
Subkingdom Tracheobionta	: Vascular plants
Superdivision Spermatophyta	: Seed plants
Division Magnoliophyta	: Flowering plants
Class Magnoliopsida	: Dicotyledons
Subclass	: Rosidae
Order	: Fabales
Family Fabaceae	: Pea family
Genus	: <i>Crotalaria</i> L. (rattlebox)
Species	: <i>Crotalaria juncea</i> L. (sunn hemp)

Crotalaria juncea L. is an herbaceous plant that typically thrives in tropical regions, exhibiting an upright growth habit with a potential height range of 2.5 to 4 meters. Its lance-shaped leaves, arranged spirally along the stem, are structurally simple, featuring a width spanning from 0.5 to 3.0 cm and a length of 4 to 12 cm, displaying a vibrant green hue.

The plant is characterized by a robust taproot and well-developed lateral roots, while the stem can attain a diameter of up to 2 cm. When cultivated under conditions with a shorter daylight duration, the flowering process commences approximately eight weeks after the initial planting



Figure 1: Leaves and flowers of Sunn hemp (original)

The flowers form clusters, measuring 8-20 cm in length, featuring hairy sepals measuring 1.5 cm in length and petals measuring 2-5 cm in length, presenting a striking yellow color. The fruit takes the form of a cylindrical pod covered in short velvety hairs, enclosing 6-12 seeds. These curved, heart-shaped seeds have dimensions of 6-7 mm in length and may vary in color from dark brown to black. The weight of a thousand seeds is approximately 35-50 grams (Rotar and Joy, 1983; Chaudhury et al., 1997; Mosjidis and Wang, 2011; Al-Snafi, 2016; Demiroğlu Topçu and Özkan, 2018).



Figure 2. Illustration of sunn hemp (*Crotalaria juncea* L.) (Anonymous, 2023)

3. ADAPTATION

Crotalaria juncea L., commonly known as sunn hemp, is the fastest-growing species within the *Crotalaria* genus and exhibits high adaptability to both tropical and subtropical climates. Successful cultivation is feasible in regions with elevations below 600 meters from sea level, particularly in temperate zones (Rotar and Joy, 1983). Moreover, it exhibits adaptability to diverse soil conditions, thriving in soils with an average annual temperature ranging between 15.0-37.5°C and a soil pH between 5.0-8.4. For fiber production, it is advisable to cultivate *Crotalaria juncea* L. in very light and well-drained soils with a sandy or loamy structure that retains sufficient moisture.

For optimal seed germination, it is advised to sow in a well-prepared seedbed with soil moisture levels not falling below 30%. The timing of sowing significantly influences the vegetative growth and development of *Crotalaria juncea* L. Despite

being a short-day plant, vegetative growth is more advantageous during longer daylight periods, making April and May the optimal sowing months. Late sowings result in a shortened vegetative growth period, reduced plant height, decreased internode count, and narrowed stem diameter.

Recommended practices include sowing *Crotalaria juncea* L. in rows, with seeds typically sown at a depth of 2-3 cm. Research indicates that narrow-row planting yields higher seed production compared to wide-row planting, with an ideal row spacing of 20-30 cm. The inter-row distance should be maintained between 5-10 cm if necessary. Germination is epigeal, occurring within approximately three days. Plant growth is significantly affected by the sowing date and early-season rainfall.



Figure 3: Seeds of Sunn hemp (original)

The seeding rate depends on germination and soil moisture, with a minimum germination rate of 80%. For row planting, 20-30 kg per hectare of seeds is recommended, while for broadcast planting, 40-50 kg per hectare should be used (Chaudhury et al.,1997). As a leguminous plant, *Crotalaria juncea* L. does not necessitate nitrogen fertilization, but applying a small amount of nitrogen fertilizer at planting can enhance yield. For green manure purposes, planting can occur in any month, with subsequent burial of plants around the 30th or 45th day of the growing season. Weeds are generally left unmanaged, except for *Ipomoea* spp., which may grow concurrently with sunn hemp.



Figure 4: Sunn hemp epigeal germination and stem diameter(original)



Figure 5: Pods of Sunn hemp (original)

Harvest timing varies based on ecological conditions and cultivation goals. The recommended harvest time for fiber production is during flowering or when the seed pods are fully ripe. It is noteworthy that there is little discrepancy in strength and fiber quality during this period. Additionally, in certain regions, the upper part of the plant (approximately 30 cm) is initially mown and utilized for fodder. Following harvest, the plants are categorized based on their height and thickness, bundled into approximately 20-25 cm bundles, and left in the field for 2-3 days to facilitate leaf shedding. Subsequently, the leaves are manually removed, and the stems are directly sent for retting. In some parts of India, the plants are left on the ground for 10-15 days, and the separation of fibers takes place overnight with sufficient dew, which can be quite substantial (Duke, 1981).

For green forage or silage production, the optimum harvest period is around 50% flowering and early pod stages. Harvesting can be performed at ground level using a sickle or a machine. Moreover, during this period, it is also utilized for grazing in some countries around the world.

The seed yield of sunn hemp exhibits considerable variation, influenced by factors such as planting time, variety, and the impact of diseases and pests. Ideally, in the chosen region for seed production, the latitude should not exceed 24°N, temperatures should not drop below 10°C, ample sunlight should be available, and there should be no precipitation during the fruiting period. Cultivation areas in India typically range between 17-30°N. In Brazil, it is feasible to cultivate the plant in the equatorial zone up to 22.5°N, under conditions of moderate to heavy rainfall. Under optimal conditions, the average seed yield is in the range of 300-700 kg per hectare.

4. YIELD AND QUALITY

4.1. Nutritive value of forage

Crotalaria juncea L. is recognized as the most aggressive species within its genus (Mosjidis and Wang, 2011). Furthermore, it can achieve a green forage yield of 27 t ha⁻¹ in 60 days (Warren et al., 2012), and the rapidly growing plant attains a height of 1.2 meters 60 days after sowing and 1.8 meters after 90 days (Rotar and Joy, 1983; Mansoer et al., 1997). The leaves of the plant are known to contain 30% protein (Warren et al., 2012). Additionally, Mansoer et al. (1997) reported in their study that the ratios of lignin, cellulose, and hemicellulose in the leaves were lower at each harvest time than the ratios in the stem. Sheep and goats have been observed to prefer the leaves and upper parts of the plant (Burke et al., 2011).



Figure 6: General appearance of the Sunn hemp (original)

Grazing can be initiated when the plants reach approximately 45-90 cm in length. Despite having high leaf quality (about 4-5% N equivalent, 25-30% protein, 22-28% NDF, 22-27% ADF), the stem quality is low (about 1.3-1.7% N equivalent, 8-10% protein, 74-76% NDF, 64-65% ADF). However, the stems can provide the roughage needed by ruminants. Intensive growth until flowering may lead to the loss of some lower leaves and a decrease in forage quality. When the plant is 80% flowered, approximately 35-40% of the biomass consists of leaves. Consequently, early harvest is preferable for forage use because the plants are less mature, leading to an increase in leaf proportion and improved forage quality. Additionally, *Crotalaria juncea* L. has demonstrated successful results in silage production (Coutinho et al., 2011; Demiroglu Topcu and Ozkan, 2021; Ozkan, 2022). In some regions of the world, such as South Africa, Brazil, and Hawaii, it is also cultivated as a green manure and cover crop (Romin and Fitt, 1938; National Academy of Science, 1979; Rotar and Joy, 1983; Stallings, 2015; Meagher et al., 2017).

4.2. Green manure and crop rotation

In animal production, leguminous forage crops serve as the primary source for providing the crucial input of feed, playing a vital role in enhancing feed quality. These plants not only contribute to animal nutrition but also, through the *Rhizobium* bacteria in their roots, fix atmospheric nitrogen into the soil. This process not only improves soil structure but also enhances the yield and quality of subsequent crops in crop rotation. The nitrogen fixed by leguminous forage crops becomes a significant nitrogen source for non-nitrogen-fixing plants in mixed plantings (Duke, 1981; Lindemann and Glover, 2003). Research indicates that common vetch (*Vicia sativa*) can fix 180 kg ha⁻¹ of nitrogen, and hairy vetch (*Vicia villosa*) can fix 110 kg ha⁻¹ of nitrogen (Erkovan, 2007).

Crotalaria juncea L. is widely grown as green manure worldwide (Diamond, 2006). Under suitable soil conditions, *Crotalaria juncea* L. can provide sufficient fertilizer to meet the nutritional requirements of many plants for N, P, and K (Phatak et al., 2002). *Crotalaria juncea* L., known for its soil improvement capability and suitability as a summer crop, provides approximately 165 kg ha⁻¹ of nitrogen to the soil (Rotar and Joy, 1983). This value is considered quite satisfactory for a rapidly developing summer crop. As most nitrogen and other macro-nutrients are present in its leaves, the early or mid-flowering period is the most suitable for incorporating

Crotalaria juncea L. into the soil as green manure or organic mulch (Marshall, 2002).

The organic matter of *Crotalaria juncea* L. decomposes rapidly in tropical climates (approximately 2 weeks), with the highest nitrogen mineralization rate occurring during this period (Wang et al., 2004). Therefore, producers should plan to seed and fertilization practices to ensure that nutrients are readily available in the soil within the first 2 weeks after incorporating *Crotalaria juncea* L. residues.

Crotalaria juncea L. residues can be left on the soil surface as organic mulch. This mulch decomposes much more slowly over an extended period. The use of *Crotalaria juncea* L. plant residues as surface mulch in strip-tillage systems allows some residues to be incorporated into the soil, releasing nutrients immediately, while others remain on the soil surface, gradually releasing nutrients as mulch (Reeves et al., 1996).

The most significant advantage of *Crotalaria juncea* L. in crop rotation systems is its ability, as a leguminous plant, to fix atmospheric nitrogen in its root nodules, thereby meeting its nitrogen needs and having a good potential for soil improvement. Additionally, it is beneficial in rotations for areas exposed to nematode infections (Wang et al., 2002; Kamil et al., 2009). Rotation trials have been conducted with crops such as sugar cane, rice, wheat, and jute (Barros Salgado et al., 1972). In Cuba, it is rotated with kenaf, and in the U.S., it is rotated with cotton. In Brazil, it is rotated with wheat, sorghum, sugar cane, and beans. It has been determined that planting *Crotalaria juncea* L. before beans increases yield by an average of 41%. In India, suitable cropping patterns include rotations such as sunn hemp-wheat, sunn hemp-potato, sunn hemp-rice-wheat, sunn hemp-mustard, and sunn hemp-mustard-wheat. Studies on various combinations have shown that planting sunn hemp as a preceding crop increases wheat yield by 10-15% (Chaudhury et al., 1997).

4.3. Toxicity

Research on *Crotalaria juncea* L. in the United States commenced in the 1930s (Cook and White, 1996). *Crotalaria juncea* L., with its rapid growth potential, has been included in the breeding program by the National Academy of Science (1979) to increase its potential uses and benefits. Previous studies on this plant have frequently expressed concerns about potential toxic effects in animal nutrition,

particularly regarding its seeds or green tops used as fodder (National Academy of Science, 1979; Purseglove, 1981; Rotar and Joy, 1983; Williams and Molyneux, 1987; Strickland et al., 1987; Hess and Mosjidis, 2008; Mosjidis et al., 2012). However, recent research and the development of new varieties have demonstrated the absence of toxic effects (National Academy of Science, 1979; Purseglove, 1981; Rotar and Joy, 1983; Williams and Molyneux, 1987; Strickland et al., 1987; Hess and Mosjidis, 2008; Mosjidis et al., 2012). However, some researchers have conclusively determined that only certain species within the same genus, such as *Crotalaria spectabilis*, *Crotalaria retusa*, and *Crotalaria pallida*, are toxic (Ritchey et al., 1941; Martin et al., 1976; Hooper and Scanlan, 1977; Williams and Molyneux, 1987).

Purseglove (1981) reported that the seeds of *Crotalaria juncea* L. can be utilized as feed for farm animals in certain countries without inducing toxic effects. Rotar and Joy (1983) determined that the seeds of the “Tropic Sun” variety, developed in Hawaii, were non-toxic to animals. In a study conducted by Williams and Molyneux (1987) to ascertain the toxic effects of seeds from various *Crotalaria* species on chicks, it was found that there were no toxic effects of *Crotalaria juncea* L. seeds in chickens fed with 10 mg g⁻¹ body weight. Mosjidis et al. (2012) concluded, in their study investigating whether the seeds and forage of *Crotalaria juncea* L., a widely cultivated annual plant in tropical regions, exhibit toxic effects, that this plant serves as a valuable forage source (non-toxic). It was determined that the seeds do not cause acute toxicity in domestic animals, despite the detection of trace amounts of pyrrolizidine alkaloids. Therefore, it was reported that there is no issue in utilizing it as fodder.

4.4. Biofuel and Bio-oil

In global plant production, the emphasis is not only on food supply but also on energy production from plants, particularly focusing on the feasibility of cultivating crops in marginal areas. This approach aims to contribute to the economy by utilizing non-arable lands. Currently, there is a goal to increase forage crop farming to 30% and energy crop farming to 20% of total agricultural production (Eser et al., 2007). Clean biodiesel can be produced from biomass-based agricultural oils. *Crotalaria juncea* L., being a versatile plant belonging to the legume family and capable of being evaluated as a green manure or forage crop, can also be used

to produce biodiesel through transesterification using methanol and different catalysts (Sadhukhan and Sarkar, 2016). Although the energy content of *Crotalaria juncea* L. oil ($34.128 \text{ MJ kg}^{-1}$) is slightly lower than that of gasoline (47 MJ kg^{-1}) and diesel fuel (44.8 MJ kg^{-1}), its other characteristics indicate significant potential for use. This biological oil may have the possibility of being used as fuel for a diesel engine with some modifications (additives) (Demiroğlu Topçu et al., 2017).

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