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Crotalaria juncea: A Potential Multi-Purpose Fiber Crop

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Sunn hemp (*Crotalaria juncea* L.) is one of the earliest and most distinctly named fibers of India. Past research efforts have shown that the soft, lignified fibers produced in the stem of sunn hemp could be utilized in the manufacturing of pulp and paper, and more recent efforts have indicated that other potential products can be developed from these fibers. Additional characteristics that enhance the value potential of sunn hemp as a nonwood, fiber crop are low nitrogen fertilization requirements, the ability to fix nitrogen and to grow in marginal soils, drought resistance, and resistance to root-knot nematodes. Unlike kenaf (*Hibiscus cannabinus* L.), another potential nonwood fiber crop, which produces consistently greater yields and is less susceptible to lodging, sunn hemp is highly resistant to root-knot nematodes and the stalks dry out more rapidly after a killing frost prior to harvest. Past and present research efforts have identified sunn hemp as a potential nonwood fiber source that could be used in the manufacturing of several products, including newsprint, specialty papers, and as a component of commercial nursery potting media. This paper reports on the potential use of *Crotalaria juncea* as a nonwood source of fiber.

ECONOMIC IMPORTANCE

Sunn hemp, a member of the legume family (Fabaceae), has great potential as an annually renewable, multi-purpose fiber crop. It is the most important species of the *Crotalaria* genus, which is comprised of over 350 species located in the tropics and subtropics of both hemispheres. As one of the most widely grown green manure crops throughout the tropics, sunn hemp is often grown in rotation with several different crop species (Kundu 1964; White and Haun 1965; Lai et al. 1967; Purseglove 1968; Srivastava and Pandit 1968; Barros Salgado et al. 1972; Mascarenhas et al. 1980; Rotar and Joy 1983). The stems of sunn hemp are composed of two fibers, the bast and woody core. The bast fibers, which are located in the outer bark, are much longer than the core fibers, but the two fiber widths are very similar (Cunningham et al. 1978). The proportion of bark in the total stalk, by dry weight, generally ranges from 15% to 20%. Kundu (1964) reports that the actual proportion of bast fiber in dry stalks ranges from 6.4% to 10.5%.

Research with sunn hemp has been conducted in the United States since the 1930s, where it was reported to be an excellent soil-improving crop. It produced high organic matter yields, was able to fix nitrogen, and could reduce the build-up of root-knot nematode populations (Breitenbach 1958; Dempsey 1975). However, the difficulty in producing seed caused many farmers to abandon the growing of this crop. Interest in growing sunn hemp was renewed during World War II, as *C. juncea* was added to the list of critical war materials in 1942 because of its potential use as cordage fiber, especially for Marine Oakum. Attention again focused on sunn hemp from the late 1950s through the 1960s. This was the result of efforts to identify annually renewable sources of nonwood fiber which could be used in the manufacture of paper and pulp. Although research showed that sunn hemp possessed good pulping characteristics and that high macerate yields could be obtained (Nieschlag et al. 1960; Nelson et al. 1961), most research eventually concentrated on kenaf. Kenaf received more attention because of its ability to produce consistently greater yields and have less lodging, which could reduce yields and harvest efficiency. A more recent report by Cunningham et al. (1978) indicates that sunn hemp may be superior to kenaf for some fiber properties, including bast fiber length (3.79 vs. 2.62 mm) and width (24.3 vs. 19.7 µm). They concluded that sunn hemp possessed the following properties that made it an excellent candidate for papermaking: (1) good yields of bleachable sulfate pulps, (2) pulp strength properties that are equal to or greater than those of mixed southern hardwood pulp, and (3) bast fiber length to width ratio that is greater than those of wood fibers. A study by Scott and Cook (1994) indicated the potential yield advantage of sunn hemp compared to kenaf when grown in soils infested with the southern root-knot nematode [*Meloidogyne incognita* (Kofoid and White) Chitwood]. In tests conducted under growing conditions in South Texas, Kansas, and South Carolina total stalk yields have been reported to range from 14,800 to 18,450 kg/ha (White and Haun 1965; Scott and Cook 1994; Scott et al. 1991).

Most of the present-day sunn hemp production is located in India, Bangladesh, and Brazil, where it is grown as a green manure crop, a fodder crop, or for the bast fibers. The bast fibers are utilized for the manufacture of cordage and high quality paper. In addition to the uses as a green manure crop and as a fiber source, research is being conducted in Texas to determine if the shorter core fibers of sunn hemp can be utilized in the manufacture of soil-less potting media for commercial nursery application.

ORIGIN

Crotalaria juncea is generally considered to have originated in India, where it has been cultivated since prehistoric times (Montgomery 1954). The genus name *Crotalaria* means rattle and is indicative of the noise made by the seeds shaken in the mature pods (White and Haun 1965). The species name *juncea* was given to this plant by Linnaeus because of its resemblance to *Spartium junceaum* L., the Spanish broom of the Mediterranean region with its green rushlike, scantily-leaved branches (Kundu 1964).

ADAPTATION

Crotalaria juncea is the most important and fastest growing species of the *Crotalaria* genus. Although generally considered to be a tropical or subtropical crop, it is drought resistant and has a wide range of adaptation to soil types. For fiber production, a light loam, moderately rich, well-drained soil is preferred (Montgomery 1954; Kundu 1964). Vigorous growth can be achieved on clay or low lying soils; however, the bast fiber may be coarser and yields lower. The major sunn hemp growing areas of India and Brazil are characterized by high humidity, an average temperature of 23.0° to 29.4°C, and a rainfall of 170-200 mm during the growing season (Dempsey 1975). Sunn hemp is typically photoperiod-sensitive and flowering occurs in response to short days (White and Haun 1965).

BOTANICAL DESCRIPTION

Sunn hemp is a short-day, erect shrubby annual, generally 1 to 4 m in height. The stems are cylindrical and ribbed. Branching in the upper portion is minimized with dense plantings. The simple, elliptic to oblong shaped leaves, are spirally arranged on the stem. The root system is characterized by a long, strong taproot, well developed lateral roots, and much branched and lobed nodules, up to 2.5 cm in length. The inflorescence is a terminal open raceme to 25 cm in length with deep yellow flowers. Flowering is indeterminate. Extensive cross-pollination occurs in sunn hemp and self-pollination takes place after the stigmatic surface has been insect or mechanically stimulated (Purseglove 1968). Seeds are small, flattened, kidney-shaped, and contain approximately 35% protein. Due to cultivar and environment, seed weight is highly variable, ranging from 18,000 to 30,000 seed per kg (Dempsey 1975). 'Tropic Sun', a Hawaiian cultivar, was reported to have 30,000 to 35,000 seed per kg (Rotar and Joy 1983).

CULTIVATION AND MANAGEMENT

Good land preparation should be made before planting sunn hemp for fiber production (White and Haun 1965; Ghumary and Bisen 1967; Barros Salgado et al. 1972). Although reports on fertilization requirements vary, additions of P are generally recommended for low phosphorous soils (Barros Salgado et al. 1972; Rotar and Joy 1983). Sunn hemp is fast growing and generally suppresses weed populations due to dense canopy shading (Burnside and Williams 1968). However, early season weed control has been shown to improve yields when sunn hemp is grown for fiber (White and Haun 1965). No herbicides are currently registered for use in sunn hemp production. However, several preemergence herbicides (most notably clomazone at 1.38 kg a.i./ha) recently have been identified as causing minimal phytotoxicity and providing efficient weed control (J.R. Smart and C.G. Cook, unpubl.).

Recommendations for seeding rates vary greatly among production areas. In the 1995 South Texas commercial planting, seeds were sown at 17 kg/ha in double-drilled rows spaced 1.02 m apart (G. Kinney pers. commun). White and Haun (1965) recommended seeding rates of 16.8 to 22.4 kg/ha in rows spaced 30.5 to 35.6 cm apart. For fiber production in Brazil, Lovadini et al. (1970) advocated 60 kg/ha of seed in rows spaced 50 cm apart, while Barros Salgado et al. (1972) suggested a seeding rate of 35 to 40 kg/ha. Ghumary and Bisen (1967) report that the broadcast seeding rate in India is 66.5 to 88.5 kg/ha. However, when drill-planted on rows spaced 30 cm apart, they reported that a seeding rate of 6.6 kg/ha can yield 10% more fiber than the higher broadcast rate. Preliminary results from studies conducted at

Weslaco, Texas indicate that plant height and total stalk dry yield was not changed for four different seeding rates of ca. 4.9, 6.8, 8.7, or 10.8 kg/ha on rows spaced 1.02 m apart.

Planting dates also differ among locations; however, adequate soil moisture and frost-free, warm weather conditions will provide rapid emergence and the highest yields (Kundu 1964; White and Haun 1965). In Kansas, White and Haun (1965) reported a 40% decrease in yield due to a two-week delay in a 1962 planting. However, a two-week delay in 1963 did not affect yields. Preliminary results in South Texas also indicate that significant decreases in yield, plant height, and stalk diameter may occur when planting is delayed by two, four, or six weeks. Later harvest dates do not appear to improve yields of late planted crops and delaying harvest may actually result in lower yields.

HARVESTING

To obtain the highest quality fiber, harvesting should be done at the optimum time. Although opinions differ, the general recommendation is that harvesting should take place during the seed pod stage (Medina et al. 1961; Kundu 1964; Purseglove 1968). Mechanized harvests will be necessary for large-scale commercial plantings. White and Haun (1965) reported that although forage harvesters had been successfully used, precision cutting was difficult to obtain and the chopped material was bulky to handle. A whole stalk kenaf harvester that was designed using sugarcane technology will be used to harvest the South Texas sunn hemp crop. This harvesting system is adjusted to cut the stalks slightly above ground level and to remove the very upper foliar portion of the stalk, which may be necessary if the fiber is to be utilized in the manufacture of paper. The experimental harvesting of small research plots in 1994 with this machinery indicated that this method of harvest should be successful. However, more efficient, rapid, and specifically designed machinery for harvesting and processing may be necessary for large-scale commercial operations, since it was reported by Scott et al. (1991) that increasing the growing season beyond six months may not be beneficial and may actually result in declining fiber yields.

SEED PRODUCTION

Sunn hemp is generally photoperiod-sensitive and flowering commences in response to short days (White and Haun 1965). Because of the lateness in flowering, with the exception of Texas, very little seed production has occurred in the continental United States. The primary sources of seed for the sunn hemp grown in the continental United States are from Hawaii and South America (most notably Brazil and Columbia). The short-day, frost-free environments of these locations allow for reliable and excellent yields of good quality seed to be produced. Small-scale seed production has occurred in South Texas, but the possibility of early frost always poses a threat of reducing yields of seed crops grown in the continental United States. Recommended seed rates vary from 3 to 5 kg/ha in Hawaii (Rotar and Joy 1983) to 17 to 22 kg/ha in South Africa (DeToit 1946).

Seeds are ready for harvest when pods begin to turn yellow in color and the seeds rattle in the pods (DeToit 1946; Rotar and Joy 1983). For mechanical harvest, a combine with the header raised as high as possible without leaving the seed pods on the stalk should be used. This technique will result in cleaner seed, less moisture, and maintain the speed of the combine harvesting operations. Seed yields are variable between locations. DeToit (1946) reported 450 to 900 kg/ha could be produced in South Africa, while Baird et al. (1957) found that yields in

Columbia ranged from 555 to 1000 kg/ha. Rotar and Joy (1983) indicated that 1460 to 2240 kg/ha could be produced in Hawaii.

Many species of *Crotalaria* contain toxic pyrrolizidine alkaloids in the seeds. In *C. juncea*, trichodesmine was identified as the principal toxic alkaloid (Zhang 1985). Studies have indicated that poisoning can occur in both horses (Nobre et al. 1994) and pigs (Zhang 1985) when *C. juncea* seed are ingested.

MAJOR DISEASES AND OTHER PESTS

No serious diseases have developed in South Texas and few have been reported for the United States. However, the soils of South Texas are naturally infested with Phymatotrichum root rot, incited by *Phymatotrichum omnivorum* Duggar [= *Phymatotrichopsis omnivora* (Duggar) Hennebert], a fungal pathogen that attacks over 2,000 plant species (Streets and Bloss 1973). Sunn hemp is reported to be susceptible to attack from this fungal pathogen (Streets and Bloss 1973; Cook and Hickman 1990). However, laboratory studies have indicated that sunn hemp is more resistant to *P. omnivorum* than kenaf (Cook and Hickman 1990). Control of this pathogen can be achieved through cultural practices and crop rotations (Streets and Bloss 1973). Other pathogens of sunn hemp that have been reported from the United States are a powdery mildew, caused by *Microsphaera diffusa* Cook and Peck, and a root and stem rot, incited by *Sclerotium rolfsii* Sacc. (Farr et al. 1989).

Serious diseases of sunn hemp grown in India are anthracnose, caused by *Colletotrichum curvatum* Briant and Martyn (Mitra 1934; Whiteside 1955) and a wilt, caused by *Fusarium udam* E.J. Butler f. sp. *crotalariae* (G.S. Kulkarni) Subramanian (Mitra 1934; Kundu 1964; Purseglove 1968). Fungicide seed treatments and crop rotations are the most recommended and practiced disease control measures (Mitra 1934; Whiteside 1955). Sources of resistance to anthracnose have been reported by Dey et al. (1990), indicating the potential to reduce disease losses through the development of anthracnose resistant varieties. A fungus (*Ceratocystis fimbriata* Ellis & Halst) that causes a wilt disease of sunn hemp in South America has been reported by Barros Salgado et al. (1972) and Malaguti (1951). In addition to implementing crop rotations for disease control, sunn hemp germplasm which possesses resistance to *C. fimbriata* has been reported (Ribeiro et al. 1977).

The major insect pests of sunn hemp in the United States are reported to be the lima bean pod borer, *Etiella zinckenella* Treit. and bella moth, *Utetheisa bella* L. (Seale et al. 1957). In Florida, these insect pests were reported to attack the fruiting pods, with little to no seed being produced. In India, the two major insect pests of sunn hemp are the sunn hemp moth (*Utethesia pulchella* L.), which feed on the leaves and seed pods, and the top-shoot borer (*Laspeyresia pseudonectis* Meyr.), which bores into the apical tip of the plant, causing excessive branching and cessation of growth (Kundu 1964). Dempsey (1975) reports that significant shoot borer resistance has been identified.

Other insect pests that are reported to periodically attack sunn hemp are the leaf feeding catapillars, *Argina cribraria* Clerck and *A. syringa* Cramer. Additional stem or shoot borer species include *Laspeyresia tricenta* Meyr., *Cymotricha tetraschema* Meyr., and *Selinas monotropa* Gaert. Dempsey (1975) and Reddy (1956) also report that the sunn hemp mirid (*Ragmus importunitas* Distant), flea beetle (*Longitarsus belgaumensis* Jac.), and stink bug (*Nezara viridula* L.) will attack sunn hemp. In 1995, the silverleaf whitefly (*Bemisia argentifolii* Bellows & Perring) was observed to feed and reproduce on the lower surface of sunn hemp leaves. Although no actual damage was quantified, premature leaf defoliation appeared to occur.

GENETICS AND BREEDING

Sunn hemp, $2n = 16$, is generally reported to be a self-incompatible plant. Cross-pollination is extensive and self-pollination occurs only after the stigmatic surface has been stimulated by insects or some other means (Kundu 1964). More recently, successful efforts in breeding for self compatibility have been reported (Ribeiro et al. 1977). The development of self compatible germplasm should accelerate the development of true breeding, stable pure lines.

According to Purseglove (1968) and Dempsey (1975), most of the sunn hemp cultivars have originated from selection of improved types suited to specific localities, rather than by breeding procedures. These selections generally focused on early maturity, improved fiber yield, and resistance to pests. Dempsey (1975) provides lists of improved sunn hemp cultivars that have been selected for the growing conditions of India, Brazil, and Taiwan. Past attempts to develop strains from interspecific crosses among *Crotalaria* have not been successful (Kundu 1964).

In more recent years, genetic research and breeding procedures have been conducted on sunn hemp in Brazil (Ribeiro et al. 1977; Miranda et al. 1989; Miranda 1991). Miranda (1991) conducted a genetic study in 1990 to determine the inheritance pattern of seed yield and plant height for sunn hemp. Results indicated that the estimation of the dominant effect was nine times larger than the additive effect. Since pollination generally can be controlled in sunn hemp due to the self incompatibility factor, these findings indicate the possibility of exploiting heterosis. Ribeiro et al. (1977) described the breeding methodology used in the development of sunn hemp germplasm possessing both self compatibility and resistance to *C. fimbrata*. The presence of a self compatibility factor in sunn hemp will allow breeders to treat sunn hemp like a self pollinated crop, ie. single, individual plant selections can be made and the potential exists for a more rapid development of true breeding, pure line cultivars. Preliminary results indicate that final plant height and basal stem diameter are positively correlated with total stalk dry matter, indicating selections for these traits could result in higher yielding cultivars.

SUMMARY AND FUTURE

As the world faces an increased need for fiber, sunn hemp, a nonwood fiber crop, has the potential to be grown on a large commercial scale. Present known industrial uses for sunn hemp fiber include the manufacture of pulp, specialty papers, and as a component of a soil-less potting media. In the past, sunn hemp bast fiber was used for cordage and for making specialty paper. Today, in countries outside of the United States, sunn hemp is often grown in crop rotations as a green manure crop to improve soils and reduce root-knot nematode infestations. Future efforts should focus on the expansion of product research and development, the development of harvesting and processing equipment, and the identification of more efficient crop management strategies. The future of sunn hemp appears very promising given the fact that worldwide demands for fiber are increasing and current wood fiber supplies cannot continue to meet the industrial market demands of the future. Research has shown that sunn hemp can be successfully grown as a fiber crop and that these fibers can supplement many of the current fiber market needs.

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