Management of Nematodes and Soil Fertility with Sunn Hemp Cover Crop[1]

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Introduction

Sunn hemp, *Crotalaria juncea* L. is a rapidly growing crop that is used for fiber production in India and Pakistan. It is most popular as a green manure and organic N source in many tropical and subtropical areas in the world. Recently, there is a growing interest in rotating sunn hemp with agronomic crops in the southern United States and in using sunn hemp as a summer cover crop in Florida and other southeastern states. Sunn hemp suppresses weeds, slows soil erosion, and reduces root-knot nematode populations (Rotar and Joy 1983). When plowed under at early bloom stage, nitrogen recovery of this leguminous plant is the highest. Under optimum growing conditions such as in Hawaii, 'Tropic Sun' sunn hemp can produce 134 to 147 lb/acre of nitrogen (N) and 3 tons/acre air-dry organic matter at 60 days of growth at 40 kg seed/ha (Rotar and Joy 1983). In northern Florida, sunn hemp is usually grown in the summer and can produce 2.4 tons/acre of dry biomass and 98 to 125 lb N/acre (Marshall 2002). In southwestern Alabama, plants grown for 9 to 12 weeks produced 2.6 tons/acre dry matter and 112 lb N/acre (Reeves et al. 1996). Although in the tropics, 'Tropic Sun' grows and produces seed year-round at elevations of 0 to 900 ft, and in summer up to 1800 ft, sunn hemp does not set seed well in Florida (R. Gallaher personal communication). Recently, cultivars adapted for seed production in the southeastern United States have been introduced. Sunn hemp is usually planted in summer in Florida (Rotar and Joy 1983), but it is suitable as a green manure crop as far north as Maryland. Although sunn hemp is most commonly used as a cover crop, it also has promise for use as a forage crop. This publication is intended to inform agricultural professionals of the impacts of sunn hemp cover cropping on soil fertility and plant-parasitic nematodes in order to make informed management choices.

Figure 1. Sunn hemp (*Crotalaria juncea* 'Crescent Sun') at early flowering stage in research plots near Citra, FL. Background cover crops are sorghum-sudangrass and foreground is pearl millet.
Credits: Z. J. Grabau, UF/IFAS

History and Production Considerations

In 1958, the National Resources Conservation Service (NRCS) (formerly the Soil Conservation Service), and the University of Hawaii purchased seeds of *Crotalaria* from a farmer who was growing it as a cover crop on the island of Kauai. This germplasm was used to develop the sunn

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hemp cultivar 'Tropic Sun'. 'Tropic Sun' seed was released in 1982 by the NRCS and University of Hawaii (Rotar and Joy 1983). The Agricultural Research Services Poisonous Plant Laboratory and the University of Hawaii determined that seeds of this cultivar were not toxic to livestock, and the plant was resistant to root-knot nematodes (Rotar and Joy 1983).

Seed cost and limited seed availability have historically been a barrier to wider sunn hemp adoption because 'Tropic Sun' and other varieties such as 'Crescent Sunn' and 'Blue Leaf' can be readily produced only in Hawaii or tropical countries. This is because they are *short day* plants, meaning flowering and seed set is triggered when daylight length is shorter than a given period. High temperatures and a long growing season are also required for plentiful seed set. These conditions for consistent seed production are not met in the continental United States. Recently, seed availability has increased somewhat, and, correspondingly, seed costs have also decreased. Current prices may range from \$1.10–\$1.50/lb, compared with historical prices near \$2/lb. Even with relatively lower prices, total seeding costs can still be high because recommended seeding rates in Florida range from 10–50 lb/acre (Wang et al. 2019; Fall et al. 2020). Higher seeding rates are needed for broadcast applications, particularly when quick, consistent ground cover or high biomass is desired for weed suppression or forage production. Lower seeding rates are adequate when planting in rows, and clipping/harvesting biomass at crucial times can enhance production at low seeding rates (Marshall 2001).

Recently, sunn hemp cultivars have been developed with day-neutral characteristics, meaning they flower and seed after a fixed period of time and are less dependent on day length. This makes them more adapted for seed production in the Southeast, which could expand seed availability, and may increase flexibility for sunn hemp production in cooler conditions or shorter growing seasons. 'AU Golden' and 'AU Durbin' were developed at Auburn University in Alabama and released in 2014. 'Ubon' is another day-neutral cultivar that was developed in Ubon Ratchathani, Thailand. 'AU Golden' may flower 5–6 weeks after planting and can produce 400–1,800 lb seed/acre in the Southeast. AU cultivars yield up to 10,000 lb biomass/acre in Alabama with optimum seeding timing in mid-June (Mosjidis et al. 2013). In south Florida trials at Ona, 'AU Golden' and 'Ubon' flowered at 80–90 days and were terminated (minimal biomass is accumulated after flowering), producing 8,600 and 1,100 lb dry matter/acre, respectively (Garzon et al 2020). In the same trial, short day 'Crescent Sunn' produced 33,600 lb dry matter/acre, but was allowed to grow 159 days because it did not flower (Garzon et al. 2020). In central Florida trials at Citra, 'AU Golden' produced up to 400 lb seed/acre when planted in April or 40 lb seed/acre when planted in June (Meagher et al. 2017). Continued research on day-neutral cultivars is needed to establish production practices in Florida. Whereas overall biomass production may be greater with short-day cultivars, day-neutral cultivars may fit better in cooler or shorter growing windows or when excessive height is not desired. Detailed information on sunn hemp production practices in Florida can be obtained from the UF/IFAS EDIS SS-AGR-444 (Fall et al. 2020) and SL 306 (Wang et al. 2019).

Figure 2. Sunn hemp ('Crescent Sunn') late flowering stage near Citra, FL.
Credits: Z. J. Grabau, UF/IFAS

Sunn Hemp as a Fertilizer

Sunn hemp is most commonly used as a green manure, where it is grown for 2 to 3 months before cash crop planting and then incorporated into the soil at early blooming stage. Besides use as a green manure, sunn hemp can also be used as organic mulch where the cover crop is mowed and left on the soil surface. The advantage of using a leguminous cover crop as an organic mulch rather than green manure is that this practice will slow down the release of nutrients from the crop residues and allow the nutrients to be available for the subsequent cash crops over a longer period of time. It had been demonstrated that sunn hemp can be grown as a winter cover crop in Alabama, and leaving the residues on the soil surface over the winter resulted in the release of 67 to 71 lb N/acre (Reeves et al. 1996). Research done in south Florida suggested that when sunn hemp is used as green manure and organic mulch, it should be seeded at high rates (50 lb/acre) and the crop terminated at 10–12 weeks from the planting date (Abdul-Baki et al. 2001).

Work on maximizing biomass and seed production at low seeding ratings has been a focus due to issues with seed availability and cost. Research in south Florida concluded that cutting sunn hemp stems at 1 ft above soil level 100 days after planting (when plants were about 5 ft tall) and allowing the plants to grow for an additional 70 days resulted in the highest quality of green manure harvested as compared to uncut or cutting at a higher stem height. This is because cutting at 1 ft increased leaf yield (Abdul-Baki et al. 2001). This increased the N content of the biomass harvested because the leaf tissues contained higher concentrations of N (3.96%) than the stem tissues (0.88%) and whole-plant tissues (2.5%) (Marshall 2002).

Since most of the macro-nutrients in sunn hemp are found in leaves and flowers, use of sunn hemp as green manure or organic mulch would be most beneficial at the early to mid-blooming stage (Marshall 2002). Short-day sunn hemp cultivars will only flower in fall when day length becomes shorter in north Florida. However, sunn hemp is very susceptible to frost kill, and so opportunity for growth and biomass increase is limited by cool temperatures in the fall. Therefore, immediate use of most sunn hemp residues is limited to supplying nutrients only to benefit winter vegetable crops. Another option for use of a sunn hemp cover crop is to harvest the cover crop residues, air dry them, grind up the residues, and store them as organic fertilizer for later use (Marshall 2002). While this form of application is time consuming, it offers opportunities to manipulate fertilizer application rate and timing. The introduction of day-neutral sunn hemp cultivars may also expand the window for growing this crop, opening opportunities for green manure before crops not grown in winter.

Seaman et al. (2004) reported that frequent harvest of the top 18 inches of new growth by clipping sunn hemp at 16 to 32 inches height above soil line produced an organic fertilizer of 4% N. This means that if 3 tons/acre of dried sunn hemp clipped biomass is harvested as described above, it will contain 240 lb of N. Therefore, this high concentration of N in clipped sunn hemp materials has great potential as an organic N fertilizer.

The whole plant sunn hemp residues harvested at early blooming stage contained N-P2O5-K2O in amounts of 123–42–80 lb/acre, which gives a ratio of 3:1:2 (Marshall 2002). Using this ratio, one can formulate a fertilizer according to the specific crop nutrient requirement. Marshall (2002) demonstrated that sunn hemp residue supplied N levels comparable to those derived from inorganic N for bush bean (*Phaseolus vulgaris*), lima bean (*P. lunatus*), okra (*Abelmoschus esculentus*), cucumber (*Cucumis sativus*), cowpea (*Vigna unguiculata*), sweet corn (*Zea mays*), and squash (*Cucurbita pepo*).

Nematode Suppression

Suppression of plant-parasitic nematodes by *Crotalaria* spp. has been known for decades. Godfrey (1928) noted that sunn hemp had few galls from root-knot nematodes (*Meloidogyne* spp.). Most of the plant-parasitic nematodes suppressed by *Crotalaria* are sedentary endoparasitic nematodes, which are nematodes that remain and feed in one place within the root system. These include root-knot, soybean cyst (*Heterodera glycines*),and reniform (*Rotylenchulus reniformis*) nematodes (Wang et al. 2002). Some migratory nematodes such as sting (*Belonolaimus longicaudatus*), stubby root (*Paratrichodorous minor*), dagger (*Xiphinema americanum*), and burrowing (*Radopholus similis*) nematodes were also suppressed by other plants in the genus *Crotalaria* (Wang et al. 2002). Table 1 summarizes results of studies on host status of sunn hemp and effects of using sunn hemp as a preplant cover crop or intercrop on various plant-parasitic nematodes.

How does sunn hemp suppress plant-parasitic nematodes?

Sunn hemp uses different modes of action to suppress plant parasitic nematodes, making it an efficient cover crop for nematode management. Sunn hemp is not only a poor host or nonhost to many plant-parasitic nematodes (Table 1), but it has been shown to produce allelopathic (toxic) compounds against several key nematode pests. Jasy and Koshy (1994) demonstrated that leaf extract of sunn hemp was lethal to burrowing nematodes (*Radopholus similis*) at dilutions of 1:5 within 24 hours. Wang et al. (2001) also found that sunn hemp leaf leachate essentially stopped movement of the reniform nematode, *R. reniformis*.

Sunn hemp also can enhance natural enemies of plant-parasitic nematodes, such as fungi that trap nematodes or feed on their eggs (Wang et al. 2001). Besides suppressing plant-parasitic nematodes directly, sunn hemp can also manage nematode damage on crop indirectly by increasing plant tolerance against these pests. Sunn hemp amendments have been demonstrated to enhance free-living nematodes in the soil that are involved in nutrient cycling (Wang et al. 2003b), thus increasing nutrients available for plant uptake. A healthier plant will then have a higher tolerance to plant-parasitic nematode damage.

Figure 3. Variation in spring field corn root development at harvest following various summer cover crops. Preceding cover crop from left to right: sunn hemp (residues mulched in), pearl millet without fertilizer, sorghum-sudangrass, corn, pearl millet with fertilizer, and sunn hemp (residues harvested).
Credits: Z. J. Grabau, UF/IFAS

Pests and Diseases

The crop has few pest and pathogen problems. Major diseases of sunn hemp are *Fusarium* wilt caused by *Fusarium udum* var. *crotalariae* and anthracnose caused by *Colletotrichum curvatum* (Purseglove 1974). In Brazil, the only disease reported on the crop is *Ceratocystis fimbriata* (Melo Filho et al. 2002). The three most serious insect pests for sunn hemp are larvae of the sunn hemp moth, *Utetheisa pulchella;* the stem borer *Laspeyresia pseudonectis;* and pod borers (Purseglove 1974). Pod borers can lower seed production of *C. juncea.* Sunn hemp is also a host to the stink bug *Nezara viridula* in Hawaii (Davis 1964) and African sorghum head bug, *Eurystylus oldi*,in France (Malden and Ratnadass 1998).

How to enhance sunn hemp effects in suppressing nematode pests

Although sunn hemp has good potential as a cover crop for managing several important plant-parasitic nematodes, the residual effects are short-term (a few months). While sunn hemp is a poor host to many plant-parasitic nematodes, nematode numbers can resurge to damaging levels on subsequent host crops (McSorley et al. 1994). This scenario strongly suggests that integrating the sunn hemp rotation system with other nematode management strategies is necessary. Among the possibilities for integration are rotation with non-host cash crops, crop resistance, enhanced crop tolerance, selection for fast growing crop varieties, soil solarization, biological control, and nematicide application.

Nematicides, particularly fumigation, should be avoided in a cropping system if the objective is to enhance nematode-antagonistic microorganisms. Several studies have demonstrated the destructive effect of fumigation treatments to nematode antagonistic microorganisms. Sunn hemp could enhance activities of nematode-trapping fungi (NTF) in the rhizosphere or in soil amended with its biomass (Wang et al. 2001, 2003a), but it failed to enhance NTF populations in soils that were recently treated with the nematicide 1,3-dichloropropene (Wang et al. 2003a).

In summary, sunn hemp, besides serving as an efficient green manure, is a poor host to many important plant-parasitic nematodes, produces compounds toxic to nematodes, and is able to enhance some nematode-antagonistic microorganisms. Therefore, using sunn hemp as a cover crop could offer an alternative for managing nematodes. When integrated with other pest management strategies, sunn hemp promises to be a valuable element in the development of new sustainable cropping systems.

References

Abdul-Baki, A. S., H. H. Byran, G. M. Zinati, W. Klassen, M. Codallo, and N. Heckert. 2001. “Biomass Yield and Flower Production in Sunn Hemp—Effect of Cutting the Main Stem.” *Journal of Vegetable Crop Production* 7: 83–104.

Braz, G. B. P., R. S. Oliveira, S. Rubem Jr., and W. T. Crow. 2016. “Susceptibility of Different Accessions of *Crotalaria juncea* to *Belonolaimus longicaudatus*.” *Nematropica* 46:31–37.

Davis, C. J. 1964. “The Introduction, Propagation, Liberation, and Establishment of Parasites to Control *Nezara viridula* Variety *smaragdula* (Fabricius) in Hawaii (Heteroptera: Pentatomidae).” *Proceeding of Hawaiian Entomological Society* 18:369–375.

Fall, T., A. Freidenreich, S. Swartz, C. Vincent, Y. Li, and Z. Brym. 2020. *Questions and answers for using sunn hemp (*Crotalaria juncea *L.) as a green manure cover crop.* SS-AGR-444. Gainesville: University of Florida Institute of Food and Agricultural Sciences. https://edis.ifas.ufl.edu/publication/AG443

Garzon, J., J. M. B. Vendramini, M. L. Silveira, P. Moriel, H. M. S. da Silva, J. C. B. DuBeux Jr., M. Kaneko, C. C. Carnelos, and P. A. Mamede. 2021. “Harvest Management and Genotype Effects on Sunn Hemp Forage Characteristics.” *Agronomy Journal* 113: 298–307. https://doi.org/10.1002/agj2.20465

Godfrey, G. H. 1928. “Legumes as Rotation and Trap Crops for Pineapple Fields.” *Experiment Station of the Association of Hawaiian Pineapple Canners Bulletin* 10:3–21.

Jasy, T., and P. K. Koshy. 1994. “Effect of Certain Leaf Extracts and Leaves of *Glyricidia maculata*, (H. B. & K) Steud. as Green Manure on *Radopholus similis*.” *Indian Journal of Nematology* 22:117–121.

Malden, J. M., and A. Ratnadass. 1998. “*Crotalaria juncea* (Fabaceae) Cited for the First Time as Alternative Host of *Eurystylus oldi* Important Pest of Sorghum and Ricinus (Hem., Miridae).” *Bulletin de la Societe Entomologique de France* 103:272.

Marshall, A. J. 2002. *Sunn Hemp (Crotalaria juncea L.) as an Organic Amendment in Crop Production*. M.S. Thesis, University of Florida, Gainesville, FL.

McSorley, R., D. W. Dickson, J. A. Brito, T. E. Hewlett, and J. J. Frederick. 1994. “Effects of Tropical Rotation Crops on *Meloidogyne arenaria* Population Densities and Vegetable Yields in Microplots.” *Journal of Nematology* 26:175–181.

Meagher, R. L., R. N. Nagoshi, J. T. Brown, S. J. Fleischer, J. K. Westbrook, and C. A. Chase. 2017. “Flowering of the Cover Crop Sunn Hemp, *Crotalaria juncea* L.” *HortScience* 52:986–990. https://doi.org/10.21273/HORTSCI11981-17

Melo Filho, P. A., M. L. P. Lima, C. H. Uesugi, and B. Ueno. 2002. “A Wilt Caused by *Ceratocystis fimbriata* on Sunn-Hemp in the Federal District, Brazil” *Summa Phytopathologica* 28:211–21.

Mosjidis, J. A., K. S. Balkcom, J. M. Burke, P. Casey, J. B. Hess, and G. Wehtje. *Production of the Sunn Hemp Cultivars ‘AU Golden’ and ‘AU Durbin’ Developed by Auburn University*. Departmental series No. 328. Auburn: Alabama Agricultural Experiment Station. https://aurora.auburn.edu/handle/11200/44129

Purseglove, J. W. 1974. *Tropical crops: Dicotylendons*. Longman Group Limited, London.

Reeves, D. W., Z. Mansoer, and C. W. Wood. 1996. “Suitability of Sunn Hemp as an Alternative Legume Cover Crop.” *In* Proceedings of the New Technology and Conservation Tillage 96 (7): 125–130. University of Tennessee Agricultural Experiment Station, Tennessee.

Rosa, J. M. O., J. N. Westerich, and S. R. S. Wilcken. 2015. “*Meloidogyne enterolobii* Reproduction on Vegetable Crops and Plants Used as Green Manure.” *Revista Ciencia Agronomica* 46:826–835. https://doi.org/10.5935/1806-6690.20150071

Seaman, K. A., R. N. Gallaher, and R. McSorley. 2004. “Maintaining Clipping Heights to Enhance Yield and Nitrogen Content for Sunn Hemp.” *Soil and Crop Science Society of Florida Proceedings* 63:115.

Van Biljon, E. R., A. H. McDonald, H. Fourie. 2015. “Population Response of Plant-Parasitic Nematodes in Selected Crop Rotations over Five Seasons in Organic Cotton Production.” *Nematropica* 45:102–112.

Wang, K. -H., B. S. Sipes, and D. P. Schmitt. 2001. “Suppression of *Rotylenchulus reniformis* by *Crotalaria juncea*, *Brassica napus*, and *Target erecta*.” *Nematropica* 31:237–251.

Wang, K. -H., B. S. Sipes, and D. P. Schmitt. 2002. “*Crotalaria* as a Cover Crop for Nematode Management: A Review.” *Nematropica* 32:35–57.

Wang, K. -H., B. S. Sipes, and D. P. Schmitt. 2003a. “Suppression of *Rotylenchulus reniformis* Enhanced by *Crotalaria juncea* Amendment in Pineapple Field Soil.” *Agriculture, Ecosystem and Environment* 94:197–203.

Wang, K. -H., R. McSorley, and R. N. Gallaher. 2003b. “Effect of *Crotalaria juncea* Amendment on Nematode Communities in Soil with Different Agricultural Histories.” *Journal of Nematology* 35:294–301.

Wang, Q., Y. Li, W. Klassen, and E. A. Hanlon Jr. 2019. *Sunn hemp—A Promising Cover Crop in Florida*. SL-306. Gainesville: University of Florida Institute of Food and Agricultural Sciences. https://edis.ifas.ufl.edu/publication/TR003

Table 1. Host status and effects on plant-parasitic nematodes of using *Crotalaria juncea* in a crop rotation or intercropping system.

Nematode species (and common name)	Host Status[a]	Crop Rotation or Intercropping Effect
Belonolaimus longicaudatus (sting nematode)	Poor host (Braz et al. 2016)	-
Meloidogyne arenaria (peanut root-knot nematode)	Poor host (McSorley 1999)	-
Meloidogyne enterolobii (guava root-knot nematode)	Poor host (Marques et al. 2012; Rosa et al. 2015)	-
M. hapla (northern root-knot nematode)	Host: severe galling but few egg masses (Martin 1958).	-
M. incognita (southern root-knot nematode)	Poor host (McSorley 1999; Santos and Ruano 1987); poorer host than cotton (Robinson and Cook 2001)	Suppressed numbers on cotton (Robinson et al. 1997; Van Biljon et al. 2015). Suppressed numbers (Claudius-Cole et al. 2014, Curto 2015).
M. javanica (Javanese root-knot nematode)	Poor host (Araya and Caswell- Chen 1994; McSorley 1999; Ortiz et al. 2015; Silva et al. 1990b). Host: galls visible (Martin 1958).	Suppressed numbers on taro (Sipes and Arakaki 1997); on tobacco (Shepherd and Barker 1993); on sugarcane (Moura 1991). No effect on numbers (Ortiz et al. 2015)
Pratylenchus brachyurus (lesion nematode)	Poor host: survived but failed to multiply (Charchar and Huang 1981)	-
P. zeae (lesion nematode)	Poorer host than sorghum but can penetrate roots (Silva et al. 1989).	Increased numbers (Van Biljon et al. 2015)
Rotylenchulus reniformis (reniform nematode)	Poor host (Caswell et al. 1991; Wang et al. 2001; Silva et al. 1989; Robinson and Cook 2001). Leaf leachate toxic (Wang et al. 2003)	Reduced numbers on pineapple (Wang et al. 2002); increased or did not affect numbers on cowpea (Marahatta et al. 2012).
Radopholus similis (burrowing nematode)	-	Intercropping with banana reduced nematode numbers (Charles 1995); did not suppress nematodes when grown as preplant cover crop without biomass incorporation (Inomoto 1994). Leaf extract at 1:5 dilution is toxic (Jasy and Koshy 1994).
M. exigua (coffee root-knot nematode)	Poor host (Silva et al. 1990a)	-
Helicotylenchus multicinctus (spiral nematode)	-	Intercropping with banana reduced nematode numbers (Charles 1995).
Hoplolaimus indicus (lance nematode)	-	Intercropping with banana reduced nematode numbers (Charles 1995)
Scutellonema bradys (spiral nematode)	Host (Claudius-Cole and Fawole 2016)	

[a] "Poor host" indicates sunn hemp may be suitable for managing the given nematode because it does not reproduce well on that crop. "Host" indicates sunn hemp increased populations of a given nematode. See also Wang (2002) for a review of sunn hemp impacts on plant-parasitic nematodes.