COOPERATIVE EXTENSION
UNIVERSITY OF HAWAI'I AT MĀNOA
COLLEGE OF TROPICAL AGRICULTURE AND HUMAN RESOURCES

Subbing Sunn Hemp with Sorghum in Fusarium Soils

Roshan Paudel[1], Lauren Braley[1], Joshua Silva[2], and Koon-Hui Wang[1]

Department of Plant and Environmental Protection Sciences[1], Department of Tropical Plant and Soil Sciences[2], University of Hawaii at Manoa.

Introduction

Ever since its release in 1983, 'Tropic Sun' sunn hemp, *Crotalaria juncea*, has been a popular cover crop in Hawaii for soil health management. This is because sunn hemp is a fast-growing leguminous plant. Under optimum growing conditions, 'Tropic Sun' sunn hemp can produce an estimated 140 lbs/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). These make it an ideal green manure cover crop, serving as an organic nitrogen source that outcompetes weeds and reduces soil erosion. Sunn hemp possesses an allelopathic compound that when plowed under, suppresses key plant-parasitic nematodes in Hawaii such as *Meloidogyne* spp. and *Rotylecnhulus reniformis* (Wang et al., 2002). Unfortunately, in the last decade, farmers growing sunn hemp suffered from Fusarium wilt caused by *Fusarium udum f. sp. Crotalariae* (*Fuc*) (Wang and Dai, 2018), causing the cover crop to die within 30 days after seeding (Fig. 1). With 'Tropic Sun' sunn hemp plagued by soil-borne pathogens that severely decrease its biomass production and seed availability, this project aimed to find alternatives to 'Tropic Sun' in Hawaii for soil health management.

Seedlings in infested soil	1st year planting	2nd year planting

Fig. 1. Progression of Fusarium wilt on sunn hemp caused by *Fusarium udum sp. Crotalariae* (Fuc). A) Initial symptom of chlorotic leaves, B) young sunn hemp seedlings die back sporadically, C) widespread of diseased sunn hemp appeared when planted sunn hemp repeated in an infested soil.

Sorghum/sorghum-sudangrass hybrids (SSgH) accumulate more dry-biomass, transpire less water, decompose slower, and contribute to more soil organic matter than annual leguminous cover crops. Soil dwelling microbes play an essential role in decomposing organic matter, nutrient cycling, and maintaining soil structure and stability. SSgH cover crops release root exudates into the soil, supporting microbial growth and activity. Roots of SSgH can penetrate deeper soil layers creating channels and openings for better water infiltration and reducing soil compaction. The roots, shoots, and leaves of SSgH contain different toxic compounds, particularly sorgoleone that can smother weeds. In addition, SSgH hybrids are also known to inhibit plant-parasitic nematodes by releasing the poisonous gas hydrogen cyanide (HCN) through hydrolysis of dhurrin (Busk and Moller, 2002). Rotating SSgH cover crops with sunn hemp could help farmers to cope with *Fu*c infested soil.

Fig. 2. Healthy sunn hemp and sorghum 1.5 months after planting in a disease-free field.

Specific objectives of this research were to 1) compare susceptibility of different species of *Crotalaria* and sorghum (*Sorghum bicolor*) to *Fuc*, and 2) examine the potential of sorghum cover crop against *Fusarium oxysporum* on mustard green (kai choi, *Brassica juncea*) in the field.

Greenhouse Experiment

Objective 1: Evaluate susceptibility of *Crotalaria* species to *Fusarium udum f. sp. Crotalariae (Fuc)*

Field soils with a history of Fusarium wilt on *C. juncea* from the Poamoho Experiment Station (Trial I) and Go-Farm in Waialua (Trial II), respectively, were used in two greenhouse trials. For both trials, half of the soil was autoclaved at 121°C, 15 PSI for 30 minutes whereas the other half was not. In Trial I, a 2×3 (soil treatment × *Crotalaria* species) experiment was conducted where 3 *Crotolaria* species (*C. juncea*, *C. mucronata*, and *C. spectabilis*) were tested (Fig. 3A and 3B). A forage sorghum (*Sorghum bicolor*) variety 'Bundle King' was added in Trial II along with the 3 *Crotalaria* species used in Trial I (Fig. 3C and 3D). Due to low germination rates of *C. mucronata* and *C. spectabilis*, we adjusted the seeding rates to 30 seeds/pot for *C. mucronata* and *C. spectabilis*, and 15 seeds/pot for *C. juncea* and sorghum. All treatments were replicated 4 times in each trial. Plant growth and incidence of plant wilt (Fig. 4) were recorded weekly. Total plant biomass accumulated at one month after planting were recorded. Percentage of plants that germinated and remained healthy was calculated for each pot. Data were subjected to analysis of variance (ANOVA) and means were separated by Waller-Duncan *k*-ratio (*k*=100) *t*-test using SAS 9.4 (SAS Institute Inc., Cary, NC) wherever appropriate.

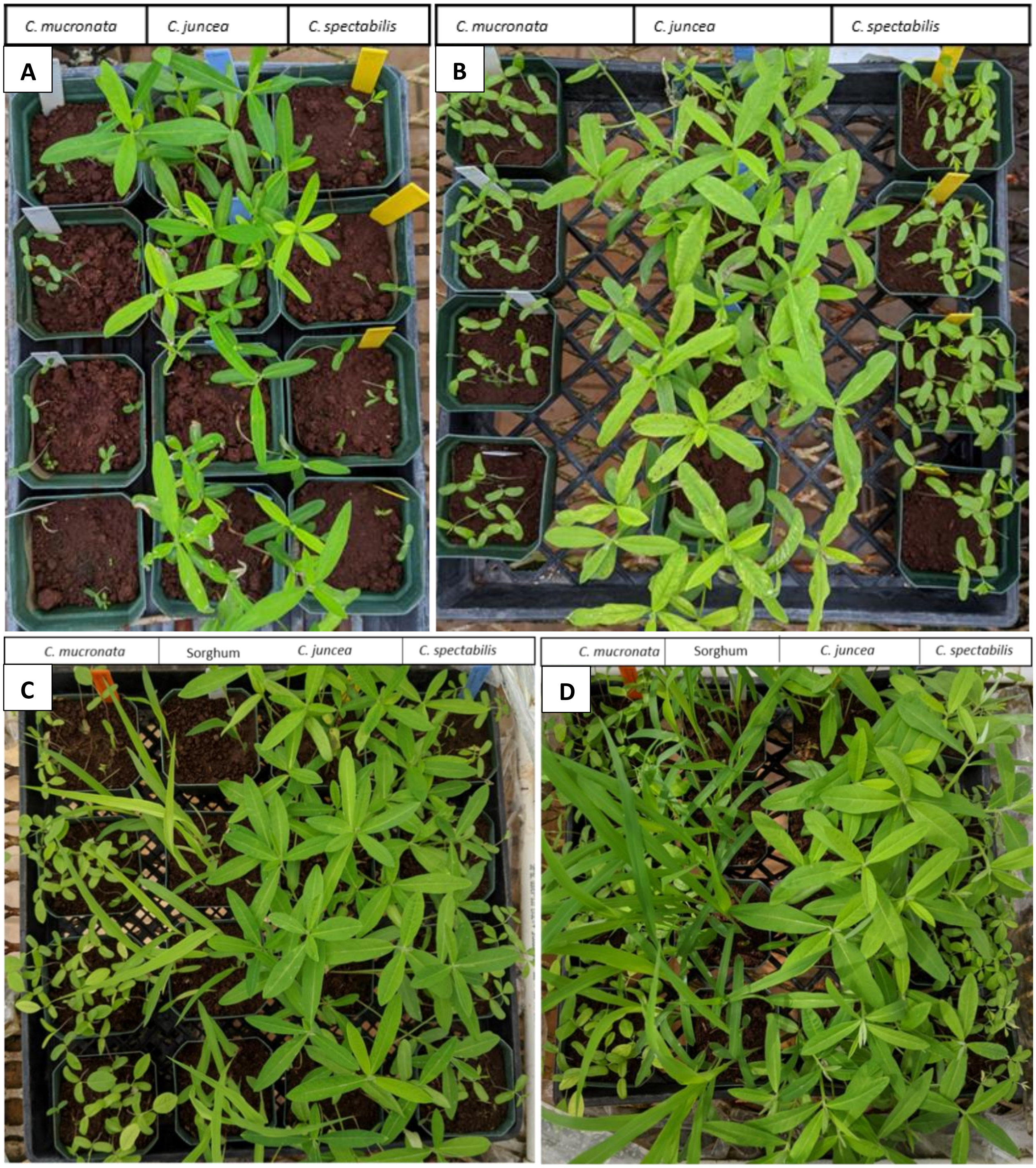

Fig. 3. *Crotalaria juncea*, *C. mucronata*, *C. spectabilis*, and *Sorghum bicolor* planted in A) non-autoclaved soil infested with *Fusarium udum f. sp. Crotalariae* (*Fuc*); and B) autoclaved soil collected from Poamoho in Trial I; C) non-autoclaved soil infested with *Fusarium udum f. sp. Crotalariae* (*Fuc*); and D) autoclaved soil collected from GoFarm Waialua in Trial II.

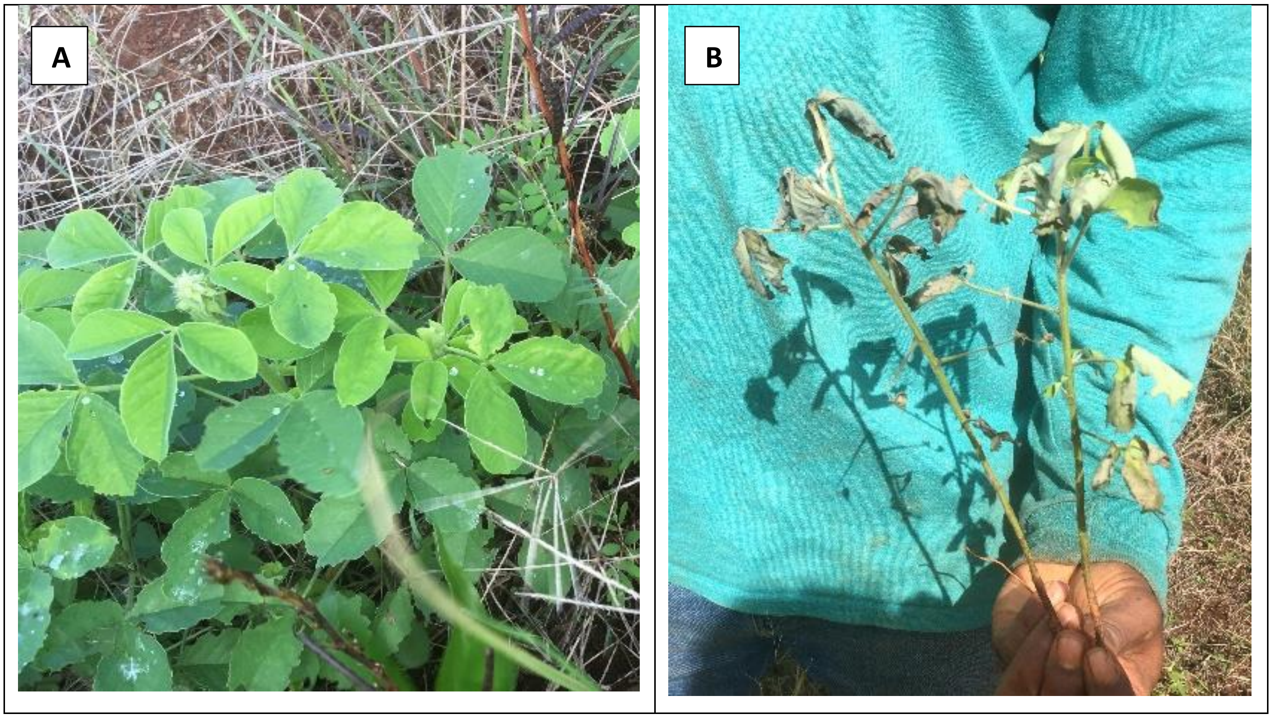

Fig. 4. A) Relatively healthy *Crotalaria spectabilis*, and B) wilted *C. spectabilis*.

Since no interaction between soil treatment and *Crotalaria* species was detected, means from the main factors were presented. In both trials, percent of healthy plants at one month after seed sowing was higher in autoclaved compared to non-autoclaved soil indicating that soil-borne pathogen was present in the non-autoclaved soil (Fig. 5A and 5D). Sorghum did not show any symptom of *Fusarium* wilt whereas all three *Crotalaria* species were infected. Among the *Crotalaria* species, *C. mucronata* had the highest percentage of healthy plants, higher than that of *C. juncea*, suggesting that *C. mucronata* might be more resistant to the *Fusarium* wilt disease. In Trial I and Trial II, *C. mucronata* showed survival rates of 94% and 84%, compared to 64% and 48% for *C. juncea*, respectively (Fig. 5B and 5E).

*Crotalaria jun*cea and *C. spectabilis* were both very susceptible to *Fuc*. None-the-less, regardless of autoclaved or non-autoclaved soil, biomass generated by *C. juncea* within one month after seeding was significantly higher than that of *C. mucronata* and *C. spectabilis* (Fig. 5C and 5F). Therefore, *C. juncea* is still a better cover crop than *C. mucronate* despite its susceptibility to *Fuc*. Although it is encouraging to see higher survival rates of *C. mucronata* in *Fuc* infested soil than *C. juncea*, it is not recommended to replace *C. juncea* with *C. mucronata* as a cover crop. This is because *C. juncea* generates more biomass, grows faster than most weeds, but is not a noxious weed like *C. mucronata* and *C. spectabilis* (Lacerda et al., 2021). Nonetheless, sorghum produces higher biomass than all the *Crotolaria* species examined and is not susceptible to *Fuc*.

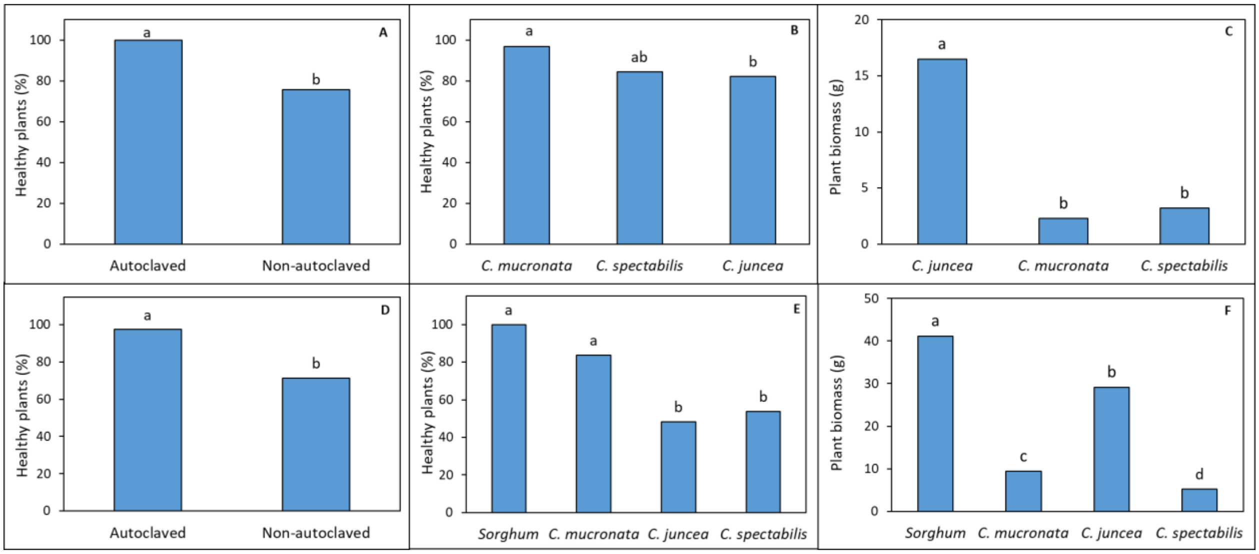

Fig. 5. Plant health assessment at 1 month after seeding in Trial I (A-C) and Trial II (D-F). A and D) Percentage of healthy plants in autoclaved vs non-autoclaved soil; B and E) Percentage of healthy plants of *Crotalaria*, and a sorghum cultivar; C and F) plant biomass.

Field Experiment

Objective 2: Biofumigation potential of sorghum against *Fusarium oxysporum* of kai choi.

A field trial was conducted at a *Fusarium oxysporum* infested site, Owen Kaneshiro Farm, LLC, Waianae, HI in the fall of 2021. Six preplant soil treatments installed were: 1) Vapam HL at 80 gal/acre (a.i. sodium methyldithiocarbamate, AMVAC, Newport Beach, CA) fumigation (standard practice by farmers); 2) 'NX-D-61' sorghum cover crop (50 lb seeds/acre) grown for 1 month (Fig. 6A) then mowed down as surface organic mulch using rotary mower; 3) brown mustard tissue harvested from elsewhere, macerated and buried into soil as biofumigant at 0.5% amendment rate; 4) 0.5% and 5) 1% papaya ground seed (PGS) based on soil dry weight (dw) as biofumigants; and 6) untreated control. 'Hirayama' mustard green or kai choi (*Brassica juncea*) seedlings were transplanted in 4 rows in a 4×10 ft^2 plot with an approximate of 48 plants per plot. Each treatment was replicated 4 times, and treatments were arranged in randomized complete block design. Plots were amended with their respective treatments 1 week prior to kai choi planting. Mustard, PGS, and Vapam amended plots were covered with black plastic (Fig. 6A) to avoid volatile escape. After 1 week, 3-week-old kai choi seedlings were planted into the plots. Kai choi was harvested 6 weeks after transplanting.

At 3 weeks after planting of kai choi, level of Fusarium wilt incidence was recorded from the center two rows from each plot (number of wilted plants versus the number of healthy plants, Fig. 6B). A plant was considered diseased if at least one leaf was exhibiting symptoms of wilt. All data was subjected to one-way analysis of variance using SAS 9.4. Means were separated by Waller-Duncan *k*-ratio (*k*=100) *t*-test wherever appropriate.

Fig. 6. A) Sorghum was grown for 1 month whereas fumigated or biofumigated plots were covered with black plastic for 1 week prior to crop transplanting; B) kai choi plants were monitored for incidence of wilt at 3 weeks after transplanting.

Results revealed that Vapam treatment had the lowest disease incidence followed by sorghum (Fig. 7). Sorghum was more effective than all other biofumigant treatments (ground papaya seed or brown mustard) in reducing Fusarium wilt of kai choi despite not being incorporated into the soil (residues left on soil surface), resulting in 20% less disease than the untreated control. Mustard and papaya ground seed treatments had slightly higher disease incidence compared to control (Fig. 7) which means they were not effective in suppressing the pathogen despite effective suppression in greenhouse pot experiments when PGS or brown mustard residues were evenly mixed into the soil particularly at 1% amendment rate (dw/dw) (Braley et al., 2022). Sorghum biofumigation was comparatively more effective than the other biofumigants tested here perhaps because of its month-long field cultivation, which may have generated a change in the soil microbiome potentially antagonistic to Fusarium. Future research should examine effect of sorghum biofumigation by soil incorporation to at least 4 inches deep. None-the-less, this field experiment showed that a short-term rotation (1 month) of sorghum cover cropping could reduce 20% disease incidence of Fusarium wilt of kai choi.

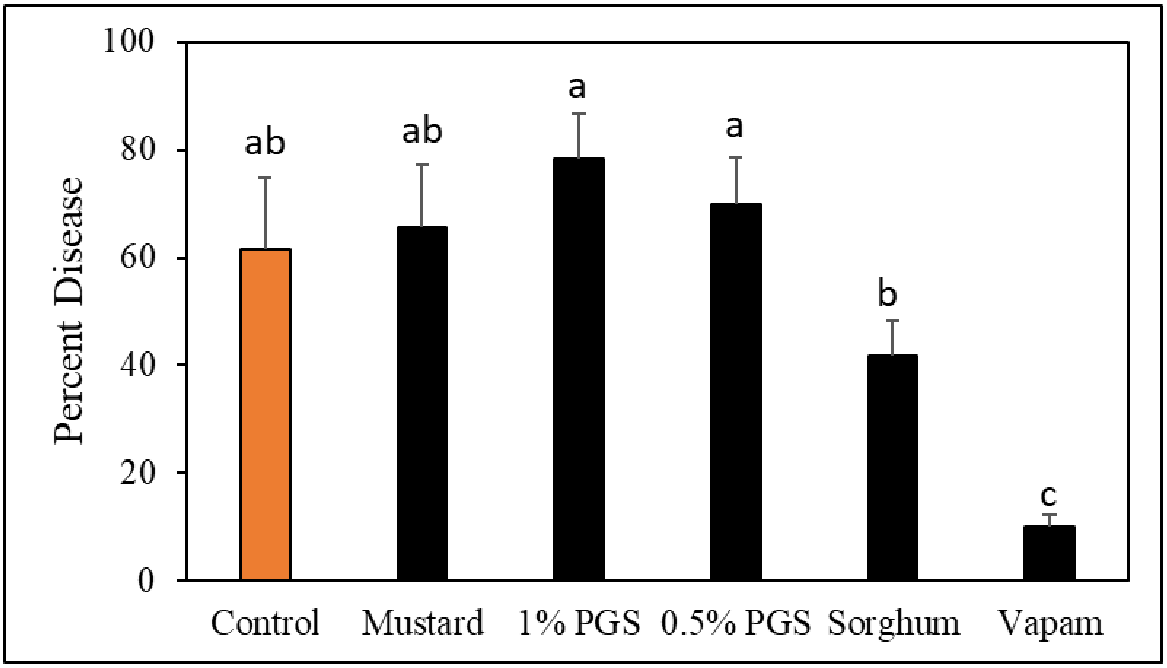

Figure. 7. Percentage of kai choi with disease incidence at 3 weeks after transplanting into *Fusarium oxysporum* infested field pretreated with brown mustard (M), 1% papaya ground seed (PGS), 0.5% PGS amendment, planting sorghum for 1 month, or fumigate with Vapam fumigant vs untreated (Control). Bars followed by the same letter were not different based on Waller-Duncan *k*-ratio (*k*=100) *t*-test.

Conclusion

Although it is encouraging to find *C. mucronate* relatively tolerant to *Fuc* compared to high susceptibility of *C. juncea* to the disease, it is not recommended to replace *C. juncea* with *C. mucronata* as it is a noxious weed in Hawaii as its foliage is harmful to livestock upon feeding. Continuous planting of *C. juncea* in the same field that became infested with *Fuc* would cause a widespread Fusarium wilt on sunn hemp resulted in cover crop failure. This study determined that sorghum can be a good rotation cover crop either with sunn hemp or other cash crops in either *Fuc* or *F. oxysporum* infested soils. As a part of an ongoing research, we will continue to examine the potential of sorghum biofumigation through soil incorporation on different soil-borne pathogens.

Literature cited

Braley, L., K.-H. Wang, J. Silva, T. Yan, S. Nakamoto, and W. W. Su. 2022. Repurposing papaya: Examining the potential of instant biofumigation using papaya seed waste for soil-borne disease management on leafy greens. CTAHR Cooperative Extension Publication PD-123. 7 pp. https://www.ctahr.hawaii.edu/oc/freepubs/pdf/PD-123.pdf.

Busk, P.K. and Møller, B.L. 2002. Dhurrin synthesis in sorghum is regulated at the transcriptional level and induced by nitrogen fertilization in older plants. Plant Physiology, 129(3), pp.1222-1231.

Doran, J. W. 1996. Soil health and global sustainability. In: MacEwan, R. J. and M. R. Carter (eds) Soil Quality is in the Hands of the Land Manager. The Proceedings of an International Symposium on Advances in Soil Quality for Land Management: Science, Practice and Policy. p. 45.

Lacerda, M.D.S.C., Wilson, T.M., de Souza Argenta, V.L., de Araújo Pinto, É.G., e Macêdo, J.T.S.A., Soto-Blanco, B., Keller, K.M., Pedroso, P.M.O. and Câmara, A.C.L., 2021. *Crotalaria spectabilis* poisoning in horses fed contaminating oats. Toxicon, 197, pp.6-11.

Rotar, P.P. and R.J. Joy. 1983. 'Tropic Sun' sunn hemp, *Crotalaria juncea* L. HITAR Research Extension Series 036. 8 pp.

Wang, C.L. and Y.L. Dai. 2018. First Report of sunn hemp Fusarium wilt caused by *Fusarium udum f. sp. crotalariae* in Taiwan. Disease Notes (https://doi.org/10.1094/PDIS-10-17-1563-PDN).

Wang, K.-H., B.S. Sipes, and D.P. Schmitt. 2002. Management of *Rotylenchulus reniformis* in pineapple, Ananas comosus, by intercycle cover crops. J. Nematol. 34: 106-114.

Acknowledgement

This project is supported by NRCS CIG Hawaii NR1992510002G001, NIFA OREI (HAW09705-G) CTAHR Hatch, Multistate (NE2140), Plan of Work (HAW9048-H, 9034-R and POW 16-964), and WSARE graduate student grant GW20-212.

WESTERN SARE Sustainable Agriculture Research & Education

NRCS

Sustainable Pest Management Lab
University of Hawai'i at Mānoa,
College of Tropical Agriculture and Human Resources

USDA

NIFA