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Potential Cover Crop Options for Nematode and Weed Suppression in Haiti

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Cover crops can provide a replacement for chemical management of weeds and plant-parasitic nematode (PPN) pests while protecting the soil from erosion and contributing fertility through organic matter. These ecosystem services are especially important for smallholder farmers in Haiti and in developing nations throughout the tropics, for whom imported fertilizers and pesticides are often inaccessible. In the dry season from January to March, a study was conducted to evaluate the potential of tropical cover crops in one upland and one lowland site in Haiti. The objective was to determine the weed and nematode suppression potential of cover crop treatments, including the legumes sunn hemp [(SH) *Crotalaria juncea* L.], cowpea [(CP) *Vigna unguiculata* (L.) Walp], and lablab [(LB) *Lablab purpureus* (L.) Sweet cv. Rongai] in monoculture, two-way mixes of each legume with sorghum sudangrass [(SS) *Sorghum bicolor* (L.) Moench × *S. sudanense* (Piper) Stapf cv. Surpass BMR], a four-way mix of all species, and a natural fallow(NF) control. At 8.5 weeks after planting (WAP) the cover crop treatments did not differ in their shoot biomass production. Cover crop treatments also did not result in a significant decrease in weed biomass compared to the natural fallow by 8.5 WAP. Shoot biomass of *Parthenium hysterophorus*, a dominant weed at upland site, was higher with the CP cover crop than with the NF. Root-knot nematode (RKN; *Meloidogyne* sp.) was found only at the lowland site. The reproduction factor of RKN with LB was significantly higher than with LB/SS mix, SH, and the SH/SS mix. Eight other genera of PPN were recorded for the first time to our knowledge in Haiti (*Rotylenchulus, Pratylenchus, Tylenchorhynchus, Hoplolaimus, Criconomella, Helicotylenchus, Heterodera*, and *Xiphinema*) but were not significantly affected by cover crops. While the cover crop treatments were not effective during this season for weed suppression, evaluation of better adapted cultivars and/or at a different time of year may provide both weed and RKN suppression.

Climatic and geographic factors, certain agricultural practices, and weed and pest competition can potentially lead to soil loss and reduced yields (Brady and Weil, 2010). Between cropping cycles, soils exposed to wind and rain can be easily eroded, especially on sloping terrain (Lal, 2001). While natural fallows can provide some cover, they can lead to increased populations of weeds and plant-parasitic nematodes (PPN) that can reduce yields in the growing season. Cover crops can provide many ecosystem services for farmers, including pest management, soil protection, and increased fertility (SARE, 2012). Nearly half of a farmer's yield is at risk due to weeds (~34%) and plant-parasitic nematodes (PPN) (~14.6%) in the subtropics and tropics (Jabran et al, 2015; Nicol et al., 2011). Haitian farmers attribute reduced yields to erosion, pests, and exhaustion of the soil (McClintock, 2004), while crops may be selected based on the amount of labor they require and the reliability of yields.

Cover crops, including grasses, legumes, and forbs are defined by their ability to provide seasonal cover to conserve the soil and provide ecosystem services, though many can be harvested as a feed or cash crop if needed (SARE, 2012). Cover crops are often selected for rapid growth and terminated at the maximum nitrogen stage (Daimon, 2006), by cutting, crimping or herbicide application. Their residues are left on the surface or incorporated to improve soil structure, cation exchange capacity and water infiltration, and provide continued defense against pathogen and weed competition for the subsequent crop (Brady and Weil, 2008, Widmer et al., 2002, Lynch et al., 2016, Widmer and Abawi, 2002). Leguminous cover crops such as sunn hemp (*Crotalaria juncea* L.), cowpea [*Vigna unguicalata* (L.) Walp], and lablab [*Lablab*

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purpureus (L.) Sweet] are often called green manures for their ability to provide mineralized nitrogen (N) to the soil, which can become available for a subsequent crop (Chikowo et al., 2004; Creamer and Baldwin, 2000; Rao and Li, 2003). Large grasses like sorghum (*Sorghum bicolor* L. Moench) and sorghum sudangrass [*S. bicolor* (L.) Moench × *S. sudanense* (Piper) Stapf] produce large quantities of biomass, and when mixed with legumes, benefit from the N fixation of the legumes while decreasing the amount of the more expensive legume seed needed (Bybee-Finley et al., 2016; Lynch et al., 2016; Cho et al., 2012).

Aboveground biomass and growth habit contribute to canopy cover, which can limit the access of weeds to sunlight and water (Bybee-Finley et al., 2017; Collins et al., 2008). Certain plants like *Sorghum* spp. also produce allelochemicals that can suppress the germination or growth of other plants (Peerzada et al., 2017). Belowground growth can create channels for greater water infiltration, reducing runoff. Roots can exude secondary metabolites throughout the life cycle of the plant (Cruz-Silva et al., 2015; Głab et al., 2017; Jabran et al., 2015; Javaid et al., 2015, Weston et al., 2013). Chemicals secreted from the roots or the decaying plant residues, are often not the primary means of weed suppression (Adler and Chase, 2007; Cruz-Silva et al., 2015), but they can suppress or stimulate other pests such as PPN (Rasmann et al., 2012).

Plant-parasitic nematodes are microscopic roundworms that feed on the nutrients inside of live plant cells of their host, either from outside (ectoparasites) or inside of the plant (endoparasites) (Coyne et al., 2007). Soilborne nematode species primarily feed and reproduce in the rhizosphere and are therefore subjected to plant root exudates and signaling. Plant species are considered non-hosts or poor hosts to PPN if they prevent feeding or reproduction (Oostenbrink, 1966) while host status may vary among varieties, due to differing concentrations of suppressive chemicals (Widmer and Abawi, 2002).

Research on nematology in developing nations in the tropics and subtropics has not been as well-funded as in temperate regions (Nicol et al., 2011), and only three PPN have been recorded in Haiti, root knot (*Meloidogyne incognita*), yam (*Scutellonema bradys*), and stem and bulb (*Ditylenchus dipsaci*) nematodes (Crill et al., 1973; CABI/EPPO, 2009; CABI/EPPO, 2011). Throughout the Caribbean, PPN research has focused mainly on banana and coconut (Luc et al., 2005, Godefroid et al., 2017). Root knot nematode, having the widest host range and being a highly damaging pest of vegetables worldwide, was the initial focus of this study.

Weeds in natural fallows may be susceptible/good hosts to PPN, allowing their populations to grow (Ntidi et al., 2016). Quénéhervé et al. (2006) found that many common weeds of Martinique, such as *Amaranthus dubius* and *Euphorbia heterophylla*, are good hosts for PPN including *Meloidogyne* spp. and *Rotylenchulus reniformis*.

Several cultivars of sunn hemp have shown resistance to root knot nematode, either by preventing root penetration, such as with *M. javanica* and *C. juncea* cv. Tropic Sun and PI 207657 (Araya and Caswell-Chen, 1994), or by allowing penetration but disrupting the reproduction cycle, as with 'IAC-KR1' (Miamoto et al., 2016). Cultivars can vary in their host status, as with cowpea. 'Iron Clay' has shown resistance to root knot nematode, while others such as 'White Acre' cowpea have not (McSorley, 1999, Wang et al., 2003). Sudangrass cultivars have been shown to vary in their suppression of *Meloidogyne* spp., based on the concentration of cyanogenic compounds (Widmer and Abawi, 2002; Weaver et al., 1995). Due to the limited seed availability in Haiti (World Food Programme, 2016) and the constraints associated with obtaining phytosanitary permits for seed export to Haiti, our study included some cultivars that have not been previously tested for root knot nematode suppression.

Previous studies and reports from Haiti have focused on soil and yield improvement (Bargout and Raizada, 2013, McClintock, 2004, Jaffe, 1989, Smucker, 2007, Lynch et al., 2016), with an emphasis on plant species that improve soil retention and fertility, establish quickly and reliably under prevailing weather conditions (appropriate for rainfed systems considering the bimodal rainfall pattern), and can serve multiple purposes, such as a food, feed, or other saleable commodities if needed. Our research utilized cowpea, which is already commonly used as food in Haiti, and sorghum sudangrass, which can also be used as fodder or forage. Lablab is grown for food or feed in Nigeria (Baligar and Fageria 2007, Medvecky et al., 2007), and sunn hemp has been used as a food in Kenya (Linguya et al., 2015) and as a forage resource and fiber crop elsewhere (Baligar and Fageria 2007, Purseglove, 1968). These crops also perform well in mixtures in dry tropical conditions (Ngongoni, 2007).

As in many developing nations, outmigration from rural areas in Haiti has depleted the pool of laborers available to work in agriculture, especially affecting productivity on farms that rely on labor beyond that available in the household. Manual labor is especially important in managing pests, particularly weed. Chemical and mechanical alternatives to manage crops, weeds, and pests are much less available to farmers in Haiti than those in the United States and Europe (Smucker, 2007). While weeds are obvious, nematodes can be easily overlooked. More research is needed to assess the distribution of previously identified nematodes in Haiti as well as detecting the occurrence of unreported PPN species. Haitian subsistence farmers may grow a diverse range of vegetable crops. The wide host range of PPN (such as root knot nematode) often with crop hosts including [*Daucus carota* ssp. *sativus* (Hoffm.) Arcang.], lettuce (*Lactuca sativa* L.), pea (*Pisum sativum* L.), okra [*Abelmoschus esculentus* (L.) Moench], eggplant (*Solanum melongena* L.), tomato (*Lycopersicon esculentum* Mill.), watermelon [*Citrullus lanatus* (Thunb.) Matsum. & Nakai], bell pepper (*Capsicum annuum* L.), and sweet corn (*Zea mays* L.) (Anwar and McKenry, 2010, Wang et al., 2008, Freeman, 2015) makes geographically isolating and reducing populations of these parasites critical.

The objective of this study was to evaluate the efficacy of cover crop monocultures and mixtures for suppressing weeds and PPN in two rural locations in Haiti. It was hypothesized that one or more cover crops would outperform the natural fallow control in terms of suppression of weeds and PPN.

Materials and Methods

Experimental sites. This study was conducted at two agricultural research stations in Haiti, the Centre Rural de Développement Durable (CRDD) at Bas Boen and the CRDD at Duvier. Sites were selected as part of a larger UF-managed project known as Feed the Future Haiti, Appui à la Recherche et au Développement Agricole (AREA), or Support to Agricultural Research and Development, which aims to address food insecurity by building capacity in public and private institutions within Haiti's agriculture sector. The Bas Boen CRDD is located at 18°34'5.33"N; 72° 9'8.29"W, at an elevation of 60 m. The Duvier CRDD is located at 18°28'48.19"N; 72°14'16.43"W, at an elevation of 1083 m.

Table 1. Treatments and broadcast seed rates (kg·ha-1) for each cover crop species: sunn hemp (SH), cowpea (CP), lablab (LB), and sorghum sudangrass (SS).

Treatment	Cover crop SH	CP	LB	SS
SH monoculture	44	--	--	--
CP monoculture	--	113/450z	--	--
LB monoculture	--	--	90	--
SH/SS Mix (Two-way)	22	--	--	22
CP/SS Mix (Two-way)	--	56/225z	--	22
LB/SS Mix (Two-way)	--	--	45	22
SH/CP/LB/SS (Four-way)	7.33	19/75z	15	22
Natural Fallow	--	--	--	--

zCowpea was seeded at 125% at Duvier and 500% at Bas Boen due to seed damage by weevil (*Callosobruchus maculatus* F.) infestation.

The soil at Bas Boen is a coarse-silty, carbonatic, isohyperthermic fluventic Haplustepts (Libohova et al., 2017) with a pH of 7.7. In Duvier, pH was 7.21, and the soil is dominated by Alfisols (Wesly Jeune, personal communication, 2018).

The two trials were conducted over 60 days during the dry season from early January to early March 2018. The experimental design was a randomized complete-block with eight treatments (Table 1) and four blocks, totaling 32 plots 8 m^2 each, with 0.5 m alleys separating plots. Cover crop treatments consisted of three monocultures of the legumes sunn hemp, cowpea, and lablab; the same legumes in two-way mixes with sorghum sudangrass; a four-way mix of all cover crop species; and a naturally weedy fallow control. All seeds were originally sourced from Hancock Seed (Dade City, FL). 'Iron Clay' cowpea was purchased for use at both sites, however, due to insect damage only enough seed was available for Bas Boen, and an unnamed cowpea landrace was acquired locally for use at Duvier.

Field preparation. Both fields were cleared and tilled using local methods with hand tools within a week of planting in early Jan. 2018. Seed was planted on 4 Jan. at Bas Boen and 6 Jan. at Duvier. Final biomass collection occurred [~60 days after planting (DAP)] on 7 and 5 Mar., respectively. Plots were rain-fed; there was sufficient rain at both sites to initiate visible sprouting at 2 DAP.

Planting. Seeds were broadcast-seeded by hand in monocultures at recommended cover crop seeding rates for Florida and at modified rates for mixtures, at a 50% rate for legume species in two-way mixes, at 25% for each legume in the four-way mix. Sorghum sudangrass was planted at 50% of its recommended monoculture rate in the mixes (Table 1). Plots were then raked to incorporate the seed.

Cover crop and weed biomass and density sampling. Fresh shoot mass was recorded in the field for each cover crop species and weeds by type—broadleaf, grass, and sedge—within a 0.5 m × 0.5 m quadrat at 30 and 60 DAP. Densities of weeds and cover crops by species were determined and recorded at the same time.

Nematode sampling, extraction, and identification. Five 15-cm deep cores were collected from each plot in an "M" pattern using a cone sampler (Nematology Supply Associates, LLC, Gainesville, FL). A composite sample of each plot was mixed in a bucket, and a 100 mL subsample of the composite was taken for nematode extraction. This procedure was repeated at 60 DAP, while the cover crops were still in the field.

Nematodes were extracted using the modified Baermann funnel method for each 100 mL soil sample by placing the sample into a coffee filter, on top of a mesh screen raised approximately 2 cm from the bottom of a plastic bowl (Coyne et al., 2007). Water was slowly added to each bowl until the soil was wet throughout. After 24 h, the water was carefully drained into a No. 500 brass sieve, and the nematode suspension that remained was gently washed into a tube to total 5 mL. The nematodes were preserved for transport to Florida in a 2% formalin solution by adding 5 mL of 4% formalin. PPN were identified by morphology and counted using an inverted microscope at 40 or 60× magnification at the University of Florida Nematology Assay Lab.

Data analysis. The effect of treatment on fresh cover crop and weed biomass was analyzed separately by site due to pH and soil type differences. Both were modeled using the GLIMMIX procedure of SAS 9.4 (Cary, NC) using the lognormal distribution to improve homoscedasticity. Block was treated as a random effect, and both 30 and 60 DAP measurements were included as a repeated measure, by treating time as a random effect using a heterogeneous first-order autoregressive structure. Least square means of the transformed data were back-transformed to the original scale. Comparisons among untransformed means were accomplished using the ADJUST = TUKEY and LINES options.

Nematode Reproduction Factor (RF) was determined by dividing final population (Pf) by initial population (Pi) by plot. Counts were first transformed using (x + 1) to account for zeros (Gallaher and Mcsorley, 1991). The effect of cover crop treatment on Nematode RF was analyzed by species in SAS using the GLIMMIX procedure, using a lognormal distribution with block as a random factor. Sites were analyzed separately due to edaphic differences, as previously described. Type III tests were used to determine model significance.

Results and Discussion

Cover crop biomass. Cover crop biomass production was very uneven at Bas Boen, while biomass was unusually low for all species at Duvier. There was no significant effect of cover crop treatment on cover crop biomass at Bas Boen at 30 or 60 DAP (Table 2), which may have been due to ineffective blocking. At Duvier, at 30 DAP, sunn hemp (SH) produced only 635 kg·ha-1 of fresh shoot biomass, which was significantly lower than the

Table 2. Fresh cover crop biomass (kg·ha-1) 30 and 60 days after planting (DAP)z at Bas Boen and Duvier.

Treatment	Bas Boen 30 DAP	Bas Boen 60 DAP	Duvier 30 DAP	Duvier 60 DAP
Natural fallow	--	--	--	--
SHy	2272	4699	635 b	1305
SH/SS	2245	3284	1179 ab	1857
CP	3046	4630	2352 a	2125
CP/SS	1808	1753	2166 ab	1966
LB	624	372	1840 ab	1805
LB/SS	3897	4964	1805 ab	2155
SH/CP/LB/SS	1190	1796	1494 ab	2561
Significance	NS	NS	*	NS

zData are LS-means of four replications of each treatment per site, determined using samples from within a 0.5 m × 0.5 m quadrat from each plot.
ySH = sunn hemp; SS = sorghum sudangrass; CP = cowpea; LB = lablab.
*Significant ($P < 0.05$); NS = not significant.

Table 3. Fresh biomass ($kg\cdot ha^{-1}$) of weeds at 30 and 60 days after planting (DAP)[z] at Bas Boen and Duvier.

	Bas Boen		Duvier	
Treatment	30 DAP	60 DAP	30 DAP	60 DAP
Natural fallow	4915	4441	3465 a	4850
SH[y]	3216	4175	2481 ab	4884
SH/SS	3025	6908	2256 ab	3298
CP	1963	8214	1575 b	3283
CP/SS	1825	2508	1415 b	4367
LB	1703	3326	1480 b	2770
LB/SS	3014	3495	1344 b	2643
SH/CP/LB/SS	1793	2035	2185 b	2573
Significance	NS	NS	*	NS

[z]Data are LS means of four replications of each treatment per site, determined using samples from within a 0.5 m × 0.5 m quadrat from each plot.
[y]SH = sunn hemp; SS = sorghum sudangrass; CP = cowpea; LB = lablab.
*Significant ($P < 0.05$); NS = not significant.

2352 $kg\cdot ha^{-1}$ of fresh biomass obtained with the cowpea monoculture but not significantly different from the other cover crop treatments. Previous research has identified short-day and day-neutral photoperiod responses in sunn hemp. A possible explanation of the poor sunn hemp performance could be that the short daylength in Haiti during the trials may have triggered early transition from vegetative growth to flowering in a short-day variety, resulting in low shoot biomass. The sunn hemp cultivar AU Golden is a day-neutral cultivar (Cho et al., 2016) and may offer better biomass production with the short daylength and cooler temperatures at high altitude locations like Duvier.

Weed biomass and density. Cover crop treatment also had no significant effect on weed biomass at Bas Boen at 30 or 60 DAP (Table 3). At Bas Boen, *Portulaca oleracea* was the dominant weed, making up 80 to 89% across treatments (data not shown). At Duvier, by 30 DAP only the cowpea and lablab monocultures and their bicultures with sorghum sudangrass had resulted in a lower weed biomass than the natural fallow control. However, significant differences were no longer apparent at 60 DAP. *Parthenium hysterophorus* and *Oxalis intermedia* were the dominant weed species at Duvier (data not shown). Interestingly, the natural fallow had a lower density of *P. hysterophorus* than the cowpea monoculture at 60 DAP (Fig. 1). *Parthenium hysterophorus* densities with the other cover treatments were not significantly different from its density with the natural fallow.

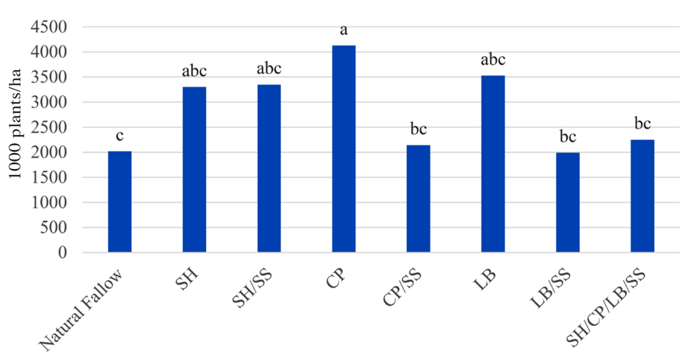

Fig. 1. Effect of cover crop treatment on *Parthenium hysterophorus* density at Duvier at 60 days after planting. Data shown are back-transformed LS means of *P. hysterophorus* densities for each cover crop or natural fallow treatment. Model was fit to a negative binomial distribution. The DIFF option of the LSMEANS statement was used for separation of the transformed LS means ($P \leq 0.05$).

Nematode reproduction factor. Plant-parasitic nematodes from the genera *Pratylenchus*, *Rotylenchulus*, *Tylenchorhynchus*, *Hoplolaimus*, *Helicotylenchus*, *Meloidogyne*, *Criconomella*, *Heterodera*, and *Xiphinema* were identified in the plots in varying densities (Table 4). To our knowledge, for all but *Meloidogyne* this is the first report of the occurrence of these plant parasitic nematodes in Haiti. Generally, the PPN detected were in low abundance (< 10 nematodes per 100 cm^3) including *Hoplolaimus*, *Criconomella*, *Heterodera*, and *Xiphinema*. *Rotylenchulus* was found in low abundance in Bas Boen, a mean of 50 nematodes per 100 cm^3 of soil were detected at 60 DAP at Duvier. *R. reniformis* has an action threshold of one nematode in vegetable crops, and has a wide host range including cowpea, papaya, okra, tomato, pineapple, and pigeon pea (Khan, 2005). The effect of cover crop treatment on nematode RF was only significant for *Meloidogyne* at Bas Boen (Table 4).

An RF above 1 represents a good or efficient host, meaning that reproduction of the nematode was possible and the population increased. An RF < 1 represents resistance or a poor or inefficient host, and thus the population decreased this less than the starting population. An RF of 1 suggests the population was maintained but did not proliferate.

At Bas Boen, the natural fallow appears to represent a stable *Meloidogyne* population, with an RF of 1.02, but did not differ significantly from any other treatment (Table 5). Kokalis-Burelle and Rosskopf (2012) found that *P. oleracea*, the dominant weed at Bas Boen, can harbor large numbers of nematodes in the roots but can be mistaken as a non-host due to low populations in the soil. When interpreting these results and in future studies evaluating cover crops, it should be considered that we did not evaluate root samples, and it is possible that where this weed occurs, it may harbor nematodes inside the roots.

The lablab monoculture appears to be a good host of *Meloidogyne* sp. at Bas Boen, with an RF of 3.04, consistent with previously reported susceptibility to *M. javanica* (Araya and Caswell-Chen, 1994) and specifically 'Rongai' (Medvecky et al., 2007; Smith, 2006). When mixed with sorghum sudangrass, reproduction was suppressed significantly (RF = 0.23). Osei et al. (2010) reported

Table 4. Nematode genera detected and their populations at cover crop planting and termination (nematodes per 100 cm^3 of soil) at Bas Boen and Duvier.[z]

	Bas Boen			Duvier		
Nematode	Pi	Pf	Sig.[y]	Pi	Pf	Sig.[y]
Pratylenchus	1.6	0.8	NS	0.5	1.1	NS
Rotylenchulus	0.2	0.2	†	10.4	50.3	NS
Tylenchorhynchus	0.4	1.7	NS	2.1	13.6	NS
Hoplolaimus	0.1	0.0	†	–	–	†
Criconomella	0.03	0.00	–	–	–	†
Meloidogyne	5.0	3.1	*	–	–	†
Helicotylenchus	0.1	0.0	†	1.7	6.8	NS
Heterodera	0.13	0.06	†	–	–	†
Xiphinema	–	–	†	0.09	0.06	†

[z]Data shown are least squares (LS) means of nematode populations before planting (Pi) and at termination (Pf), for four replications of each treatment. A dash (–) indicates no nematodes of this genus were identified at the site.
[y]Significance (Sig.) is determined by treatment effect on LS means of reproduction factor [RF = Pf+1/Pi+1] of nematode genus.
* = significant at ($P < 0.05$); NS = not significant at ($P < 0.05$); † = analyses were not carried out due to low densities across the field.

Table 5. *Meloidogyne* sp. populations (nematodes per 100 cm^3) and reproduction factor (RF) at Bas Boen[z].

Treatment	Pi	Pf	RF[y]
Natural fallow[x]	2.5	3.3	1.02 ab
SH	8.0	3.0	0.40 b
SH/SS	8.3	1.5	0.26 b
CP	1.8	1.5	0.96 ab
CP/SS	8.0	4.0	0.63 ab
LB	1.8	8.3	3.04 a
LB/SS	8.3	0.5	0.23 b
SH/CP/LB/SS	1.3	2.5	1.19 ab

[z]Pi and Pf are least square means of nematode populations before planting (Pi) and at termination (Pf), of four replications of each treatment, respectively.

[y]RF values [Pf+1/Pi+1] are least square means of four replications from each cover crop or natural fallow plot shown. Least squares means followed by the same letters were not different ($P \leq 0.05$). RF > 1 represents a good nematode host; RF < 1 is a poor host.

[x]Natural fallow plots composed of 82% *Portulaca oleracea*. SH = sunn hemp; SS = sorghum sudangrass; CP = cowpea; LB = lablab.

that lablab supported *Meloidogyne* spp but found that leaf eluants, rather than root eluants, were toxic to these nematodes. This suggests that the presence of sorghum sudangrass may have been responsible for the increased nematode resistance in the lablab/sorghum sudangrass biculture. Sorghum sudangrass was expected to be a poor host based on previous findings with other cultivars, but the extent of suppression can vary by genotype due to the cyanide content (Widmer and Abawi, 2002). Our findings indicate the 'Surpass BMR' is likely a poor host of the *Meloidogyne* sp. found at Bas Boen.

Sunn hemp (RF = 0.40) and sunn hemp/sorghum sudangrass (RF = 0.26) also had significantly lower nematode populations than lablab. Sunn hemp ('Tropic Sun', PI 207657, and 'IAC-KR1') has been previously shown to suppress reproduction in *M. javanica* and *M. incognita* (Araya and Caswell-Chen, 1994; Marla et al., 2008; Miamoto et al., 2016). Our results of root-knot nematode suppression with sunn hemp is consistent with those in previous reports and inclusion of sorghum sudangrass in a biculture with sunn hemp did not negate the nematode-suppressive effect of sunn hemp. The lack of root-knot reproduction in bicultures of sorghum sudangrass with lablab and sunn hemp may indicate that 'Surpass BMR' is a poor host of the *Meloidogyne* sp. at Bas Boen.

Weed pressure at both locations was high and the cover crop treatments used did not effectively suppress weeds during the sixty-day cover cropping period from early January to early March. In particular, the sunn hemp cultivar appeared to be poorly adapted for use in Duvier, the upland location. We suggest that these cover crops be evaluated again during the summer rainy season when air temperatures and daylengths will be more conducive to rapid cover crop growth and canopy closure and thus more effective weed suppression. We documented the occurrence of several previously unreported nematode species in Haiti, information that can be used to inform decisions about crop and cover crop selection. Finally, of critical importance for reducing the cost of cover cropping by decreasing legume seeding rates, we report that cover crop mixes that include the root-knot nematode-susceptible lablab as a component do not appear to promote the proliferation of the nematode that is observed with a lablab monoculture.

Literature Cited

Adler, M.J. and C.A. Chase. 2007. Comparison of the allelopathic potential of leguminous summer cover crops: Cowpea, sunn hemp, and velvetbean. HortScience 42(2):289–293.

Anwar, S.A. and M. V. McKenry. 2010. Incidence and reproduction of *Meloidogyne incognita* on vegetable crop genotypes. Pak. J. Zool. 42(2):135–141.

Araya, M. and E.P. Caswell-Chen. 1994. Penetration of *Crotalaria juncea*, *Dolichos lablab*, and *Sesamum indicum* Roots by *Meloidogyne javanica*. J. Nematol. 26(2):238–40.

Baligar, V.C. and N.K. Fageria. 2007. Agronomy and physiology of tropical cover crops. J. Plant Nutr. 30(8):1287–1339.

Bargout, R.N. and M.N. Raizada. 2013. Soil nutrient management in Haiti, pre-Columbus to the present day: Lessons for future agricultural interventions. Agric. Food Security. 2:11.

Brady, N.C. and R.R. Weil. 2008. The nature and properties of soil. 14th ed. Pearson Prentice Hall, Columbus, OH.

Bybee-Finley, K.A., S.B. Mirsky, and M.R. Ryan. 2016. Functional diversity in summer annual grass and legume intercrops in the northeastern United States. Crop Sci. 56(5):2775–2790.

CABI/EPPO. 2009. *Ditylenchus dipsaci*. Distribution maps of plant diseases, No.April, pp Map 791 (Edition 2).

CABI/EPPO. 2011. *Scutellonema bradys*. Distribution maps of plant diseases, No.October, pp Map 818 (Edition 2).

Chikowo, R., P. Mapfumo, P. Nyamugafata, and K.E. Giller. 2004. Woody legume fallow productivity, biological N_2-fixation and residual benefits to two successive maize crops in Zimbabwe. Plant Soil 262(1–2):303–315.

Cho, A.H., C.A. Chase, R.L. Koenig, D.D. Treadwell, J. Gaskins, J.B. Morris, and J.P. Morales-Payan. 2016. Phenotypic characterization of 16 accessions of sunn hemp in Florida. Agron. J. 108:2417–2424.

Cho, A.H., A.W. Hodges, and C.A. Chase. 2012. Partial budget analysis of summer fallows for organic nutrient and weed management in Florida. HortTechnology 22(2):258–262.

Collins, A.S., C.A. Chase, W.M. Stall, and C.M. Hutchinson. 2008. Optimum densities of three leguminous cover crops for suppression of smooth pigweed (*Amaranthus hybridus*). Weed Sci. 56(05):753–761.

Coyne, D.L., J.M. Nicol, and B. Claudius-Cole. 2007. Practical plant nematology: a field and laboratory guide. IITA, Cotonou, Benin.

Creamer, N.G. and K.R. Baldwin. 2000. An evaluation of summer cover crops for use in vegetable production systems in North Carolina. Hortscience 35(4):600–603.

Crill, P., C.H. Blazquez, and S.L. Poe. 1973. Observations of tomato diseases in Haiti. Plant Dis. Report. 57(11):921–923.

Cruz-Silva, C.T.A., E.B. Matiazzo, F.P. Pacheco, and L.H.P. Nóbrega. 2015. Allelopathy of *Crotalaria juncea* L. aqueous extracts on germination and initial development of maize. Idesia 33(1):27–32.

Daimon, H. 2006. Traits of the genus *Crotalaria* used as a green manure legume on sustainable cropping systems, Japan Agr. Res. Quart. 40(4):299–305.

Freeman, J. 2015. Managing root-knot nematode (*Meloidogyne* spp.) in grafted watermelon. Proc. Fla. State Hort. Soc. (128):156–158.

Gallaher, R.N. and R. McSorley. 1991. Nematode population changes and forage yields of six corn and sorghum cultivars 1. J. Nematol. 23(4S):673–677.

Godefroid, M., P. Tixier, C. Chabrier, D. Djigal, and P. Quénéhervé. 2017. Associations of soil type and previous crop with plant-feeding nematode communities in plantain agrosystems. Appl. Soil Ecol. 11363–70.

Jabran, K., G. Mahajan, V. Sardana, and B.S. Chauhan. 2015. Allelopathy for weed control in agricultural systems. Crop Prot. 7257–65.

Jaffe, J. 1989. Land use, soil degradation, and farmer decision-making: a sondeo report of Cavalier, Despa, Kols, and Saut Mathurine, Haiti. USAID, Port-au-Prince, Haiti and The Proje Sove Te Participating Non-Governmental Organizations: DCCH, IRD, ORE, and UNICORS.

Javaid, M.M., M. Bhan, J. V Johnson, B. Rathinasabapathi, and C.A. Chase. 2015. Biological and chemical characterizations of allelopathic potential of diverse accessions of the cover crop sunn hemp. J. Am. Soc. Hort. Sci. 140(6):532–541.

Khan, M.R. 2005. Hosts and non-hosts of reniform nematode, *Rotylenchulus reniformis* Linford & Oliveira, 1940—A critial review. Environ. Ecol. 23:124-140.

Kokalis-Burelle, N. and E.N. Rosskopf. 2012. Susceptibility of several common subtropical weeds to *Meloidogyne arenaria*, *M. incognita*, and *M. javanica*. J. Nematol. 44(2):142–7.

Lal, R. 2001. Soil degradation by erosion. Land Degrad. Dev. 12(6):519–539.

Libohova, Z., D. Wysocki, P. Schoeneberger, T. Reinsch, C. Kome, T. Rolfes, N. Jones, S. Monteith, and M. Matos. 2017. Soils and climate of Cul de Sac Valley, Haiti: A soil water and geomorphology perspective. J. Soil Water Conserv. 72(2):91–101.

Linguya, K., O. Moraa, K. Wangai, and K. Chao. 2015. Potential of intercropping for management of some arthropod and nematode pests of leafy vegetables in Kenya. J. Agr. Sci. Belgrade 60(3):301–314.

Luc, M., R.A. Sikora, and J. Bridge. 2005. Plant parasitic nematodes in subtropical and tropical agriculture, 2nd ed, Institute of Parasitology. CABI Publishing, Wallingford, Oxfordshire, UK.

Lynch, M.J., M.J. Mulvaney, S.C. Hodges, T.L. Thompson, and W.E. Thomason. 2016. Decomposition, nitrogen and carbon mineralization from food and cover crop residues in the central plateau of Haiti. SpringerPlus 5:973.

Marla, S.R., R.N. Huettel, and J. Mosjidis. 2008. Evaluation of *Crotalaria juncea* populations as hosts and antagonistic crops to manage *Meloidogyne incognitia* and *Rotylenchulus reniformis*. Nematropica 38:155-162.

McSorley, R. 1999. Host suitability of potential cover crops for root-knot nematodes. J. Nematol. 31(4):619–623.

McClintock, N. 2004. Regenerative agriculture for Haiti's central plateau: A sustainable foundation for food and nutrition security. Zanmi Lasante, Paris.

Medvecky, B.A., Q.M. Ketterings, and E.B. Nelson. 2007. Relationships among soilborne bean seedling diseases, *Lablab purpureus* L. and maize stover residue management, bean insect pests, and soil characteristics in Trans Nzoia district, Kenya. Appl. Soil Ecol. 35(1):107–119.

Miamoto, A., C.R. Dias-Arieira, M.R. Cardoso, and H.H. Puerari. 2016. Penetration and reproduction of *Meloidogyne javanica* on leguminous crops. J. Phytopathol. 164(11–12):890–895.

Nicol, J.M., S.J. Turner, D.L. Coyne, L. Den Nijs, and S. Hockland. 2011. Genomics and molecular genetics of plant-nematode interactions. Springer, New York, NY.

Ngongoni, N.T., M. Mwale, C. Mapiye, M.T. Moyo, H. Hamudikuwanda, and M. Titterton. 2007. Evaluation of cereal-legume intercropped forages for smallholder dairy production in Zimbabwe. Livest. Res. Rural Dev. 19(9):129.

Ntidi, K.N., H. Fourie, and M. Daneel. 2016. Greenhouse and field evaluations of commonly occurring weed species for their host suitability to *Meloidogyne* species. Int. J. Pest Mgt. 62(1):11–19.

Oostenbrink, M., 1966. Major characteristics of the relation between nematodes and plants. Mededelingen / Landbouwhogeschool Wageningen no. 66:46

Osei, K., S.R. Gowen, B. Pembroke, R.L. Brandenburg, and D.L. Jordan. 2010. Potential of leguminous cover crops in management of a mixed population of root-knot nematodes (*Meloidogyne* spp.). J. Nematol. 42(3):173–8.

Purseglove, J.W. 1968. Tropical crops. Dicotyledons 1 and 2. Longmans, Green and Co. Ltd., London.

Quénéhervé, P., C. Chabrier, A. Auwerkerken, P. Topart, B. Martiny, and S. Marie-Luce. 2006. Status of weeds as reservoirs of plant parasitic nematodes in banana fields in Martinique. Crop Prot. 25(8):860–867.

Rabie, E. and H. Tustin. 2007. The effect of different cover crops (green manure) on nematode populations and soil fertility in pineapple cultivation. S. Afr. J. Plant Soil 24(4)248.

Rao, R.B. and Y.C. Li. 2003. Nitrogen mineralization of cover crop residues in calcareous gravelly soil. Commun. Soil Sci. Plant Anal. 34(3–4):299–313.

Sustainable Agriculture Research and Education (SARE). 2012. Managing Cover Crops Profitably (3rd Edition). Handbook Series.

Smith, G.R., F.M. Rouquette, and J. Starr. 2006. Evaluation of lablab for root-knot nematode resistance. ASA–CSSA–SSSA, Madison, WI.

Smucker, G.R. 2007. Environmental vulnerability in Haiti. Chemonics U.S. For. Serv. 141.

Wang, K., R. Mcsorley, and R.N. Gallaher. 2003. Host status and amendment effects of cowpea on *Meloidogyne incognita* in vegetable cropping systems. Nematropica 33(2):215–224.

Wang, K.H., R. McSorley, R.N. Gallaher, and N. Kokalis-Burelle. 2008. Cover crops and organic mulches for nematode, weed and plant health management. Nematology 10(2):231–242.

Weaver, D.B., R. Rodriguez-Kabana, and E.L. Carden. 1995. Comparison of crop rotation and fallow for management of *Heterodera glycines* and *Meloidogyne* spp. in soybean. J. Nematol. 27(4):585–591.

Weston, L.A., I.S. Alsaadawi, and S.R. Baerson. 2013. Sorghum Allelopathy-from ecosystem to molecule. J. Chem. Ecol. 39(2):142–153.

Widmer, T.L. and G.S. Abawi. 2002. Relationship between levels of cyanide in sudangrass hybrids incorporated into soil and suppression of *Meloidogyne hapla*. J. Nematol. 34(1):16–22.

Widmer, T.L., N.A. Mitkowski, and G.S. Abawi. 2002. Soil organic matter and management of plant-parasitic nematodes. J. Nematol. 34(4):289–295.

World Food Programme. 2016. Haiti—Emergency Food Security Assessment. United Nations, New York.