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

Sustainable Pest and Soil Health Management for Sweet Potato Production

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Sweet potato (*Ipomoea batatas*) is an important vegetable crop in Hawaii with a farm gate value of $2.24 mil in 2022 (NASS, 2023). However, widespread damage from multiple pests and pathogens limits sweet potato production, especially when sweet potatoes are grown for multiple years in the same location. Challenges related to pest management are especially problematic for organic producers due to the high costs and low efficacy of available organic pest control measures for sweet potatoes. This project focused on exploring sustainable pest and soil health management strategies that can help organic sweet potato producers improve productivity.

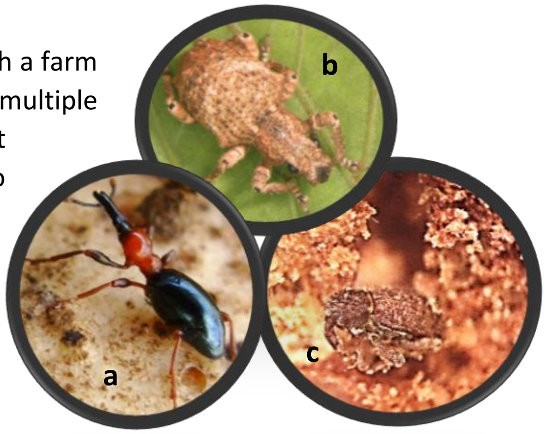

Fig. 1 a) Sweet potato weevil, b) rough sweet potato weevil and c) West Indian sweet potato weevil (Credit a and c: R. Myers, b: HDOA).

Weevils and stem borers

Among the arthropod pests that affect sweet potato, the sweet potato weevil (*Cylas formicarius*, SPW), the West Indian sweet potato weevil (*Euscepes postfasciatus*, WSPW) and the rough sweet potato weevil (*Blosyrus asellus*, RSPW) are the most widespread and damaging in Hawaii (Fig. 1). Both SPW and WSPW tunnel through the vine to reach storage roots buried in the soil and spend the majority of their life cycle in the root, making spray contact on these pests difficult. Commercial SPW pheromone traps such as Pherocon unitraps (Alpha Scents, Canby, OR) are available and can be added into an integrated pest management (IPM) program for SPW management (McQuate and Sylva, 2014). The phermone traps can be used to monitor SPW populations and should be placed 60 m apart, with 3 traps at equal distance per 40-acre field. The economic threshold for insecticide treatment is 4 weevils/pheromone trap per week (Jansson et al., 1991). Unfortunately, no pheromone trap is available for WSPW and RSPW.

Sweet potato vine or stem borer, *Omphisa anastomosalis* (Fig. 2), is also a common pest of sweet potato in Hawaii. Larvae bore into the stem and storage roots, creating cavities and causing wilting and death. Early infestation during the vegetative phase can cause 30-50% yield losses. A pile of frass can be found under the attacked stem (Amalin and Vasquez, publication year unknown).

Recommendations against weevils and stem borers include crop rotation for at least one year, planting new fields a mile from old fields, post-harvest destruction of culls, intensive pesticide sprays and installing pheromone traps, hilling-up of soil around the base of plants, sufficient irrigation to prevent soil cracking, as well as prompt harvesting to avoid a dry period (Vasquez and Amante, year unknown). Manandhar et al. (2022) reported several sweet potato varieties in Hawaii are more tolerant to these pests. Crop rotations should be made with non-host crops that do not foster weevil and stem borers. In Hawaii, suitable rotational crops include corn, turmeric, and pasture if integrating livestock with sweet potato production. Corn and many grasses used in pasture are non-hosts to reniform nematodes (Wang, 2007). To avoid pest hosts during the rotation, sweet potato volunteers or related weeds need to be avoided during the rotation period. The amount of time and land needed to effectivly use crop rotation for pest control makes it difficult for small-scale farmers to utilize crop rotation. Insecticides can help limit pest disease, but organic farmers have limited insecticides available to combat this weevil complex. Available organic pesticides include the bioinsecticides *Beauvaria bassiana* and *Metarhizium anisopliae*. However, research is needed to improve the efficacy of bioinsecticides against these pests.

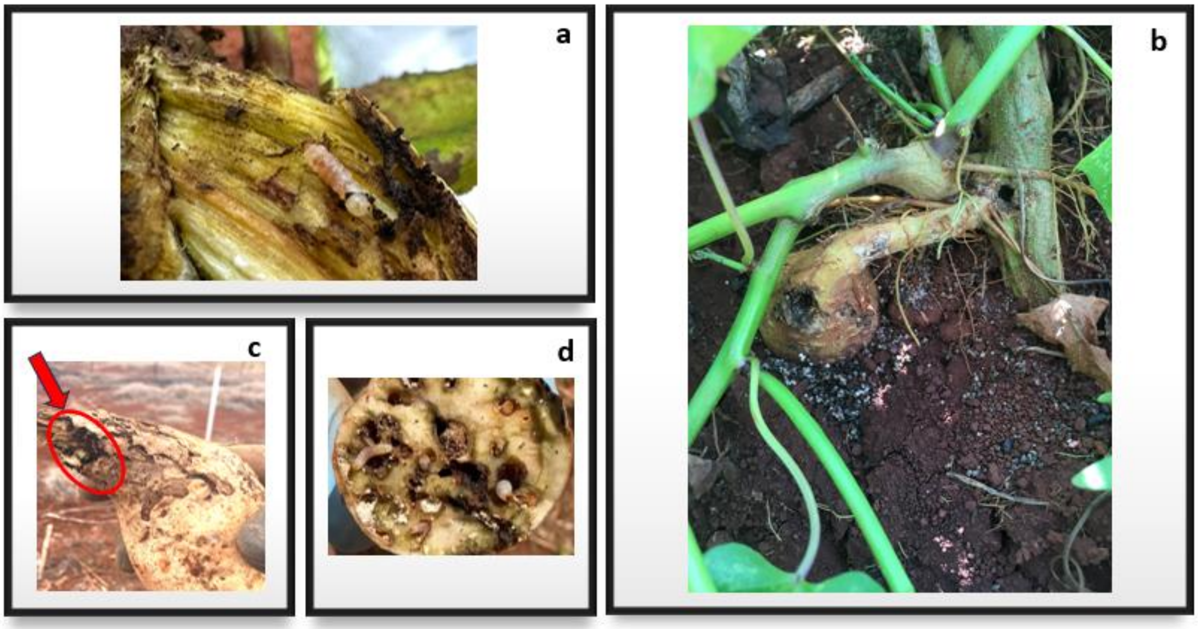

Fig. 2. a) A sweet potato stem borer larva bores into the stem of sweet potato, b) the point of penetration of stem borers into the vines close to or into the storage roots leaving a pile of frass , c) damage by stem borer to the tip of the sweet potato, and d) hollow cavities in the storage root caused by stem borers (credit: L. Wong, B. Wiseman).

Plant-parasitic Nematodes

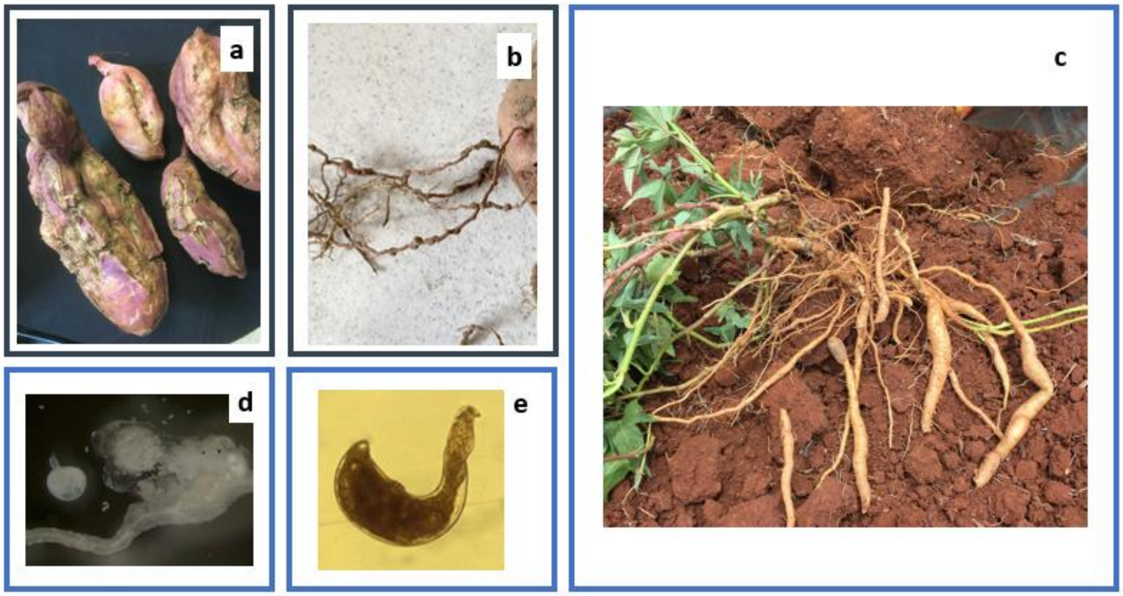

Fig. 3. Damage from nematodes on sweet potato includes a) cracking on the storage roots, b) galls formation on the lateral roots cause by root-knot nematodes, and c) slender storage roots despite healthy vegetative growth. d) A root-knot nematode female producing egg masses outside of a gall. e) a reniform nematode female is kidney shaped but does not form galls on the roots (credit: C. Shloemer and K.-H. Wang).

Plant-parasitic nematodes are another major pest of sweet potato. In Hawaii, root-knot nematode (*Meloidogyne* spp.) and reniform nematode (*Rotylenchulus reniformis*) are two common genera infecting sweet potato. Effective control of root-knot nematodes by a synthetic nematicide, fluopyram, increased the marketable yield of sweet potato by 6.3-fold compared to the untreated control (Waisen et al., 2021). Effective management of reniform nematode populations by pre-planting of sunn hemp cover crop followed by monthly application of Molt-X (a.i. azadirachtin), a neem product, did not significantly improve sweet potato yield (Waisen et al., 2021). More research is needed to identify effective organic management approaches for plant-parasitic nematodes on sweet potato.

Tropical Cover Crops for Sustainable Sweet Potato Production

We implemented cover cropping and other conservation agricultural practices in an organic sweet potato production trial and examined soil health, pest control, and other beneficial environmental outcomes.-Managing soil health is more difficult for sweet potatoes compared to other row crops due to cropping practices that require hilling of planting beds and harvesting procedures that require deep digging of the storage roots. This means constant soil disturbance is inevitable. Since we cannot harvest sweet potato crops using no-till techniques, rotating cover crops with sweet potato and terminating the cover crops with strip-till practice might be a critical step to restore soil health for sweet potato. Four tropical cover crops with nematode allelopathic (suppressive) effect were tested (Fig. 4).

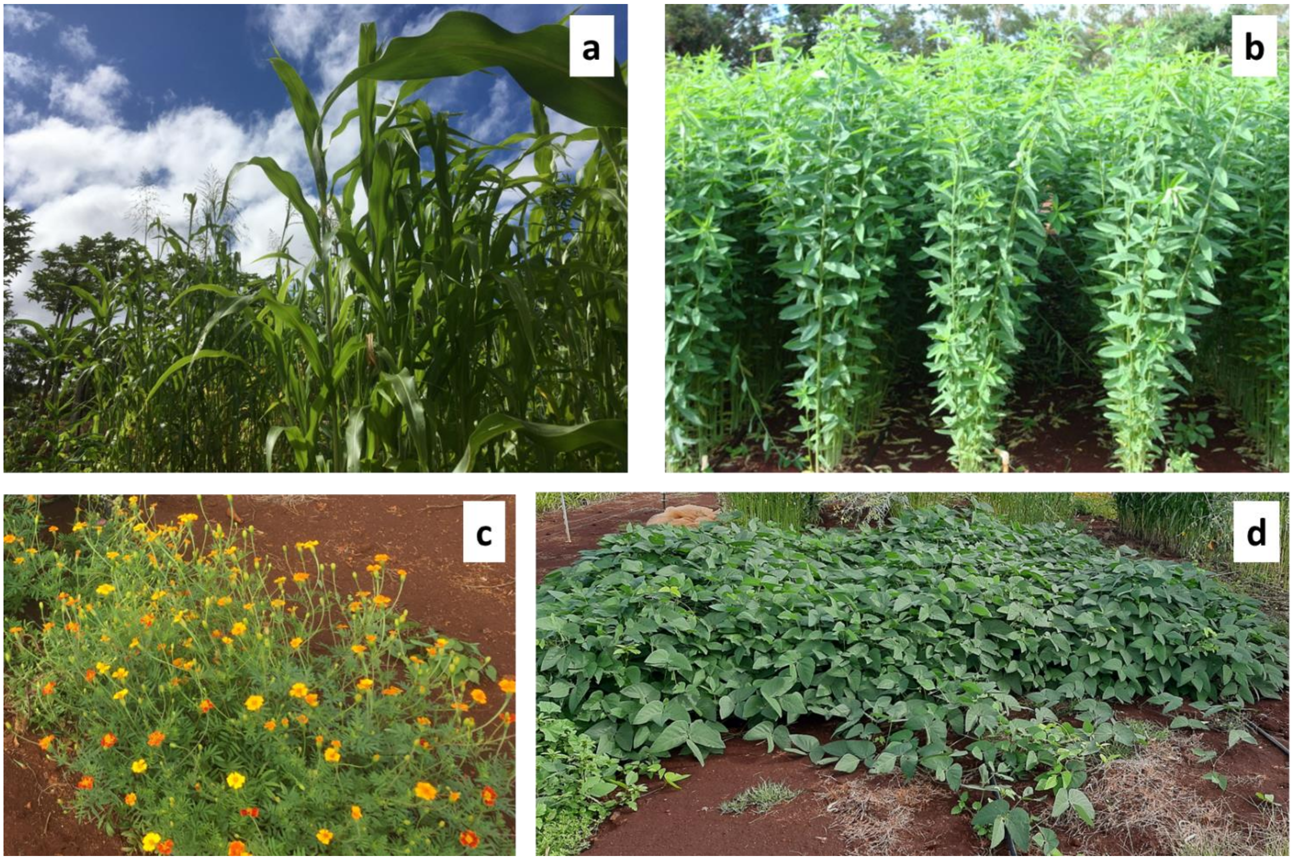

Fig. 4. Four tropical cover crops possessing nematode allelopathic compounds: a) sorghum contains dhurrin, b) sunn hemp contains monocrotaline, c) marigold contains α-terthienyl, and d) velvet bean contains L-DOPA (dopamine) (picture credit: K.-H. Wang).

Besides an ability to suppress plant-parasitic nematodes, proper cover crop selection could also overcome soil health degradation over time from constant tillage. Soil health is “the continued capacity of the soil to function as a vital living ecosystem that sustains plants, animals, and humans” (NRCS). Healthy soil is supported by a diverse arena of soil microorganisms that form a functional soil food web that can sustain soil nutrient cycling and other ecosystem functions. For example, soil bacteria and fungi contribute to plant growth regulation, nutrient cycling, and carbon sequestration. Symbiotic fungi, like arbuscular mycorrhizal fungi (AMF), assist plants to absorb soil phosphorus.

Soil microbial communities can be examined through various biological tests. Since all soil microorganisms contain phospholipid fatty acids, measurement of phospholipid fatty acids (PLFA) of the total microbial community in the soil can estimate the “living” biomass, broad microbial community structure, and environmental stress impacts on soil health. In addition, many researchers have shown that free-living nematodes are reliable soil health indicators (Ferris et al., 2001). Nematodes are ubiquitous, functionally diverse, and well classified into functional groups (Yeates et al., 1993). Further, nematodes are easy to sample and play an important role in soil nutrient cycling. Free-living nematodes directly influence soil processes and reflect the structure and function of many other taxa within the soil food web. Nematode communities are sensitive to changes in soil quality and the frequency of soil disturbances. Thus, nematode community analysis can provide an indication of how pest and soil management practices are affecting soil health (Ferris et al., 2001).

Field Study

A field trial was conducted at Poamoho Experiment Station, University of Hawaiʻi in Waialua, HI where cover crops ‘NX-D-61’ energy sorghum (*Sorghum bicolor*, Koolau Seed Supplies, HI), ‘Tropic Sun’ sunn hemp (*Crotalaria juncea*, Oahu RC&D, Kunia, HI), velvet bean (*Macuna pruriens*), and ‘Nema-Gone’ marigold (*Tagetes patula*, Burpee, Warminster, PA) were grown for 3 months (from September 1 to December 1, 2022) and compared to a bare ground control prior to sweet potato planting. To determine how long each cover crop should be irrigated to maximize cover crop biomass production, each cover crop received 3 irrigation regimes: 2, 4 or 8 weeks of 4 hours drip irrigation (approximately 120 K gal water/acre/week). Each field plot was 10 × 5 ft^2 in size and each treatment was replicated in 4 plots arranged in a randomized complete block design. Biomass of cover crops were estimated at termination. All cover crops were terminated by flail mowing followed by strip-tilling a 2-ft wide strip in the middle of each plot to 4 inches deep with a rototiller. ‘Okinawan’ sweet potato cuttings were planted on December 8, 2022 only in the 8-week irrigated plot to compare cover crop effects on sweet potato cultivation. Soil samples were collected prior to cover crop planting and 2 weeks, 3 and 5 months (at harvest) after sweet potato planting. A SPW Pherocon unitrap was installed in the middle of the field 1 month after planting to reduce SPW pressure. Each cover crop plot was split into half. Half was treated with a foliar spray of *Beauvaria bassiana* (Mycotrol, Certis USA L.L.C., Columbia, MD) at monthly intervals beginning at 2.5 months after planting whereas the other half was not treated.

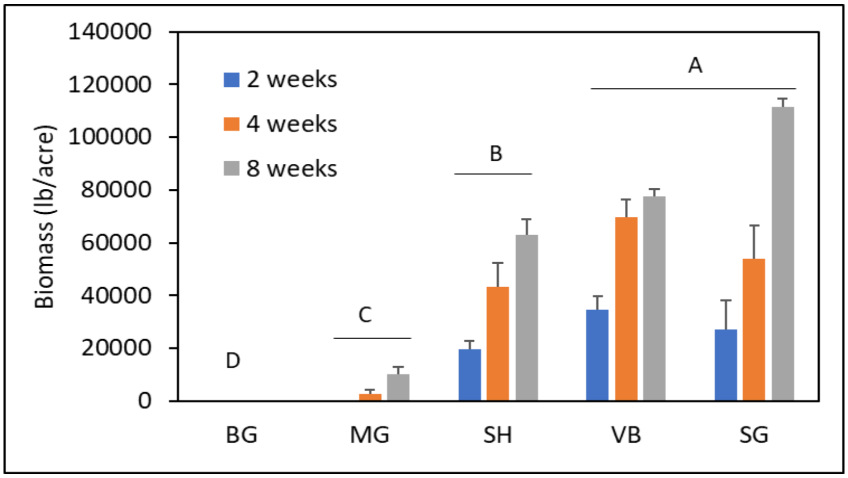

Fig. 5. Cover crop biomass generated in bare ground (BG), marigold (MG), sunn hemp (SH), velvet bean (VB) and sorghum (SG) plots after 4 months of planting. Each cover crop was split into 3 subplots that received weekly irrigation for 2, 4 or 8 weeks. Means of cover crops (average among irrigation treatments) marked with the same letter were not different based on Waller-Duncan k-ratio (k=100) t-test.

Results and Discussion

Irrigation Needs of Cover Crops: Among the cover crops tested, sorghum and velvet bean produced the most biomass ($P \leq 0.05$), especially if irrigated weekly for 8 weeks. However, velvet bean was the only cover crop that produced equivalent biomass between 4 and 8 weeks of weekly irrigation. This means that velvet bean irrigation can be terminated at 4 weeks after planting without sacrificing cover crop biomass production compared to 8 weeks of irrigation (Fig. 5). Under the 8-weeks irrigation regime, sorghum generated 55 tons/acre whereas velvet bean generated 38.8 tons/acre of biomass, and both added significant amounts of biomass to the soil.

Effects on Soil Properties: The velvet bean plots had significantly increased soil carbon (C) content 2 weeks after strip-tilling of the velvet bean compared to the bare ground (Fig. 6A). Though not significantly different from the other cover crops, planting of VB resulted in the highest water infiltration rate throughout the sweet potato cropping cycle (Fig. 6B). All soil samples collected throughout the sweet potato cropping cycle were also subjected to Solvita Labile Amino-Nitrogen (SLAN) test which reports organic nitrogen reserves present as amino-sugars in soil. VB was the only treatment that increased ammonia-N in the soil compared to BG ($P \le 0.05$, Fig 6C) indicating a higher pool of organic N that is potentially plant available.

Effects on Soil Microbial Biomass: Soil samples were collected from the rhizosphere of sweet potato from 3 plants/plot at 2 weeks and 3 months after sweet potato planting and submitted for phospholipid fatty acid (PLFA) analysis at Regen Ag Lab (Pleasanton, NE). This analysis showed that VB increased microbial diversity, gram-negative bacteria, total fungi, arbuscular mycorrhizal fungi (AMF) biomass, and fungi: bacteria ratio (F/B) ($P \le 0.05$, Table 1), but lowered actinomycete (ACT) microbial biomass compared to some other treatments. These results indicate a more diverse soil microbial community and less stressful (nutrient depleted) soil in the VB plots, and these changes may be due in part to higher SLAN in VB treated soil.

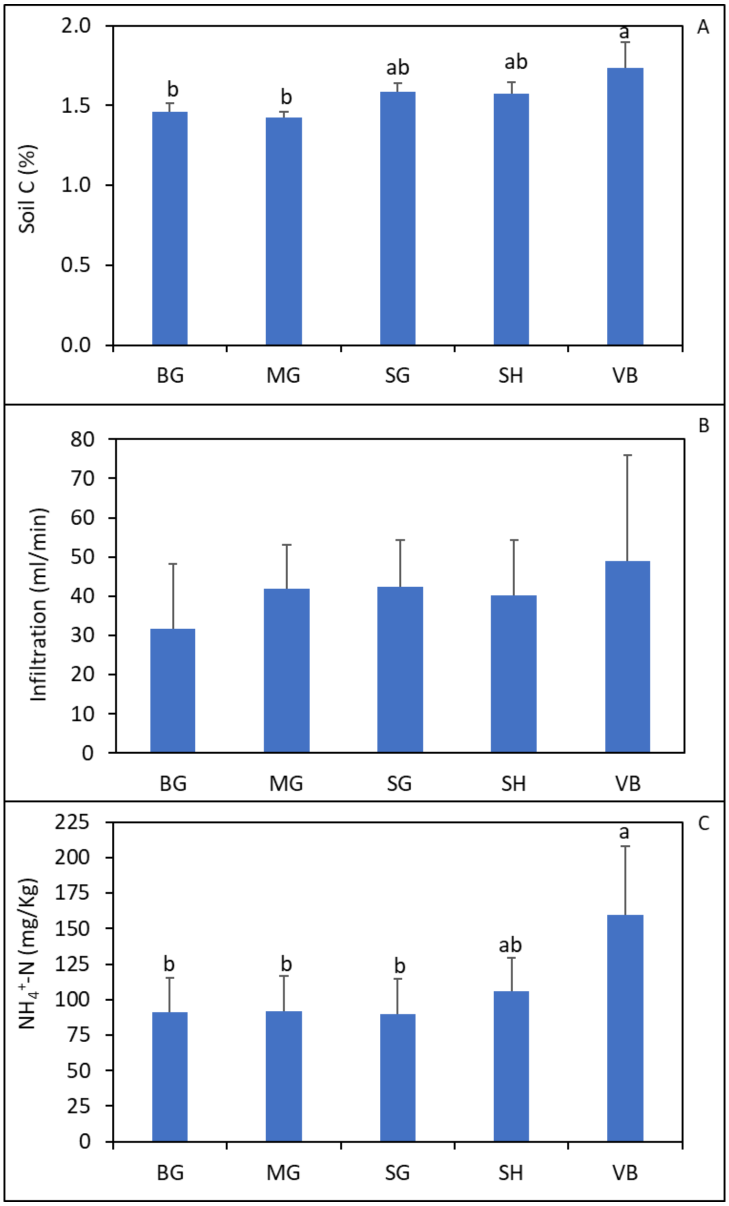

Fig. 6. A) Total soil C content (n=8), B) soil infiltration rate (n=8) and C) soil ammonia-nitrogen measured by Solvita SLAN test (n=20).

Table 1. Effect of cover crop on soil microbial biomass on sweet potato based on phospholipid fatty acid (PLFA) analysis. ACT= Actinomycetes, GN = gram negative bacteria, AMF = Arbuscular Mycorrhizae Fungi, F/B = Fungal/Bacterial PLFA biomass. Means (n=8) in a column with the same letter are not different based on Waller-Duncan *k*-ratio *t*-test ($P \le 0.05$).

Trt	Total (ng/g)	Diversity	ACT (ng/g)	GN (ng/g)	Fungi (ng/g)	AMF (ng/g)	F/B
BG	1585.78	1.11 b	140.51a	120.28 b	13.05 b	0.00 b	0.03 b
MG	1584.07	1.14 b	132.43a	145.73 b	51.80 ab	3.79 b	0.06 b
SG	1956.59	1.16 b	153.45ab	217.39 ab	27.96 b	4.86 b	0.04 ab
SH	1979.20	1.13 b	157.60ab	201.29 ab	22.70 b	0.40 b	0.03 b
VB	2227.05	1.30 a	141.66b	288.49 a	105.96 a	33.06 a	0.13 a

Effects on Plant-parasitic Nematodes and Free-living Nematodes: Reniform nematodes (*Rotylenchulus reniformis*) were the dominant plant-parasitic nematode at the field site. At sweet potato planting, the average populations of plant-parasitic nematodes were less than 100/250 cm^3 soil in all treatments. By the time the sweet potatoes were harvested, the average population densities of plant-parasitic nematodes ranged from 1000 to 3000/250 cm^3 soil, depending on the preceding cover crop. The data suggested that sunn hemp and velvet bean contributed to decreasing the final nematode populations ($P \leq 0.10$, Fig. 7). Effects of the cover crop on the plant-parasitic nematode population will be examined again in the second cropping cycle when the starting populations of plant-parasitic nematodes are expected to be higher. Examination of the free-living nematodes and calculated nematode-derived soil health indicators did not show differences among the cover crop treatments.

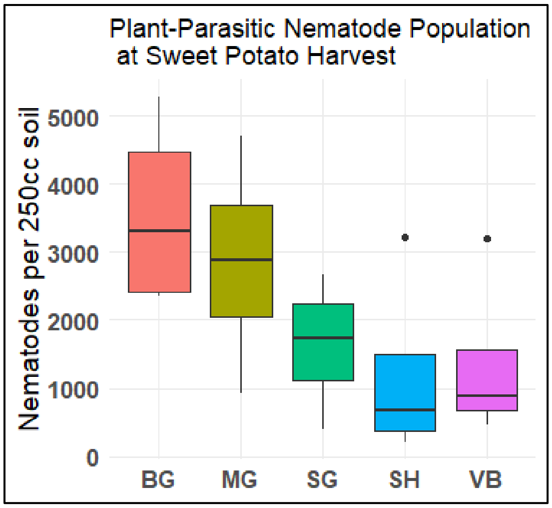

Fig. 7. Population densities of plant-parasitic nematodes (n=4) at sweet potato harvest, separated by cover crop that preceded sweet potato.

Effects on weevils and yield: Sweet potatoes were harvested 5 months after planting. Based on the grading standards for Hawaii-grown sweet potatoes (Hawaii Department of Agriculture, Marketing and Consumer Services Division, Commodities Branch, 1986), the total marketable yield of sweet potatoes was not different among the cover crop treatments ($P > 0.05$). Depending on the cover crop treatment, between 26-51% of the roots were damaged by RSPW, 9 -13% by SPW, and only 0-7% by plant-parasitic nematodes (Fig. 8). VB was the only treatment that reduced the damage of sweet potato roots from RSPW compared to the bare ground control ($P \leq 0.05$, Fig. 9A), and no differences in SPW and nematode damage was detected among the cover crop treatments.

Fig. 8. A) Numerous pitted holes caused by sweet potato weevils, B) skin scarification caused by rough sweet potato weevils, and cracking and small storage roots indicative of reniform nematode infection (credit a, b: M. Pitiki, c: K.-H. Wang).

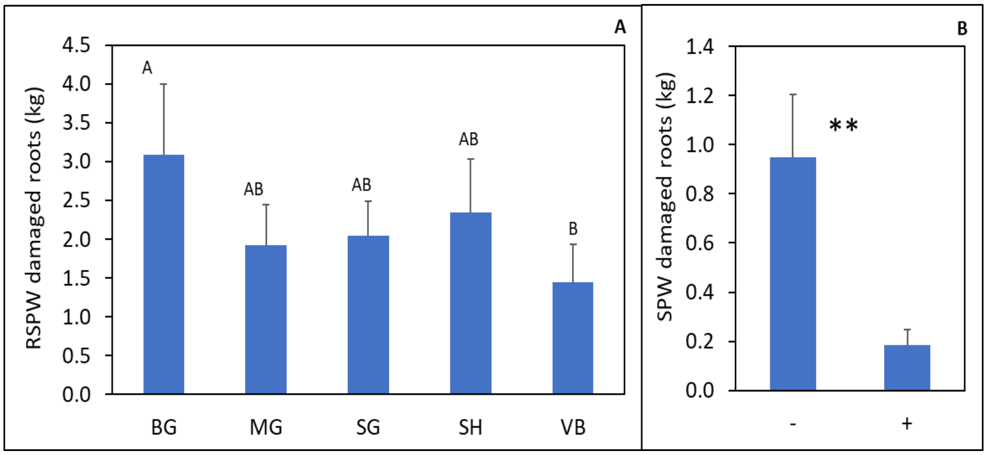

Fig. 9. A) Effects of pre-plant cover crops on sweet potato roots damaged by rough sweet potato weevil (RSPW), and B) effects of *Beauvaria bassiana* application on sweet potato roots damaged by sweet potato weevils (SPW) at harvest. Means (n=8 and n=20 for A and B, respectively) followed by a different letter or marked with ** indicate significant level at $P \leq 0.05$ and $P \leq 0.01$, respectively).

The monthly foliar application of Mycotrol (*B. bassiana*) reduced SPW damage by 80% ($P \leq 0.01$, Fig. 9B) compared to untreated plots when both plots were in the presence of a SPW pheromone trap. While this is an encouraging result for managing SPW, the Mycotrol treatment did not affect RSPW damage.

At one and two months after planting, we monitored the occurrence of *B. bassiana* and *M. anisopliae*, two natural fungal enemies of the three weevils and stem borer. Field cages filled with field soil and baited with 5 wax worm (*Galleria mellonella*) larvae, buried 2 inches (5 cm) deep in the VB and BG plots for 1 week, and brought into the lab to observe and record incidence of wax worm larvae colonization by *B. bassiana* (Bb) or *M. anisopliae* (Met) 2 weeks after lab incubation. Approximately 30% of the wax worms were either colonized by Bb or Met over the two sampling times, but no colonization of these entomopathogenic fungi was observed on the BG plots, suggesting that VB treatment might have enhanced the colonization of Bb and Met in the soil. Future research will investigate consistent performance of VB in enhancing EPF in the soil.

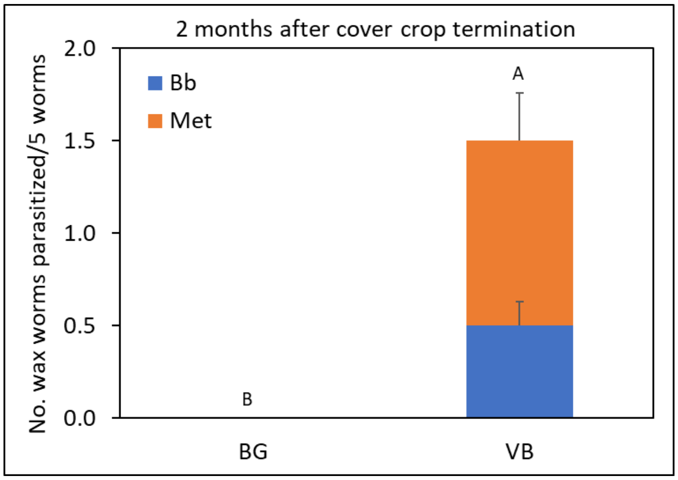

Fig. 9. Incidence of wax worm baits colonized by *Beauvaria bassiana* (Bb) or *Metarhizium anisopliae* (Met) in field cages buried in velvet bean (VB) or bare ground (BG) plots. Means (n=8) with letters indicate significant differences based on Waller-Duncan *k*-ratio

Summary

This field trial demonstrated that planting velvet bean prior to sweet potato planting is a promising tropical cover crop for sweet potatoes. Velvet bean:

- was the most water efficient in generating biomass compared to the other cover crops and generated a similar amount of biomass with 1 or 2 months of irrigation.
- increased total soil C and soil labile amino-nitrogen (SLAN) in one cropping cycle.
- fostered a more diverse and less stressful soil community as evidenced by increased soil microbial diversity, gram-negative bacteria, total fungi, arbuscular mycorrhizal fungi biomass, and fungi: bacteria ratio, while reducing actinomycete (ACT) microbial biomass.
- reduced the proliferation of plant-parasitic nematodes in the soil during the sweet potato growing season.
- reduced the damage of sweet potato roots from rough sweet potato weevils and increased the colonization of soil insects by indigenous entomopathogenic fungi such as *B. bassiana* and *M. anisopliae.*

This research also demonstrated that an integrated pest management strategy combining the SPW pheromone trap and monthly foliar spray of *B. bassiana* during the sweet potato root formation stage provided a promising organic approach to manage SPW. Future work is needed to improve management of other weevils and stem borer pests of sweet potatoes.

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