HS387

Annual Cover Crops in Florida Vegetable Systems Part 1. Objectives: *Why grow cover crops?*[1]

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Cover crops are crops grown to improve the farming system. Cover crops can improve the physical, chemical and biological properties of the soil, supply nitrogen, reduce leaching of nutrients and pesticides, reduce erosion, mitigate damage from plant pests and/or reduce their population densities, and attract beneficial insects. Cover crops can also generate additional income when grown for seed or as an energy crop. While it is difficult to achieve all of the listed benefits with one crop, producers should select cover crops that offer multiple benefits at once. Producers should also consider potential drawbacks before deciding to include a cover crop. In some instances, the cover crop can require additional labor and expense, delay crop planting, or serve as an alternate host to crop insects or diseases. A cover crop should:

- satisfy the producer's main objective
- be easy to establish with minimal to no inputs
- be managed with equipment and labor resources at hand
- not compete with the vegetable crop and perform well during episodes of drought or flooding and under various other adverse environmental conditions.

Prioritizing objectives for cover crops necessitates an understanding of when and under what conditions benefits can occur. Some benefits occur during cover crop growth, while other benefits occur after cover crop termination. Generally, benefits are only fully realized with a robust

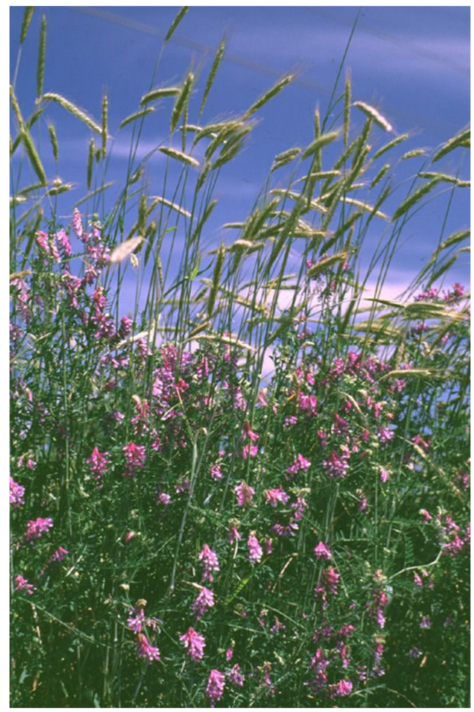

Figure 1. A robust stand of winter annual hairy vetch and Wrens Abruzzi cereal rye.

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stand of cover crop (Figure 1). A wide variety of cover crop species and management options are available to fit a farm operation. This publication is part one of a three-part series. For remaining parts to the series "Annual Cover Crops in Florida Vegetable Systems" including "Part 2: Production" and "Part 3: Species Selection and Sourcing", please visit http://edis.ifas.ufl.edu.

Why Plant Cover Crops?

1a. Cover Crops Improve Soil Quality

Soil Quality. Soil organic matter is the sum of living soil organisms, actively decomposing soil organisms, plant and animal materials, and their stable breakdown products. Soil organic matter is considered to be the most important factor that contributes to soil quality because of the significant influence it has on soil chemical, physical, and biological properties. Soil organic matter can be sustained and increased with regular additions of plant residues including cover crops and other organic amendments such as stable compost. The following discussion describes the impact of cover crops on soil physical, chemical, and biological properties, and the relationship of those properties to soil organic matter.

Soil Physical Properties. The texture and distribution of particles in the soil determine its physical properties. Soil texture is the proportion of the three minerals (sand, silt, and clay) that are present in a particular soil. The distribution of these minerals in space, and the manner in which they clump together or form aggregates is referred to as soil structure. Soil structure is an important physical property that not only describes aggregation but also the distribution of soil pores. Soil pores allow air and water movement in soil. Even under saturated conditions, a soil with good structure will allow water movement. Soil structure affects the bulk density (weight of dry soil per unit volume) and porosity of the soil. Compaction decreases soil porosity and thereby increases soil bulk density. Plants tend to grow best in soil with an intermediate bulk density, which allows good root development and penetration, while still allowing sufficient root-soil contact.

Cover crops decrease soil bulk density (Turner et al., 1994), reduce erosion, increase water retention, and improve soil texture or tilth. Soil erosion is the detachment of soil particles from the surface. Erosion occurs when the soil is exposed to rainfall and wind. In the U.S., approximately 6.9 billion tons of soil is lost to erosion each year (Pimentel, 2000). If soil is exposed, a single rainfall event can cause the loss of soil to a one millimeter depth that equates to a loss of 6 tons of soil per acre (Pimentel, 2000).

Soil loss results in a decline of crop productivity and contributes to the sedimentation of rivers and streams. Soil carries chemical fertilizers, pesticides and other toxins to surface water bodies. The loss of nutrients alone costs U.S. producers 20 billion dollars a year (Troeh et al., 1991). The amount of erosion in agricultural systems depends in part on management factors including the timing and intensity of tillage and rotation selection. The estimated soil lost to erosion has declined in recent years due largely to conservation efforts, planting of cover crops, and adoption of reduced tillage systems.

Cover crops reduce erosion by providing coverage to soil during periods of rainfall and wind. Cover crops intercept raindrops and thus reduce the force that can cause soil displacement. In a study of cropping system effects on soil loss in the Georgia piedmont, West et al. (1991) observed a 70% decrease in soil loss in no-till production systems compared to conventionally tilled systems.

When cover crops are actively growing, roots help to anchor the soil in place (Figure 2). When roots die and decompose, the spaces they occupied become micro and macropores in the soil. These pores improve water

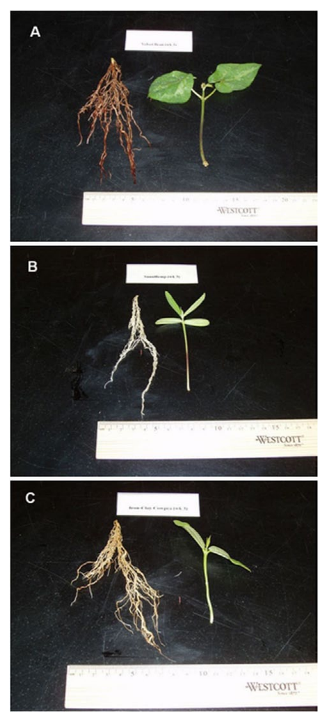

Figure 2. Root systems of 3 week old summer cover crops common in Florida. A) Velvetbean (root length = 5 inches); B) Sunn hemp 'Tropic sun' (root length = 8 inches); C) Cowpea 'Iron clay' (root length = 8 inches)

infiltration rates. The pores also increase the air supply in the soil, which enables soil organisms and plant roots to "breathe."

Once cover crops have been incorporated, the additional organic matter provides food for soil organisms. Roots and above-ground vegetation release sugars, proteins and other solutes when the cover crops are terminated. In addition, roots and other plant parts release these same nutrients, known collectively as exudates, throughout the life cycle of the cover crop.

An important role of cover crops is the "cementing" of soil particles together, thus increasing aggregate stability (McVay et al., 1989). This process of aggregate formation is enhanced both by actions of the soil biota in the cover crop's rhizosphere (the area of soil that is immediately affected by a plant's roots) and by the sugars released from cover crop decomposition (Curl and Truelove, 1986). Soil that is aggregated into small clusters has good aeration and water retention, and thus has good tilth.

Soil Chemical Properties. Cover crops take up and add chemical substances to the soil, thus changing the soil chemical environment. Cover crops use residual nutrients from applied fertilizer and previous crops and eventually return these nutrients to the soil. Deep-rooted covers can access nutrients from soil depths greater than vegetable roots can and pull the nutrients up, thus increasing the total amount of nutrients cycled in the tillage layer of the soil horizon. Cover crops also add beneficial plant metabolic waste products through root exudates and decomposing foliage.

Soils in Florida tend to have a low capacity to hold calcium, magnesium, potassium and other positively charged nutrients or cations, some of which are essential for plant growth. The potential of the soil to retain and release plant nutrients is known as the cation exchange capacity (CEC). The CEC can be increased greatly through the addition of organic matter to the soil.

Soil organic matter has a large number of available bonding sites for nutrients. Fertilizer nutrients bond to soil organic matter and are then released slowly over time. This release is mediated by soil organisms and the physical and chemical conditions of the soil environment. In this way, the risk of losing nutrients to groundwater is reduced.

Cover crops can also reduce pesticides in the soil and groundwater. Researchers in Florida observed that a summer cover crop of sunn hemp reduced leaching of the herbicide atrazine and its decomposition products to groundwater compared to research plots without cover crops (Potter et al., 2007). Other researchers found that cover crops reduced the amount of the herbicide 2,4-D in the soil (Gaston, 2003). Scientists hypothesize that cover crops might reduce herbicides in soil and water due to the enhanced soil conditions for pesticide-degrading organisms after cover crops are terminated and incorporated.

Soil Biological Properties. Soil biological properties depend on all other soil factors. Cover crops create an environment favorable for soil microorganisms by moderating temperature, retaining moisture, and providing a food source for them. Cover crops contribute to soil organic matter which in turn contributes to the diversity and mass of soil organisms (Drinkwater et al., 1995). These organisms are mainly fungi and bacteria, but also include algae, protozoa, and other microfauna. The soil microbial biomass composes 1- 3% of the soil's organic C and 2-6% of the soil's organic N and acts as a source and a sink of plant nutrients (Kumar and Goh, 2000). Management practices that foster a diversity of beneficial soil organisms will contribute to the overall pest management effort. Beneficial soil organisms moderate fluctuations of soil pest densities in a number of ways, including competition for resources, predation and parasitism.

1b. Cover Crops Provide Nitrogen

Nitrogen Transformations. Cover crops can offset fertilizer nitrogen costs by providing nitrogen to the subsequent cash crop. Primarily, this is accomplished through biological nitrogen fixation. A number of species of soil bacteria, known as Rhizobia, form nodules on the roots of leguminous and some nonleguminous cover crop species and provide nitrogen to the plants by converting dinitrogen (N_2) gas found in the atmosphere to ammonia nitrogen (NH_3). In this way, legumes provide for their own nitrogen requirements, as well as contribute nitrogen to the following cash crop via cover crop decomposition.

Rhizobium inoculant should be added to legume seeds prior to planting, especially if the location has not been rotated with legume cover crops in several years. It is important to get the correct strain of inoculum for the cover crop species. See Parts 2 and 3 of this series for more information on inoculants. Rhizobial symbionts are active in the nodules until the legume flowers. At that time, the N uptake of the legume slows, the rhizobial nodules fall off the roots, and the rhizobial bacteria become dormant until the next opportunity for symbiosis presents itself. Once seeds begin to set, the N in the legume is transformed into complex proteins in the seed and is not readily decomposed. For this reason, legume cover crops should be terminated and soil-incorporated at early to mid-bloom for maximum N content.

Once the cover crop has been incorporated into the soil, soil organisms consume and digest organic plant material. Through their natural metabolic processes, nutrients are transformed from organic forms to mineral, plant available forms. These mineral nutrients are then added to the soil solution when the soil organisms release waste products or die. The conversion of organic nitrogen to ammonium (NH_4^+) is called mineralization. This process is accomplished by a variety of soil organisms including bacteria and fungi. The next step in the process is nitrification. During this step, ammonium is transformed to nitrate (NO_3^-) in the presence of oxygen by soil bacteria. One group, called *Nitrosomonas* spp., oxidizes NH4+ to nitrite (NO_2^-) and a second group, *Nitrobacter* spp., quickly oxidizes (NO_2^-) to nitrate (NO_3^-). The rate of these transformations depends on soil moisture and temperature, the ratio of carbon to nitrogen present in cover crop plant tissues, and the chemical and physical properties of the soil (Box 1).

Box 1. Transformation of nitrogen by soil nitrifying bacteria.

Mineralization

$$R{-}NH_2 + H_2O \rightarrow OH^- + R{-}OH + NH_4^+$$

Nitrification

1. $NH_4^+ + O_2 \rightarrow 4H^+ + NO_2^-$
2. $NO_2^- + \frac{1}{2}O_2 \rightarrow NO_3^-$

Figure 6. Chemical equations for N transformations in soil

Soil microbes that decompose plant material require both carbon (C) and nitrogen (N) to fuel their metabolic processes. Soil mineralizing and nitrifying bacteria maintain an internal carbon to nitrogen ratio of 20:1 and therefore must consume a diet of carbon and nitrogen in a comparable ratio. As plant material ages, it can become woody or desiccated, and the carbon content may greatly exceed the nitrogen content. This causes the microbes to utilize nitrogen from the soil environment to maintain the preferred C:N ratio. When nitrogen from the soil solution is removed by microbes, less nitrogen is available for crop uptake. This situation is called nitrogen immobilization, because nitrogen has become immobilized in the microbes, and will not be available to plants until the organism produces waste products or dies.

Most soil biological activity occurs in the top 3 inches of the soil, but soil organisms are present at greater depths in the soil profile as long as there is a food source. The rate of activity increases as soil temperature increases until it reaches a maximum at 90°F. Microbial activity is greatly reduced when soil temperature is less than 40°F, when moisture levels are near saturation, or when the soil is very dry. Although surface soil temperatures may reach above 90°F in the summer months, they rarely drop below 40°F in the winter even in the northern part of Florida.

Nitrogen Contributions. Nitrogen fixing legumes and non-nitrogen fixers are both useful on the farm to improve nutrient use efficiency. As they grow and develop, cover crops can recover excess nutrients from previous crops and make them available to the following crop. Typically, grasses can accumulate about 1 pound N for every 100 pounds of dry plant material, while legumes can accumulate up to 4% N by dry weight.

As a general rule, cover crop residues with C:N ratios less than 25:1 will decompose and result in the generation of NO_3-N if there is sufficient soil to residue contact and the soil environment is favorable for soil bacteria (Figure 3). Soil NO_3-N levels can become significantly high when high N cover crops are incorporated (Hu et al., 1997). A summary of dry matter yield and nitrogen uptake for Florida cover crops is presented in Table 1.

The most accurate way to determine the amount of N in a cover crop is to measure the amount of biomass per unit area, submit a representative sample to a laboratory for N analysis, then calculate the pounds of N per acre based on those results. However, producers do not often have the time to wait for sample results from the laboratory, so the following procedure was developed to estimate N in the field (Sarrantonio, 2001). Three steps are needed: 1) measure dried above ground plant weight (yield), 2) estimate the amount of N present, and 3) estimate the amount of N that may be available to the following crop based on the anticipated rate of decomposition. This method is summarized in Box 2 below.

The percentage of nitrogen typically found in cover crops based on their physiological growth stage is determined from previous research findings. As cover crops mature, nitrogen is translocated to seeds and becomes less available. Managing cover crops for optimum N return is discussed in part 2 of this series, "Production." In most areas in Florida, the amount of nitrogen available to the next crop is assumed to be 50% of the total nitrogen measured in the cover crop if the cover crop is incorporated, and 40% if it

Box 2. How to Estimate Nitrogen Contribution from Cover Crops

Estimate Yield

$$\text{Yield (lb/acre)} = \frac{\text{Total weight of dry sample (lb)}}{\text{Area sampled (sq ft)}} \times \frac{43{,}560 \text{ sq ft}}{1 \text{ acre}}$$

Estimate Nitrogen

Total N (lb/acre) = Yield (from above) X amount of N as a *decimal* (%N ÷ 100)

Nitrogen Content of Cover Crops – Use these values to estimate N above.

Cover Crop Group	Percent (%) N at Cover Crop Growth Stage			
	Before Flowering	Early Flowering	Early Seed Set	Mature Seed
Non – Woody Legumes	3.5 – 4.0	3.0 – 3.5	2.0	1.5
Woody Legumes	2.5 – 3.0	2.0 – 2.5	1.0	0.75
Cereal Grains and Others	2.0 – 3.0	1.5 2.5	< 1.0	< 1.0

Adapted from Sarrantonio,

Figure 7. How to Estimate Nitrogen Contribution from Cover Crops

remains on the soil surface. This percentage is called an "availability coefficient" and is an estimate at best. The true nitrogen availability depends on temperature, precipitation, the amount of carbon in the plant material, the method of incorporation, the number and types of tillage events, the soil type and the rate of microbial decomposition. Submitting plant and soil samples to a licensed laboratory for nitrogen content at cover termination and 1-2 weeks later is the best way to determine the most appropriate availability coefficient for an operation.

On sandy soils in warm climates, even short lag times between the release of green manure N and subsequent crop demand resulted in significant leaching losses (Weinert et

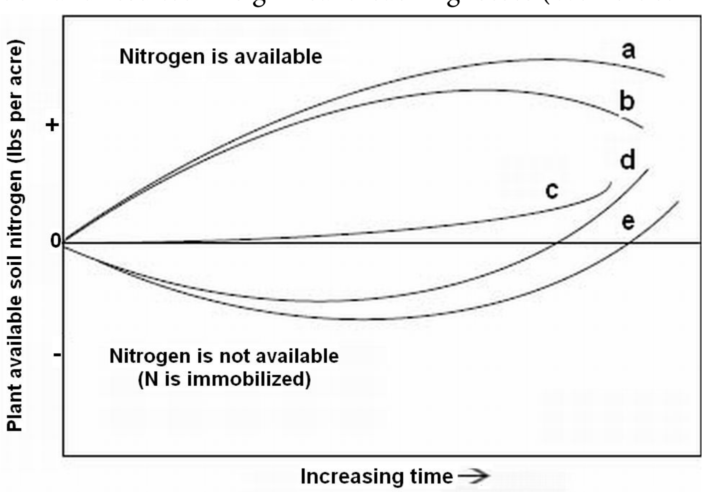

Figure 3. Generalized image showing the concentrations of plant available nitrogen in the soil over time, based on microbial transformations. The rate of N mineralization by C:N ratio of cover crops. The C:N ratios of the cover crops are as follows: a) 10:1, b) 15:1, c) 22:1, d) 30:1, and e) 40:1. The center line represents a C:N ratio of 25:1, the threshold for N mineralization.

al., 2002). In south Florida, nitrogen-fixing summer cover crops terminated and incorporated prior to fall tomato had a nitrogen content of 250-300 lb/A N from sunn hemp, 150-250 lb/A N from velvetbean and 65-210 lb/A N from cowpea (Wang et al., 2005). Excessive nitrate in soil solution poses a risk to water quality. Small transplants and seeds take time to develop root systems to utilize the soil N. Rainfall and irrigation may push soil N beyond the depth that small root systems can use. Preventative actions such as reducing the seeding rate, limiting overhead irrigation immediately following cover incorporation, planting a mixture of legume and nonlegume species, or maintaining cover residue on the surface for reduced tillage operations can help retain N in the top 12 in of soil.

1c. Cover Crops Suppress Pests

Weeds. Cover crops suppress weeds most commonly by physical, mechanical or chemical interference. The degree of weed suppression achieved depends on the native density and diversity of weed species, the cover crop species and management and climatic conditions. Frequently, cover crops can suppress weeds simply by using light, water and nutrient resources before the weeds do (Figure 4).

Figure 4. Weedy border (A) and weed-free area (B) of a stand of sunn hemp at mid-bloom in Gainesville, FL.

Cover crop residues that remain on the soil surface after termination can suppress weed germination and emergence through physical and mechanical interference (Figure 5). In long rotations where immediate incorporation of cover crops is not necessary, or in reduced tillage production of a subsequent crop, the lack of soil disturbance combined with the presence of cover crop surface residue may reduce weed emergence and establishment (Treadwell et al., 2007). Cover crop biomass production should be at least 4-6 tons per acre dry weight to observe a reduction in weed emergence. At this rate, plant material on the surface inhibits light penetration to the soil surface minimizing germination cues. Some weeds that do germinate are mechanically inhibited by a mat of straw-like mulch.

Figure 5. No-till spring watermelon in cereal rye residue in Live Oak, FL.

The term allelopathy describes a direct or indirect effect one plant has on another due to the release of plant chemicals (allelochemicals or phytotoxins) into a shared environment. In the context of crop production, this is commonly assumed to be a negative effect, although in many situations the effect can be neutral (no effect) or positive (stimulates growth). Allelopathic chemicals include many classes of compounds such as terpenoids, phenolic compounds and alkaloids. Plant chemicals are liberated from leaves by rain, exuded from roots, or volatilized from leaves. The degree of effect depends on the compound, concentration of the compound in the soil, decomposition dynamics and the fate of the plant compound in the soil. Microorganisms can play an intermediary role if cover crop decomposition of plant tissue is precursory to chemical release.

Several species of cover crops grown in Florida have demonstrated allelopathic properties. Extracts of summer legumes of cowpea, sunn hemp and velvetbean all suppressed germination of goosegrass [*Eleusine indica* (L) Gaertn.] and livid amaranth (*Amaranthus lividus* L.) compared to a control of no extract in a laboratory trial (Adler and Chase, 2007). Velvetbean produces several allelochemicals (Szabo and Tebbet, 2002) including L-dopa, which occurs in its roots and leaves at 0.5%-1.5% of fresh weight, and which accounts for much of the plant's herbicidal activity (Fujii, 1999). Extracts of velvetbean leaf blades were effective in preventing germination of lettuce and tomato seeds, while extracts of the main velvetbean roots were especially toxic to the roots of lettuce and tomato (Zasada et al., 2006). Velvetbean has been shown to suppress some weed species in tropical production systems. The smothering effect of velvetbean was equivalent to that of herbicides for cogongrass (*Imperata cylidrica* (L.) Beauv.) control in corn (Udensi et al., 1999). Velvetbean provided good control of spiny amaranth (*Amaranthus spinosus* L.), smooth pigweed (*A. hypridus* L.), field sandbur (*Cenchrus insertus* M.A. Curtis) and bitterweed (*Parthenium hysterophorus* L.) (Caamal-Maldonado, 2002).

Small seeded annual vegetables such as lettuce (*Lactuca sativa* L.) can have reduced yields when direct seeded behind a cover crop with allelopathic potential such as rye (Hoyt, 1999). The negative effects can be minimized if the residue is incorporated, at least around the seed as in strip tillage, prior to planting. The use of large seeded crops or transplants can also minimize negative effects of toxins, perhaps due to increased planting depth or more developed root systems. Cover crop species known or suspected to have allelopathic properties are identified in Table 2.

The presence of inhibitory plant chemicals is not limited to cover crops. Many weeds have known or alleged toxic effects on vegetable and agronomic crops. Negative effects of common purslane (*Portulaca oleracea* L.) on pea (*Pisum sativum*) and wheat (*Triticum aestivum*) have been reported (Putnam, 1994). Some vegetable crops, including watermelon (*Citrullus lanatus* [Thumb.] Matsum. & Nakai) are autotoxic, meaning a decline in yield and or quality has been observed when these crops are repeatedly grown at the same location (Hao et al., 2006). Forage alfalfa (*Medigo sativa* L.) produces compounds that suppress growth of subsequent alfalfa (Chon et al., 2006) as well as several common weed species including pigweed (*Amaranthus retroflexus* L.), lambsquarters (*Chenopodium album* L.) and crabgrass [*Digitaria sanguinalis* (L.) Scop.] (Chung and Miller, 1995).

The effects of allelopathy can be difficult to demonstrate in research due to the many interacting factors. Further, the exact mechanisms of allelopathy are not well understood, so site-specific applications of allelopathy in agriculture are limited. However, reports of reduced weed emergence and establishment following cover crops reported to have allelopathic properties are widespread in scientific literature, therefore it may be beneficial to select a cover crop species that can offer chemical suppression as secondary objective. A thorough review of allelopathy and the applications of current findings to weed management in sustainable agriculture are found in Singh et al. (2003).

Insects and Nematodes. Understanding the biology of insect and nematode pests that are typically present on the farm is helpful to design a successful vegetable production system. Knowing what pests are present in the soil as larvae, what pests fly or walk, when pests arrive and what their reproductive habits are will contribute to a well planned strategy for cover crop inclusion that can reduce pest density and subsequent damage to crops. Cover crops can attract beneficial insect predators, parasitoids and parasites that reduce insect density. Cover crops can provide a continuous habitat to maintain beneficial populations at a time when cash crops may not be planted yet. Beneficial species are attracted to pollen and nectar of flowering cover crops, find refuge in the plant material itself, and oviposit (lay eggs) in the soil below or on plant parts.

Careful timing of tillage operations, selection of cover crop species, and strategic crop rotation will enhance efforts to manage insects and nematodes. Pests that complete only one generation in a cropping season are less likely to recover from cultural practices intended to reduce their population than pests with multiple generations a season. Spider mites, white flies and aphids are pests with multiple generations in a cropping season and therefore have additional opportunities to re-establish their population if one generation suffers in an unsuitable habitat (Kennedy and Storer, 2000).

When cover crops are in production, root exudates of allelopathic chemicals can suppress populations of soil-dwelling pests including nematodes. Cover crops including cowpea and sorghum and its relatives are most commonly used to suppress nematodes in Florida. Pasture grasses kept weed-free for two consecutive years strongly suppress root knot nematodes (Adeniji and Chheda, 1971; Chellemi, 2002; Dickson and Hewlett, 1989; Rodriguez-Kabana et al., 1991)

A word of caution: only some varieties of these cover crops are associated with nematode suppression, while other varieties serve as suitable habitat. For example, all cowpea cultivars appear to be susceptible to the reniform nematode, *Rotylenchulus reniformis* Linford & Oliveira (Robinson et al., 1997), whereas there are great differences among cowpea cultivars in their susceptibility or resistance to *Meloidogyne incognita* (Kofoid and White) Chitwood. *Meloidogyne*-resistant cowpea cultivars include ‘Iron Clay’ (McSorley 1999), ‘Tennessee Brown’, ‘Mississippi Silver’ and ‘California Blackeye #5’, while ‘Purple Knuckle’ is somewhat susceptible (Gallagher and McSorley 1993). Moreover, no single cover crop species suppresses all species of plant parasitic nematodes. For example, certain cultivars of sorghum and sorghum sudangrass that effectively suppress populations of root knot nematode and reniform nematode are ineffective against the sting nematode, *Belonolaimus longicaudatus* Rau and stubby-root nematode, *Paratrichodorus minor* (Colbran) (McSorley, 1996). EDIS publications summarizing appropriate varieties for nematode suppression are listed in the “Additional Resources” section below.

Surface mulch may also act as a physical barrier to prevent insects from locating their hosts for feeding or oviposition. Overwintering Colorado potato beetle (*Leptinotarsa decemlineata* [Say]) adults, egg masses, and larvae were less frequent when plant beds were mulched with straw (Zehnder and Hough-Goldstein, 1990). Straw mulch also effectively reduced numbers of eggs and larvae of the imported cabbageworm (*Pieris rapae* L.) in young cabbage, presumably by inhibiting immigration (Cranshaw, 1984).

The presence of surface mulch and degree of tillage may also influence number and species diversity of entomopathogenic nematodes (Steinernematidae and Heterorhabditidae). These nematodes are being used commercially as biological control agents against soil insect pests. As with other biological control agents, the efficacy of entomopathogenic nematodes can be affected by various abiotic and biotic factors, including soil texture, temperature, moisture, and nematode natural enemies (Kaya and Gaugler, 1993). An increase in the complexity of the soil environment associated with higher levels of organic matter and the presence of more weeds in no-tillage influences nematode species differently. Some species, such as *Steinernema carpocapsae*, live at the soil surface and are very sensitive to tillage, therefore are found in greater numbers when tillage is minimized (Millar and Barbercheck 2002). Other more mobile species that can move deeper into the soil profile are less influenced by degree of soil disturbance. In addition, the cooler soil temperatures created by the mulch create a favorable environment for nematodes that live near the soil surface.

Diseases.

Interrupting a vegetable crop rotation with a non-host cover crop can reduce the incidence of disease. Disease may not be eliminated entirely because soilborne pathogens can remain established in a field for many years. Research has not clearly demonstrated a direct cause and effect relationship between cover crops and disease reduction due to the complexity of interacting factors. Cover crops can indirectly reduce the incidence of soilborne diseases by increasing the microbial diversity in the soil. Diverse microbial populations are beneficial to disease suppression due to an increase in the number of predatory interactions between beneficial and pathogenic microbes in the soil. Hairy vetch as a soil amendment induced suppression of fusarium wilt (*Fusarium oxysporum* f. sp *niveum*) in watermelon (Zhou and Everts, 2007). In conservation tillage systems, a cover crop mulch of hairy vetch and rye in no-till pumpkin was associated with a decrease in powdery mildew, (*Podosphaera xanthii*), plectosporium bight (*Plectosporium tabacinum*) and black rot (*Didymella bryoniae*) compared to conventionally tilled pumpkin (Everts, 2002). Cover crops likely influenced disease-causing organisms indirectly. Most of the research in this area is focused on winter annual cover crops; research on the effect of summer annual cover crops on disease incidence in vegetable systems is lacking.

Researchers have investigated weeds for their capacity to serve as alternate hosts for diseases, but insufficient attention has been given to cover crops in this regard. In some cases, cover crops are in the same family and genus as susceptible weeds, indicating that cover crops may also have the capacity to be a pathogen host. Planting several different species of cover crops in the same field will reduce the risk of hosting a particular pathogen.

Id. Cover crops as a partial alternative to soil fumigation

Biofumigation is the application of plant residues to the soil to control insects, nematodes, weeds and/or fungal pathogens. This natural fumigation is due to the release of chemical exudates from plants on other organisms. Certain members of the Brassiceae family (cabbages, mustards, cole crops) are particularly effective in reducing soilborne pests. These plants release isothiocyanate, a compound that is chemically similar to the active ingredient in metam sodium, a popular synthetic soil fumigant. Brassica as green manures are documented to reduce incidence of *Streptomyces* spp. presumably by altering the microbial community structure and not by induction of plant systemic resistance (Cohen et al., 2005; Kasuya et al., 2006). In later research, *Brassica napus* seed meal did not control *Rhizoctonia solani* or *Pythium* spp. in crabapple (*Malus sylvestris* Mill.) roots, but rather initial disease control was associated with the generation of nitric oxide through the process of nitrification (Cohen et al., 2005). Synergistic effects of using more than one species of cover crops can improve effectiveness of suppression. When both *Brassica juncea* L.H. Bailey and *B. napus* L. seed meal amendment were added to soil, suppression of the pathogen complex (*R. solani*, *Pythium* spp. and the nematode *Pratylenchus* spp.) improved over use of a single brassica species (Mazzola et al., 2007).

The fumigant mixture, methyl bromide plus chloropicrin, has been used to control weeds, especially nutsedges, soil-borne pathogens and plant parasitic nematodes in Florida for four decades. However, agricultural emissions of methyl bromide have been shown to be a significant source of ozone depletion in the stratosphere. Stratospheric ozone serves to shield the earth from intense ultraviolet radiation. Therefore the phase-out of the use of methyl bromide has been undertaken under an international treaty of 1989 known as the Montreal Protocol. Under the authority of federal Clean Air Act, the U.S. Environmental Protection Agency enforced the phase-out of methyl bromide use in the U.S. by January 1, 2005.

Many growers in Florida are concerned about *Phytophthora capsici*, the soilborne fungus that causes rot and blight in tomatoes, peppers, summer squash and other crops; see: http://edis.ifas.ufl.edu/VH045. Consequently, many tomato and pepper growers in Florida are replacing the mixture of methyl bromide and chloropicrin with a combination of a nematicide, 1, 3-dichloropropene, and herbicides, as well as with metam sodium or metam potassium (Gilreath et al. 2005). Spreen et al. (1995) estimated that loss of methyl bromide would result in a $1 billion impact on the U.S. winter vegetable industry, mostly borne by Florida. Clearly, it is imperative that practical alternative strategies to control *P. capsici* be developed, including the appropriate use of cover crops, biological control agents and resistant crop cultivars.

Although several cover crops suppress most weeds sufficiently to minimize the need for weed control in the following vegetable crop, they have not been accepted as an alternative to methyl bromide for vegetable production in Florida because their suppression of populations of yellow nutsedge, *Cyperus esculentus* L., and purple nutsedge, *Cyperus ligularis* L, although strong, does not prevent these weeds from resurging before the following cash crop has been produced (U. S. Dept. of State, 2006). Nutsedge tubers have extensive energy reserves, which enable them to survive long periods of adversity. In order to avoid losses of tomato yields caused by nutsedges, the latter must be largely suppressed for 10 weeks after tomatoes have been transplanted so that their population densities during this critical period are kept below 25 nutsedge plants per m2 in order to prevent yield losses greater than 10 percent (Stall and Morales-Payan 2003).

Nevertheless in fields with modest nutsedge populations, cover crops can be used in lieu of soil fumigation for more profitable production of tomatoes or other high value crops than with soil fumigation. This was established by Abdul-Baki et al. (2005), who conducted a three-year experiment near Homestead, Florida to evaluate the feasibility of using a biologically based system for winter production of fresh-market tomatoes in south Florida fields with light to moderate infestations of the root knot nematode, *Meloidogyne incognita*, and yellow nutsedge *C. esculentus.* The system consisted of a cropping rotation in which nematode-resistant cover crops [cowpea (*Vigna unguiculata* cv. 'Iron Clay'), velvetbean (*Mucuna deeringiana*), and sunn hemp (*Crotalaria juncea* cv. 'Tropic Sun')] were each followed by cv. 'Sanibel', a nematode-resistant tomato cultivar, or by cv. 'Leila', a nematode-susceptible cultivar, or by cv. 'Agri 6153', a fusarium- and verticillium-resistant, nematode-susceptible indeterminate cultivar developed for vine-ripe production. Weed-free fallow and a methyl bromide + chloropicrin treatment preceded by a summer sorghum sudangrass cover crop, were used as controls. Tomato marketable yields in all treatments and in all years were above average annual yields in Miami-Dade County. Economic analysis showed that all treatments resulted in positive net returns in all years. Among the cover crops, sunn hemp produced the highest yields and net returns of all treatments over the two years it was used.

The main purpose of soil fumigation in vegetable production in Florida has been to suppress nutsedges and other weeds, several plant parasitic nematode species including the root-knot nematode, (*Meloidogyne incognita* Kofoid and White), reniform nematode (*Rotylenchulus reniformis* Linford & Oliveira), the sting nematode (*Belonolaimus longicaudatus* Rau), the awl nematode (*Dolichodorus* spp.), and the stubby root nematode (*Paratrichodorus minor* (Colbran) Siddiqi), fusarium wilt [*Fusarium oxysporum* f. sp. *lycopersici* (tomato), *F. oxysporum* f. sp. *melongenae* (eggplant) and *F. oxysporum* var. *vasinfectum* (pepper)], and fusarium crown rot and root rot [*Fusarium oxysporum* f. sp. *radicis-lycopersici*], sclerotinia stem rot or white mold (*Sclerotinia sclerotiorum*), rhizoctonia root rot (*Rhizoctonia solani*), corky root rot or old land disease of tomato (*Pyrenochaeta lycopersici*), southern bacterial blight (*Ralstonia solanacearum*), phytophthora blight (*Phytophthora capsici*) and damping off (*Pythium aphanidermatum*). Since only a fraction of these organisms are problematic in any given field, there is great potential to protect the crop through the joint use of combinations of cover crops, biocontrol agents and resistant cultivars (Roberts et al., 2005).

1e. Cover Crops Attract Pollinators

Many beneficial insects are attracted to flowering cover crops. In particular, cover crops with flowers that provide nectar and pollen during periods of early crop growth on the farm can help maintain pollinators in the area. Species that flower during early spring and early fall while vegetable plants are still young are excellent candidates. Planting several species in a mixture with a variety of floral structures will attract the greatest diversity of pollinators and other beneficial insects. In California, native bee visitation and pollination were strongly associated with the amount of natural area in the landscape that surrounded the farm, but not the farm inputs, field size or farm type (Kremen et al., 2004).

In the north and central part of Florida, cover crops that flower early in the spring include early maturing winter annual clovers, radish, and cereal grains. Try early maturing cv. 'FL 401' cereal rye mixed with hairy vetch or crimson clover. Buckwheat can be grown in both spring and fall in central to north Florida, and during the winter in south Florida. Buckwheat germinates in 3-5 days and blooms in as little as 6 weeks, so it is a good fit for tight rotations.

In the south, summer cover crops can be retained after the fall plantings in strips between beds or in the border areas surrounding the field. Sunn hemp attracts native bees (Glenn Hall, personal communication) and the flowering period lasts for several months.

Summary

Integrating cover crops can have significant ecological impacts on the cropping system. It can improve nutrient availability and reduce pest occurrence. Producers have many options in species selection and management, and the selection and management of species will be dictated by producer needs and production constraints.

Literature Cited

Abdul-Baki, A. A.,W. Klassen, H. H. Bryan, M. Codallo, B. Hima, Q. R. Wang, Y. Li, Y.-C. Lu and Z. Handoo. 2005. A Biologically-Based System for Winter Production of Fresh-Market Tomatoes in South Florida. Proc. Fla. State Hort. Soc. 118: 153-159.

Adeniji, M. O. and H. R. Chheda, 1971. Influence of six varieties of *Cynodon* on four *Meloidogyne* spp. J. Nematol. 3:251-254.

Adler, M. J, and C. A Chase. 2007. A comparative analysis of the allelopathic potential of leguminous summer cover crops: cowpea, sunn hemp and velvetbean. HortScience 42:289-293.

Baldwin, K. and N. Creamer. 2006. Cover crops for organic farms. North Carolina Cooperative Extension Service. Available at: http://www.cefs.ncsu.edu/resources/organic-productionguide/covercropsfinaljan2009.pdf

Barnes, J. P. and A. R. Putnam. 1986. Evidence for allelopathy by residues and aqueous extracts of rye (Secale cereale). Weed Sci. 34:384-390.

Boydson, R.A. and A. Hang. 1995. Rapeseed (*Brassica napus*) green manure crop suppresses weeds in potato (*Solanum tuberosum*). Weed Tech. 9(4):669-675.

Caamal-Maldonado, J. A, J. J. Jiménez-Osornio, A. Torres-Barragán and A. L. Anaya. 2002. The use of allelopathic legume cover and mulch species for weed control in cropping systems. Agron. J. 93:27-36.

Chellemi, D. O. 2002. Nonchemical management of soil-borne pests in fresh market vegetable production systems. Phytopathology 92:1367-1372.

Cherr, C. M, J. M. S. Scholberg and R. McSorley. 2006. Green manure as nitrogen source for sweet corn in a warm-temperate environment. Agron. J. 98:1173-1180

Chon, S.U., J. A. Jennings, and C. J. Jennings. 2006. Alfalfa (*Medigo sativa* L.) autotoxicity: Current status. Allelopathy J. 18(1): 57-80.

Chung, I. M. and D. A. Miller. 1995. Natural herbicide potential of alfalfa residue on selected weed species. Agron. J. 87: 920-925.

Cohen, M.F., H. Yamasaki, and M. Mazzola. 2005. *Brassica napus* seed meal soil amendment modifies microbial community structure, nitric oxide production and incidence of Rhizoctonia root rot. Soil Biol. and Biochem. 37(7): 1215-1227.

Cranshaw, W.S. 1984. Effect of a hay mulch and of a companionate planting on cabbage pest populations. Great Lakes Entomol. 17:9-12

Curl, E.A. and B. Truelove. 1986. The Rhizosphere. Springer-Verlag, New York. 288 pp.

Dickson, D. W. and T. E. Hewlett, 1989. Effects of bahiagrass and nematicides on *Meloidogyne arenaria* on peanut. J. Nematol. 21 (suppl.): 671-676.

Drinkwater, L. E., D. K. Letourneau, F. Workneh, A. C. H. van Bruggen and C. Shennan. 1995. Fundamental differences between conventional and organic agroecosystems in California. Ecol. Applications 5:1098-1112.

Everts, K. L. 2002. Reduced fungicide applications and host resistance for managing three diseases in pumpkin grown on a no-till cover crop. Plant Dis. 86 (10): 1134-1141.

Forney D. R. and C. L. Foy. 1985. Phytotoxicity of products from rhizospheres of a sorghum-sudangrass hybrid (*Sorghum bicolor* X *Sorghum sudanense*). Weed Sci. 33:597-604.

Fuji, Y., T. Shibuya and T. Yasuda. 1992. Allelopathy of velvetbean: Its discrimination and identification of L-DOPA as a candidate of allelopathic substances. Japan Agric. Res. Quarterly. 25:238-247.

Fujii, Y. 1999. Allelopathy of hairy vetch and mucuna: their application for sustainable agriculture. Pp. 289-300. In C. H. Chou, G. R. Waller and C. Reinhardt (eds.). Biodiversity and Allelopathy: From Organisms to Ecosystems in the Pacific. Academia Sinica, Taipei.

Gallagher, R. N. and R. M. McSorley. 1993. Population densities of *Meloidogyne incognita* and other nematodes following seven cultivars of cowpea. Nematropica 23 (1): 21-26.

Gaston, L. A., D. J. Boquet and M. A. Bosch. 2003. Fluometuron sorption and degradation in cores of silt loam soil from different tillage and cover crop systems. Soil Sci. Soc. Am. J. 67:747-755.

Gilreath, J. P., B. M. Santos, T. N. Motis, J. W. Noling and J. M. Mirusso. 2005. Methyl bromide alternatives for nematode control and Cyperus control in bell pepper (*Capsicum annum*). Crop Protection 24 (10): 903-908.

Hao, Z. P., Q. Wang, P. Christie and X. L. Li. 2006. Autotoxicity potential of soils cropped continuously with watermelon. Allelopathy J. 18(1):111-119.

Haramoto, E. R. and E. R. Gallandt. 2005. Brassica cover cropping: II. Effects on growth and interference of green bean (*Phaseolus vulgaris*) and redroot pigweed (*Amaranthus retroflexus*). Weed Sci. 53(5):702-708.

Hepperly, P., E. H. Aguilar, R. Perez, M. Diaz and C. Reyes. 1992. Pigeon pea and velvet bean allelopathy. In: S. J. H. Razvi and V. Rizvi (Eds.). Allelopathy: Basic and Applied Aspects. pp. 357-370. Chapman and Hall. London.

Hoyt, G.D. 1999. Tillage and cover crop residues affects on vegetable yields. HortTechnology. 9:351-358

Hu, S., N. J. Grünwald, A. H. C. van Bruggen, G. Gamble, L. E. Drinkwater, C. Shennan and M. W. Demment. 1997. Short-term effects of cover crop incorporation on soil C pools and N availability. *Soil Sci. Soc. Amer. J.*61: 901-911.

Kasuya, M., A. R. Olivier, Y. Ota, M. Tojo, H. Honjo, and R. Fukui. 2006. Induction of soil suppressiveness against *Rhizoctonia solani* by incorporation of dried plant residues into soil. Phytopathology 96(12):1372-1379.

Kaya, H. K. and R. Gaugler. 1993. Entomopathogenic nematodes. Annu. Rev. Entomol. 38:181-206.

Kennedy, G. G. and N. P. Storer. 2000. Life systems of polyphagous arthropod pests in temporarily unstable cropping systems. Annu. Rev. Entomol. 45:467-493

Kremen, C., N. M. Williams, R. L. Bugg, J. P. Fay and R. W. Thorp. 2004. The area requirements of an ecosystem service: Crop pollination by native bee communities in California. Ecol. Letters 7(11):1109-1119.

Kumar, K. and K. M. Goh. 2000. Crop residues and management practices: Effects on soil quality, soil nitrogen dynamics, crop yield and nitrogen recovery. Adv. in Agron. 68:197-319.

Masiunas, J. B., L. A. Weston, and S. C. Weller. 1995. The impact of rye cover crops on weed populations in a tomato cropping system. Weed Sci. 43:318-323.

Mazzola, M., J. Brown, A. D. Izzo, and M. F. Cohen. 2007. Mechanism of action and efficacy of seed meal-induced pathogen suppression differ in a Brassicaceae species and time-dependant manner. Phytopathology. 97(4):454-460.

McSorley, R. 1996. Impact of crop management practices on soil nematode populations. Soil and Crop Sci. Soc. of Florida Proceedings 55:63-66.

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

McVay, K. A., D. E. Radcliffe and W. L. Hargrove. 1989. Winter legume effects on soil properties and nitrogen fertilizer requirements. Soil Sci. Soc. Amer. J. 53:1856-1862.

Millar, L. C. and M. E. Barbercheck. 2002. Effects of tillage practices on entomopathogenic nematodes in a corn agroecosystems. Biol. Control 25(1):1-11

Pimentel, D. 2000. Soil erosion and the threat to food security and the environment. Ecosystem Health. 6:221-226.

Potter, T. L., D. D. Bosch, H. Joo, B. Schaffer, and R. Munoz-Carpena. 2007. Summer cover crops reduce atrazine leaching to shallow groundwater in southern Florida. J. Environ. Quality 36:1301-1309.

Putnam, A. R. 1994. Phytotoxicity of plant residues. In: P.W. Unger (Ed.) Managing agricultural residues. CRC Press, Boca Raton, FL. pp. 285-341.

Roberts, D. P., A. A. Abdul-Baki, I. A. Zasada, S. L. F. Meyer, and W. Klassen. 2005. Biologically Based Technologies for the Suppression of Soilborne Pathogens of Vegetables. Recent Res. Devel. Applied Microbiol. Biotechnol. 2: 51-67.

Robinson, A. F., R. N. Inserra, E. P. Caswell-Chen, N. Vovlas, and A. Troccoli. 1997. *Rotylenchulus reniformis*: Identification, distribution, host- ranges, and crop plant resistance. Nematropica 27:127-180.

Rodriguez-Kabana, R., P. S. King, D. G. Robertson, C. F. Weaver and L. Wells. 1991. Rotations of bahiagrass and castorbean with peanut for the management of *Meloidogyne arenaria.* J. Nematol. 23(suppl.): 658-661.

Sarrantonio, M. 2001. Building soil fertility and tilth with cover crops. In A. Clark (Ed.). Managing Cover Crops Profitably, 2nd Edition. pp. 22-23. Sustainable Agriculture Network, Handbook series 3. Beltsville, MD.

Singh, H. P., D. R. Batish, and R. K. Kohli. 2003. Allelopathic interactions and allelochemicals: New possibilities for sustainable weed management. Critical Rev. in Plant Sci. 22(3-4):239-311.

Spreen, T. H., J. J. VanSickle, A. E. Mosely, M. S. Deepak and L. Mathers. 1995. "Use of methyl bromide and the economic impact of its proposed ban on the Florida fresh fruit and vegetable industry. Univ. of Florida Tech. Bull. 898.

Stall, W. M., Morales-Payan, J. P., 2003. The critical period of nutsedge interference in tomato. IFAS-University of Florida, Gainesville, FL, USA, 24 July 2003. Available at http://www.imok.ufl.edu/LIV/groups/IPM/weed_con.

Szabo, N. J. and J. R. Tebbett. 2002. The chemistry and toxicity of *Mucuna* species. In: *Mucuna* as a Food and Feed: Current Uses and the Way Forward. pp. 120-141. In: M. Flores, M. Eilittä, R. Myhrman, L. Carew, and R. Carsky (Eds.). Workshop held April 26-29, 2000 in Tegucigalpa, Honduras. CIDICCO, Honduras.

Teasdale, J. R. and C. S. T. Daughtry. 1993. Weed suppression by live and desiccated hairy vetch. Weed Sci. 41:207-212.

Treadwell, D. D., N. G. Creamer, J. R. Schultheis, and G. D. Hoyt. 2007. Cover Crop Management Influences Weed Suppression in Organically Managed Sweetpotato Systems. Weed Tech. 21(4):1039-1048.

Troeh, R. R., J. A. Hobbs, and R. L. Donahue. 1991. Soil and water conservation. Englewood Cliffs, NJ. Prentice Hall.

Turner, M. S., G. A. Clark, C. D. Stanley, and A.G. Smajstrla. 1994. Physical characteristics of sandy soil amended with municipal solid waste compost. Proc. Soil Crop Sci. Soc. Fla. 53:24-26.

Udensi, U. E., I. Akobundu, A. O. Ayeni and D. Chikoye. 1999. Management of cogongrass (*Imperata cylindrical*) with velvetbean (*Mucuna pruriens* var. *utilis*) and herbicides. Weed Tech. 13:201-208.

U.S. Department of State. 2006. United States Nomination for Critical Use Exemptions from the 2008 Phaseout of Methyl Bromide. Available at: http://www.epa.gov/ozone/mbr/2008_nomination.html.

Wang, Q. W. Klassen, H. H. Bryan and Y. Li. 2003. Influence of summer crops on growth and yield of a subsequent tomato crop in south Florida. Proc. Fla. State Hort. Soc. 116:140-143.

Wang, Q., W. Klassen, Y. Li., M. Codallo and A. A. Abdul-Baki. 2005. Influence of cover crops and irrigation rates on tomato yields and quality in a subtropical region. HortScience 40(7):2125-2131.

Weinert, T. L., W. L. Pan, M. R. Moneymaker, G. S. Santo, and R. G. Stevens. 2002. Nitrogen recycling by nonleguminous winter cover crops to reduce leaching in potato rotations. Agron. J. 94:365-372.

West, L. T., W. P. Miller, G. W. Langdale, R. R. Bruce, J. M. Laflen, and A. W. Thomas. 1991. Cropping system effects on interrill soil loss in the Georgia piedmont. Soil Sci. Soc. Amer. J. 55(2):460-466.

White, R. H., A. D. Worsham and U. Blum. 1989. Allelopathic potential of legume debris. Weed Sci. 37:674-679.

Zasada, I. A., W. Klassen, S. L. F. Meyer, M. Codallo and A. A. Abdul-Baki. 2006 Velvetbean (*Mucuna pruriens*) extracts: impact on *Meloidogyne incognita*, *Lycopersicon esculentum* and *Latuca sativa* survival. Pest Mgt. Sci., 62: 1122-1127.

Zehnder, G. W. and J. Hough-Goldstein. 1990. Colorado potato beetle (Coleoptera: Chrysomelidae) population development and effects on yield of potatoes with and without straw mulch. J. Econ. Entomol. 83:1982-1987

Zhou, X. G. and K. L. Everts. 2007. Effects of host resistance and inoculum density on the suppression of fusarium wilt of watermelon induced by hairy vetch. Plant Dis. 91(1):92-96.

Additional Resources

Internet

ATTRA (National Sustainable Agriculture Information Service)

- Home: http://www.attra.org
- Master Publication List: http://attra.ncat.org/publication.html
- Seed Suppliers Search: http://attra.ncat.org/attra-pub/organic_seed/

Purdue University Center for New Crops and Plant Products

- Specialty and new crop profiles, including cover crops. Home: http://www.hort.purdue.edu/newcrop/

SARE (Sustainable Agriculture Research and Education)

- Home: http://www.sare.org
- Publications: http://www.sare.org/publications/index.htm

University of California SAREP

- University of Californias Cover Crop Database. Home: http://www.sarep.ucdavis.edu/database/covercrops [April 2012].

University of Hawaii CTAHR (College of Tropical Agriculture and Human Resources)

- Cover crop and green manures database for the tropics and subtropics. Home: http://www2.ctahr.hawaii.edu/sustainag/Database.asp

University of Florida Extension Soil Testing Laboratory

- Home: http://soilslab.ifas.ufl.edu/

UF-IFAS EDIS Publications Relevant to Cover Crops in Vegetable Systems

Vegetable Production
- Index for specific vegetable guidelines: http://edis.ifas.ufl.edu/TOPIC_Vegetables_A_thru_Z
- Growing Heirloom Tomato Varieties in Southwest Florida: http://edis.ifas.ufl.edu/HS174
- Organic Vegetable Production: http://edis.ifas.ufl.edu/CV118

Cover Crops
- Cover Crop Benefits for South Florida: http://edis.ifas.ufl.edu/SS461
- Cover Crops: http://edis.ifas.ufl.edu/AA217
- Winter Forage Legume Guide: http://edis.ifas.ufl.edu/DS127
- Minor Use Summer Annual Forage Legumes http://edis.ifas.ufl.edu/ag156
- Fall Forage Update: http://edis.ifas.ufl.edu/AA266
- Alfalfa and Cool-Season Forages: http://edis.ifas.ufl.edu/AG176
- Bahiagrass: A Quick Reference: http://edis.ifas.ufl.edu/AG271
- Annual Ryegrass: http://edis.ifas.ufl.edu/AG104
- White Clover: http://edis.ifas.ufl.edu/AA198
- Cherokee Red Clover: http://edis.ifas.ufl.edu/AA190
- Limpograss (*Hemarthria altissima*) Overview and Management : http://edis.ifas.ufl.edu/AG330
- Stargrass: http://edis.ifas.ufl.edu/AG154
- Inoculation of Agronomic Crop Legumes: http://edis.ifas.ufl.edu/AA126
- Burndown of Ryegrass Cover Crops Prior to Crop Planting: http://edis.ifas.ufl.edu/AG275
- Reduction of the Impact of Fertilization and Irrigation on Processes in the Nitrogen Cycle in Vegetable Fields with BMPs: http://edis.ifas.ufl.edu/HS201
- Selected Legumes Used As Summer Cover Crops: http://edis.ifas.ufl.edu/IN483
- Guide To Using Perennial Peanut As A Cover Crop In Citrus: http://edis.ifas.ufl.edu/CH180
- Sunn hemp (Crotalaria juncea L.): A summer cover crop for Florida vegetable producers: http://edis.ifas.ufl.edu/HS376
- Buckwheat: A Cool-Season Cover Crop for Florida Vegetable Systems: http://edis.ifas.ufl.edu/HS386

Pest Management
- Biological Control for Insect Management in Strawberries: http://edis.ifas.ufl.edu/HS180
- Natural Enemies and Biological Control: http://edis.ifas.ufl.edu/IN120
- Beneficial Insects #1: http://edis.ifas.ufl.edu/IN002
- Beneficial Insects #2: http://edis.ifas.ufl.edu/IN003
- Beneficial Insects #3: http://edis.ifas.ufl.edu/IN012
- Beneficial Insects and Mites: http://edis.ifas.ufl.edu/IN078
- Management of Nematodes with Cowpea Cover Crops: http://edis.ifas.ufl.edu/IN516
- Nematode Management Using Sorghum and Its Relatives: http://edis.ifas.ufl.edu/IN531
- Diseases in Florida Vegetable Garden: Beans: http://edis.ifas.ufl.edu/PP132
- Diseases in Florida Vegetable Garden: Tomato: http://edis.ifas.ufl.edu/PP121
- Diseases in Florida Vegetable Garden: Pepper: http://edis.ifas.ufl.edu/PP122
- Soil Organic Matter, Green Manures and Cover Crops for Nematode Management: http://edis.ifas.ufl.edu/VH037
- Management of Nematodes and Soil Fertility with Sunn Hemp Cover Crop: http://edis.ifas.ufl.edu/NG043
- Vegetable Diseases Caused by Phytophthora capsici in Florida: http://edis.ifas.ufl.edu/VH045

Books
- Managing Cover Crops Profitably. 2007. A. Clark (Ed.). Sustainable Agriculture Network, SARE, Beltsville, MD. Third Edition. 248 pp.
- Online free version: http://www.sare.org/publications/covercrops/covercrops.pdf
- Manage Insects on your Farm: A Guide to Ecological Strategies. 2005. Altieri, M. A, C. I. Nicholls and M. A. Fritz. Sustainable Agriculture Network, SARE, Beltsville, MD. 119 pp. Online free version: http://www.sare.org/publications/insect/insect.pdf

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http://www.sare.org/WebStore

• FDACS. 2005. Water quality/quantity best management practices for Florida vegetable and agronomic crops, Office of Ag. Water Policy, Fla. Dept. Ag. Consum. Serv, Tallahassee, FL, 150pp, http://www.floridaagwaterpolicy.com/.

Table 1. Dry matter yield and nitrogen uptake of Florida cover crops.

Cover crop	Dry matter yield (lbs acre)	N uptake (lbs acre)	Location	Reference
Sunn hemp	7,000-10,888	130-154	Citra, FL	Cherr et al., 2006b
Sunn hemp	11,000	250-300	Homestead, FL	Wang et al., 2003; Wang et al., 2005
Velvet bean	9,907	150-250	Homestead, FL	Wang et al., 2003; Wang et al., 2005
Cowpea	10,440	65-210	Homestead, FL	Wang et al., 2003; Wang et al., 2005
Sorghum sudangrass	4,641	43	Homestead, FL	Wang et al., 2005
Lupin	3,570	93	Citra, FL	Cherr et al., 2006b
Hairy vetch	1,785	46	Citra, FL	Cherr et al., 2006b

Table 2. Cover crops known to suppress weed species common in vegetable systems.

Cover Crop	Weeds Suppressed	Reference
Rapeseed (*Brassica napus*)	Bristlegrass	Boydson and Hang, 1995
Mustard, yellow Sinapis alba L.	Redroot pigweed (*Amaranthus retroflexus*)	Haramoto and Gallant, 2005
Cowpea	Goosegrass (*Eleusine indica* L.)Livid amaranth (*Amaranthus lividus* L.)	Adler and Chase, 2007
Sorghum sudangrass	Annual ryegrass	Forney and Foy, 1985
Cereal rye	Redroot pigweed, lambsquarters, common ragweed,	Masiunas, 1995; Barnes and Putnam, 1986;
Hairy vetch	Lambsquarters, yellow foxtail, yellow nutsedge, pitted morningglory	Teasdale et al., 1993; White et al., 1989
Crimson clover	Pitted morningglory, wild mustard, Italian ryegrass	Teasdale et al., 1993; White et al., 1989
Sunn hemp	Goosegrass, livid amaranth	Adler and Chase, 2007
Velvetbean	Yellow nutsedge, chickweed, goosegrass livid amaranth, cogongrass; spiny amaranth, smooth pigweed, bitterweed, field sanbur	Adler and Chase, 2007; Fujii et al., 1992; Hepperly et al., 1992; Udensi et al., 1999; Caamal-Maldonado, 2002